Toward a Theory of

SPACEPOWER

Selected Essays

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Chapter 1:
Old Thoughts, New Problems: Mahan and the Consideration of Spacepower

Jon Sumida

Over a century ago, the rapid expansion of global overseas trade brought about by the advent of improved steam propulsion and advances in ship design and construction posed new national policy and security questions for the United States. First, to what degree did American economic prosperity depend upon being a major active participant in maritime commerce? Second, what were the naval implications of such action with respect to the extension and defense of important, if not vital, American interests? Third, what role should the U.S. Government play in the promotion of maritime commercial activity and the creation of the naval forces required to protect American overseas trade? And fourth, what changes, if any, were required with respect to the direction of American foreign policy? In 1890, Captain Alfred Thayer Mahan, a serving officer in the U.S. Navy, published *The Influence of Sea Power upon History, 1660–1783*. This book provided a comprehensive statement about maritime commerce, naval power, government policy, and international politics that became the theoretical point of departure for almost all discussion of what was widely regarded to be the most important national security problem of the day, both in the United States and around the world.

Today, the importance of space as a venue for economic and military activity in certain respects resembles the conditions of maritime commerce and naval power in the late 19th century. These circumstances prompt two questions: first, is a history-based exploration of prospects and possibilities of spacepower, in the manner of Mahan, a viable intellectual proposition? Second, does his work contain ideas that are applicable to spacepower or at least suggest potentially productive lines of inquiry? Addressing these issues, however, requires a sound foundation—namely, an accurate understanding of Mahan's major arguments and his manner of reasoning. Unfortunately, misunderstanding Mahan is the rule rather than the exception. His writing is rarely read, and the bulk of the critical literature is corrupted by serious interpretive error. What follows is a schematic representation of Mahanian argument that can be related to the consideration of the nature of the theoretical problem of spacepower.[1]

Alfred Thayer Mahan's *The Influence of Sea Power upon History, 1660–1783* is widely regarded as the first important study of the relationship between naval affairs and international politics. Mahan subsequently published more than 20 additional volumes that extended and elaborated upon the views presented in this book. Inclusion in this book of a chapter based upon the traditional summary of Mahan's main ideas could be justified as an obligatory nod to tradition or an act of faith in the capacity of patristic writing to inspire strategic insight. Recent scholarship, however, has demonstrated that Mahan's thinking about seapower has been fundamentally misunderstood. This chapter will thus examine three areas where the new interpretation of Mahan affects consideration of problems that are of interest today. The first is naval and military cooperation when fighting in inland or coastal waters. The second is the nature and role of naval supremacy with respect to a complex world system of trade. The third is the requirements of naval higher education in a period of rapid technological change. In other words, Mahan's work will be related to jointness and power projection, the expansion of the global economy, and the cognitive qualities necessary to fully grasp the process of radical changes in major weaponry and their use known as *transformation*.

There are three main arguments. First, Mahan believed that when one side in a conflict possessed absolute sea command or, in special cases, even temporary local control, naval operations in direct support of land forces could be of decisive importance. Second, Mahan maintained that naval supremacy in the 20th century would be exercised by a transnational consortium acting in defense of a multinational system of free trade. Finally, Mahan was convinced that the sweeping improvement of naval materiel by radical technological change had not eliminated tactical and strategic uncertainty from the conduct of war, and that the enhancement of executive ability through the rigorous study of history should therefore be the basis of naval officer education. Mahan is often portrayed as a purveyor of truisms about naval strategy and doctrine based upon misreadings of fragments of his writing or, all too often, upon no reading of the original texts at all. The resulting caricature is frequently either misapplied or dismissed as outdated. This chapter, which is informed by the study of all of Mahan's major publications and surviving correspondence, intends to demonstrate that there is good reason to recall the adage, "When you want a good new idea, read an old book."

Complex Interrelated Dynamics

Alfred Thayer Mahan was an officer in the Union Navy during the Civil War. Although never a participant in a major battle, his Active service included many months of inshore work in small warships enforcing the blockade of the Confederate coast. Nearly two decades after the end of hostilities, Mahan accepted a commission to write a book about naval operations on the Caribbean coast and up the Mississippi and Red Rivers in the War Between the States. In addition to being able to draw upon his own experience during this conflict, Mahan studied memoirs and documents and corresponded with veterans from both sides. The completed work, which was entitled *The Gulf and Inland Waters*, was published in 1883. Several years after the appearance of *The Influence of Sea Power upon History* and its two-volume sequel, *The Influence of Sea Power upon the French Revolution and Empire*, which came out in 1892, Mahan produced a biography of the admiral who commanded most of the Union operations described in his first book. *Admiral Farragut*, published in 1897, gave Mahan another opportunity to present his views on fighting in littoral and interior waters that involved cooperation between the Army and Navy.

During the Civil War, the lack of a fleet meant that the Confederacy could not mount an effective challenge to Union control of the high seas. Moreover, the naval weakness of the Southern States exposed their vital internal riverine communications and major ports to seaborne assault. Over the course of the 4-year conflict, the territorial integrity and economic vitality of the South were compromised by the integrated action of the Union Army and Navy, which established Northern control of the Mississippi and captured New Orleans and Mobile. Mahan's two accounts of these campaigns demonstrate that he possessed considerable knowledge of the special characteristics of brown-water fighting, appreciated the necessity of connecting the activity of land and naval forces, and recognized that the success of joint operations had been a major contributor to the ultimate Union victory. In books written before and after the Farragut biography, Mahan criticized Nelson's advocacy of amphibious operations in support of land campaigns and in general opposed overseas expeditions. But these views were applied to circumstances in which the opposing side possessed—or was supposed to possess—the capacity to dispute sea command. Mahan thus reasoned that any attempt to project power from water to land risked naval assets that were needed to preserve the general control of the oceans upon which all depended. When the maintenance of maritime lines of communication was not an issue, he had no objection to using naval force in combination with an army to achieve a military objective and understood that such action could have great strategic value.

Indeed, Mahan attributed his initial inspiration for the idea that naval supremacy was of much larger historical significance than was generally recognized to his reflections on a historical case involving the use of uncontested command of the sea to achieve decisive military success. In his memoirs, he recalled that in 1885, he had chanced upon Theodor Mommsen's history of ancient Rome. While reading this book, Mahan was struck by the thought that the outcome of the wars between Rome and Carthage would have been different had the latter possessed the ability, as did the former, of using the sea as an avenue of invasion, instead of moving its armies over land. After some reflection, Mahan decided to apply the example of the victory of a state that could use naval force effectively over one that could not to the history of European wars in the late 17th and 18th centuries. This resulted in the first of the "influence of sea power" volumes in which Mahan closed the introduction with a lengthy examination of the naval aspects of Rome's defeat of Carthage. He ended the main narrative of *The Influence of Sea Power upon History* with an account of the British defeat at Yorktown in 1781. The outcome of this battle was determined by the reinforcement of American and French armies by sea and French naval control of surrounding waters, which prevented a British fleet from relieving the besieged British army. The Yorktown disaster prompted negotiations that ultimately ended the war and established American independence. In the book that made his reputation, Mahan thus used the survival of what was to become imperial Rome and the creation of the United States as powerful historical testaments to the transcendent value of using naval force in support of military operations.

But *The Influence of Sea Power upon History* also introduced a set of propositions about the relationship between the economic basis of national strength and the development and effective use of a navy. Seaborne trade, Mahan maintained in his first bestseller, was a critically important generator of wealth. In the event of war, a nation that could protect its own maritime commerce while disrupting that of its opponent could shift the balance of national resources decisively in its favor. A fleet capable of winning and keeping command of the sea was required to accomplish both of these tasks. In peace, a great state was thus well advised to do everything it could to build the strongest possible navy. Over time, the cumulative effect of sound naval policy and strategy in peace and war was economic prosperity and territorial aggrandizement. Naval force structure and deployment were also important variables. Cruiser attacks on scattered shipping, Mahan believed, were incapable of inflicting prohibitive losses on a large merchant marine. Blockade of the enemy's main ports—implemented by a fleet of battleships capable of defeating any force that was sent against it—was the only way to accomplish the complete or near-complete stoppage of overseas commerce required to achieve a significant strategic effect against a great maritime power. For this reason, Mahan made the number of battleships the measure of naval potency, and the destruction of the enemy battle fleet through decisive engagement—for the purposes of either securing or breaking a blockade—the main operational objective of naval strategy.

These interrelated arguments addressed major concerns of Mahan's own time. From the 1880s, the general expansion of European navies in response to increasing imperial rivalry was accompanied by intensive debate over the relative merits of a naval strategy based on commerce-raiding by cruisers as opposed to one based on command of the sea by battleships. In addition, the advent of steam propulsion and metal hulls had vastly increased the efficiency of maritime transport, which in turn caused a sharp upturn in overseas commerce and the wealth generated by this kind of activity. Mahan's choice of European great power conflict during the late age of sail as the vehicle for his argument also favored discussion of the general struggle for naval supremacy over case studies of combined operations along coasts and rivers. So although Mahan clearly recognized the importance of power projection from sea to land, it was his examination of the contest for command of the sea and its political-economic consequences that created the immediate wide audience for *The Influence of Sea Power upon History* and later publications. The resulting association of Mahan with arguments about naval supremacy exclusively distorted perception of his identity as a strategic theorist, setting the stage for misleading comparisons with writers who focused more attention on the relationship of land and seapower, such as C.E. Callwell and Julian Corbett. But a far greater problem was created by the serious misunderstanding of the basic character of Mahan's rendition of European naval history in the age of sail, which led to the drawing of faulty inferences about Mahan's fundamental views on grand strategy.

The "influence of sea power" series began in the mid-17th century with a situation in which three major maritime states—France, the Netherlands, and England—were roughly balanced with respect to naval prowess and accomplishment. It ended in the early 19th century with the wars of the French Revolution and Empire, during which Britain's Royal Navy more or less ruled the waves. In addition to the two works named previously, which provided an overview of the entire period, there were two supporting case studies: a biography of Admiral Horatio Nelson and an account of the War of 1812. In terms of plot, the entire series could be read as the story of the rise of Britain's naval supremacy and its consequent achievement of economic and political preeminence in Europe. In terms of moral, the series seemed to say that Britain's sustained, aggressive use of a large fleet to obtain territory, wealth, and power could be emulated by any state that had the mind and will to follow the British example. Mahan, many believed, had produced an analytical history that was intended as a grand strategic primer for his own times, and in particular for the government of his own country. He was indeed a proponent of a much-strengthened U.S. Navy. It was thus not hard to imagine that he hoped that his homeland would become the world's greatest power in the 20th century by the same means that Britain had used to achieve this status in the period covered by his histories. And the fact that the United States ultimately rose to the top in large part through the effective use of naval supremacy only reinforced the propensity to draw inferences such as these about Mahan's underlying motive.

Careful consideration of Mahan's actual writing in the "influence of sea power" series, his political-economic outlook, and his punditry about the future course of world politics, however, makes it impossible to accept the foregoing characterizations of his account of naval warfare in the late age of sail and their intended application to the 20th century. The first installment of the series is about the failure of France to exploit its maritime assets properly, which, in Mahan's view, allowed Britain to achieve major successes in war virtually by default. Mahan chose to close the book with a disproportionately lengthy account of the American Revolution, a conflict in which sound French policy and deployments resulted in Britain's defeat and the loss of a vast and rich colonial territory. In the wars of the French Revolution and Empire, the navy of France was compromised from the start by political upheaval and institutional disintegration. The second installment was thus about Britain's use of naval supremacy to contain a militarily preeminent France through a strategy of attrition. Mahan did not hold that the ultimate outcome was preordained—that is, naval supremacy as such guaranteed victory. Given the evenness of the balance between the opposing sides, he argued in both the second and the third installments, the triumph of Britain depended upon extraordinary operational naval leadership in the person of Nelson. In the concluding installment, Mahan's main theme was that inadequate American naval strength was the fundamental explanation of diplomatic failure before the War of 1812, and naval operational impotence, with all its attendant serious strategic drawbacks, during the conflict.

Britain and its naval strategy did not, in short, represent the focus of the "influence of sea power" series. Mahan's histories did not comprise a simple morality play about a single state acting according to a prescribed general course of action but rather provided a complex picture of the interrelated dynamics of naval and maritime commercial activity on the one hand, and international politics on the other. Mahan's essentially liberal political-economic views, moreover, meant that he rejected the mercantilist conception of a world consisting of competing players with mutually exclusive interests. Mahan believed that free trade between nations promoted increases in the volume of international exchanges of goods that worked to the benefit of all participants. The great expansion of French overseas shipping after the War of the Spanish Succession, he argued in the first installment of the series, was attributable to peace and the removal of restrictions on commerce, not government initiatives. In the second installment, Mahan observed that seapower was an organism that included not only organized naval force but also free maritime enterprise. While the former depended upon state funding and direction, the latter thrived in the absence of government interference. During the wars of the French Revolution and Empire, Mahan maintained, the British state was able to exploit the prosperity produced by an international sea-based mercantile system that it could protect but did not possess. It was not, in other words, the owner of seapower, but rather its custodian.

Mahan believed that Britain had been both the defender and main beneficiary of seaborne trade in the late 18th and early 19th centuries because Parliament had been dominated by a small group of men with close ties to maritime commerce. Such an oligarchy was predisposed to favor heavy spending on the navy, which produced a fleet strong enough to defend a merchant marine that carried a large proportion of the world's overseas trade. Over the course of the 19th century, however, the democratization of the British political system undercut the manipulation of government policy by a mercantile elite. As a consequence, Mahan argued, the British state of the late 19th and 20th centuries had lost the will to finance a navy capable of defending what had become a much larger and increasingly multinational system of oceanic economic exchange. Moreover, in Mahan's view, no single democratized power could be capable of assuming such a burden. For this reason—and the fact that he was convinced that free trade conditions provided large benefits to all major maritime countries—Mahan concluded that in the 20th century, naval supremacy would be exercised by a transnational consortium of navies. The basis of such a system, he insisted, would not be formal agreement, but the absence of important conflicts of political interest coupled to a common stake in the security of a highly productive form of economic activity. Mahan was thus convinced that Britain and the United States would cooperate without recourse to a treaty, and that in such a relationship the latter would serve as the junior partner. To play even this supporting role effectively, Mahan insisted America needed a larger navy. He did not advocate the creation of an American Navy that was stronger than every other unless the British navy was weakened by inadequate financing or war with a competing European enemy.

Mahan offered his views on the future course of international affairs in articles written for periodicals that were later collected and published as books, and in several occasional book-length monographs. Mahan contemplated a range of possible courses of events. These included the containment of an expansionist Russia by an international coalition, war between Britain and Germany, and even a cataclysmic collision between European and Asian civilizations. What he did not do was apply a crude reading of the great power contests of the late age of sail to the industrial future by imagining the rise of a hegemonic United States through offensive naval war and mercantilist economic policy. And while his realist temperament prompted him to argue that war and the threat of war would be likely facts of life for the foreseeable future, Mahan did not rule out either the possibility or desirability of general peace founded upon the workings of an international system of free trade. In such a world economy, he was confident that the energy and entrepreneurial spirit of the American people would enable them to compete successfully.

In the second half of the 19th century, the onset of industrialization transformed naval materiel within the span of a generation. When Mahan was a midshipman at the United States Naval Academy just before the American Civil War, he was trained on wooden sailing ships armed with muzzle-loading guns. By the time he retired from the Service at the end of the century, steel warships propelled by steam and equipped with breechloading guns of much larger size and power were standard. The sudden obsolescence of much of what had constituted traditional naval fighting practice as a result of rapid technical change, and the virtually worldwide sense that what really mattered in war was the possession of the latest and therefore most capable naval armaments, undermined the self-confidence of naval executive officers. Conversely, naval officer technicians could celebrate the wonders of technical improvement and claim that the critical importance of qualitative advantage in materiel had made their activity central to the efficiency of the Navy. Moreover, administrative burdens were magnified by the needs of managing the new technology and also the expansion of the American fleet that began in the 1880s, which created a large class of naval officer bureaucrats with pretensions to higher status that were not directly connected to executive command at sea.

These developments alarmed Mahan. By dint of intellectual patrimony and personal experience in the greatest conflict ever fought by his Service up to his time, he had decided opinions on the paramount value of effective leadership in war and how it might be developed. Mahan's father, Dennis Hart Mahan, a distinguished professor at the United States Military Academy at West Point, believed that great executive leadership was of crucial importance in war. The elder Mahan observed that at critical junctures, a commander would be confronted with complex, contingent, changing, and contradictory information, which meant that decisionmaking could never be reduced to the mechanistic application of rules or principles. The development of the kind of temperament required to facilitate sound judgment under such circumstances, he was convinced, could be encouraged by the study of detailed and analytically rigorous operational history. There can be little doubt that this outlook was imparted to his son, in whom it was later reinforced by the younger Mahan's direct observation of command decisionmaking in the Civil War. Alfred Thayer Mahan's first publication of 1879 was an essay on naval education, in which he attacked what he regarded as the overemphasis of technical subjects and called for much greater attention to the study of what amounted to the liberal arts. Such an approach, he maintained, would develop the moral qualities that officers required to be able to make decisions in the face of danger and uncertainty. The vital role of moral strength with respect to executive command and the appropriate means of improving it in naval officers became a theme in Mahan's later writing that was no less important to him than his examination of the relationship between naval affairs and international politics.

In *The Influence of Sea Power upon History*, Mahan argued that while tactics changed as the character of armaments changed, the validity of the basic principles of strategy was relatively unaffected by technical progress, and human character was an absolute constant. History, therefore, might have little to say that was of current applicability to tactics but a great deal that was pertinent to strategy and operational command. Mahan devoted as much attention in the main narrative of this work to the strategic direction of naval operations as he did to his grand strategic argument about the relationship between naval supremacy and the course of international politics. He also made a few observations about the critical effect of individual moral character on the exercise of naval command. In later installments of the "influence of sea power" series, he remained no less attentive to strategic questions and, through his treatment of Nelson's leadership qualities, wrote at length about the moral dimensions of executive decisionmaking in war.

In several of his articles, Mahan maintained that the essence of effective command was rapid and judicious risktaking while bearing the burden of full responsibility for the outcome of action. This set of characteristics was alien to the scientific *mentalité* of the engineer, which dealt deliberately with the discovery of certainty about physical matters through controlled experiment, and the bureaucratized mindset of the administrator, which countenanced delay and fragmented accountability. In peace, an executive leader had few if any opportunities either to display his capacity for war command or acquire experience that would enable him to develop it, while technicians and bureaucrats flourished in the pursuit of engineering innovation or administrative expansion. For Mahan, therefore, serious naval history of the kind that he had produced in the "influence of sea power" series served two major practical functions. First, it reminded the Navy of what executive war command was and why it was important. And second, it provided a sound educational basis for developing it in officers who had no war experience. The latter task was accomplished through the telling of stories about naval decisionmaking in war that prompted readers to imagine the psychological dynamics as well as material circumstances that conditioned the direction of operations in a real conflict.

Mahan lacked the powers of technical ratiocination that were needed to evaluate properly a complex engineering problem such as capital ship design. His criticisms of the all-big-gun battleship in the early 20th century, therefore, failed to take into account several significant factors, which exposed his analysis to swift and thorough destruction. But Mahan was not a naval technological Luddite. If he was a critic of many of the claims made for mechanical innovation, it was because he was convinced that such progress had not eliminated uncertainty from decisionmaking in war and that the decadence of the naval executive ethos was thus a dangerous weakness. His antidote to the technological determinists of his time was history rather than political science. This was because he believed that the verisimilitude that accompanied detailed narrative about things that had actually happened could engage the minds and feelings of students of command in ways that a summary statement of lessons or abstractions could not. Mahan's preference for historical representation over the construction of explanatory systems when dealing with the past is in line with much that has been argued by proponents of chaos and complexity theory. And his recommended remedy to moral dilemma—confidence in intelligent intuition—is one that is supported by the findings of cognitive science. Viewed in light of the work in these cutting-edge areas of inquiry into the natures of human learning and behavior, the writings of Mahan may be regarded as not just relevant, but revelatory.

A Cognitive Point of Departure

For nearly 100 years, Alfred Thayer Mahan's pronouncements on naval affairs and international politics were too famous to be ignored but were also too extensive, difficult, and complicated to be easily understood as a whole. From the start, most writers on naval history and strategy misperceived his work, and successive generations compounded the errors of their predecessors, which created a large literature whose shortcomings further obstructed access to the meaning of the original texts. As a consequence, Mahan's basic ideas have been misrepresented as follows. First, sea control was always the central question of naval strategy. Second, the ideal of national grand strategy was the achievement of naval supremacy as the prerequisite to international economic and political preeminence. And third, success in naval warfare depended upon the correct application of certain principles of strategy. These propositions add little to discussions of current naval concerns, which consider the American possession of sea control and a monopoly of superpower status practically as givens and are dominated by contemplation of the transformation of fighting practice by radical technological innovation.

The major arguments of Mahan revealed by comprehensive and rigorous critical examination, however, are very different than has been supposed. Moreover, the issues that prompted him to put pen to paper were remarkably similar to those of today. He began both his naval and writing careers dealing with joint operations in coastal waters. Mahan was confronted by the rapid expansion of a global system of free trade and uncertainty about what America's proper naval role under such conditions should be. And his generation witnessed a "revolution in naval affairs" occasioned by the replacement of preindustrial with industrial naval armaments, which raised large questions about the nature of war command and the education of those who would exercise it.

Mahan's contemplation of these problems produced the following conclusions. First, close cooperation between land and sea forces is essential for the success of joint operations, whose outcomes could determine the victor in a major war. Second, the cost of building and maintaining a navy that is unilaterally strong enough to command the seas is too high for any single power, and for this reason sea control in the 20th century and beyond would be the responsibility of a transnational consortium of navies. And third, great advances in technology do not diminish reliance upon the good judgment of naval executive leaders, who could best be prepared for high-level decisionmaking in war by the proper study of history.

Identifying Mahan's basic attitudes toward power projection from sea to land, naval supremacy, and the relationship between technological change and officer education does more than correct academic error. What were believed to be Mahan's ideas created a body of theory—whether through acceptance, modification, or rejection—that forms an enduring element of the thought processes of most senior military officers and civilian defense professionals. Changing what has long been a cognitive point of departure, therefore, has significant implications for anyone concerned with the future of national security policy and military strategy.

Mahan has been widely regarded as the discoverer of what he supposedly believed were universal truths about naval strategy that were to be applied directly. The fact is that Mahan's propositions were observations about particular phenomena rather than general lessons. When dealing with Mahan, the focus of inquiry should not, for this reason, be upon the statement of principle or delineation of precedent, but rather on his choice of issues and the complexities of the historical cases that were his main subjects. The crucial linkages between his past and our present, in other words, are not to be found in his conclusions, but in his questions and his conduct of the inquiry. These are still worth engaging because Mahan faced problems that were similar to those that confront states and their militaries today, and he did so with a powerful intelligence that was informed by rich experience and wide reading. History was the venue for Mahan's scholarly labors, because he understood both the limits of theory and the power of narrative when it came to matters of human behavior and social organization under the conditions of war. While there is much more that can and should be written about the general and particular aspects of armed forces and national military power, approaching—to say nothing of matching—the intellectual standard of Mahan's pioneering achievement will not be easy.

Applying Mahan to Space

Mahan's major concerns and his questions about them can be restated in terms of spacepower as follows:

- What is the economic significance of the development of space activity, and to what degree does future American economic performance depend upon it?
- What are the security requirements of space-based economic activity?
- What role should the U.S. Government play in the promotion of space-based economic activity and its defense?
- What kind of diplomatic action will be required to support space-based economic activity and its defense?

Mahan's writing about seapower suggests the following answers. First, activity in space will, in manifold ways, have large and growing economic effects, and will therefore be highly significant for the economic future of the United States. Second, the security requirements of space-based economic activity will involve costs that are beyond the means of any single nation-state, including the United States. Third, U.S. Government policy can support the economic development of space and contribute to the defense of such activity, but the dynamics of both will be largely determined by private capitalism and other nation-states with major interests in the space economy. And fourth, American diplomacy should encourage international economic activity in space and be directed toward the creation and sustenance of a multinational space security regime.

Mahan's views on education and professionalism raise the question of what kind of study would best serve the development of a distinctive approach to spacepower. Mahan would almost certainly have opposed tendencies to think of space problems in primarily technical or operational terms. He used the history of naval and maritime affairs in the age of sail to formulate productive insights about such activity in his industrial present and future. His contention was that analysis of the distant past had utility in spite of very great differences in political-economic perspective (mercantilism as opposed to free trade) and technology (wooden construction and sail power as opposed to steel ships and steam propulsion). A similar approach to spacepower would be to use the history of industrial navies in the 20th century as the basis of significant thought about certain salient aspects of spacepower. Such an expedient would in effect transpose the venue of historical study forward—that is to say, the history of the 20th century would serve as an instructive platform for the 21st as Mahan had used the history of the 18th century to guide the 19th. In addition, the naval subjects studied would change, emphasis being shifted from the examination of campaigns and wars to the consideration of technological change on the one hand, and patterns of change in grand strategic, strategic, operational, and tactical practice on the other. A great deal of attention would also have to be paid to such matters as the forms of transnational political, economic, and military and naval cooperation, and the interplay of economics, finance, legislative and executive politics, and bureaucratic administration with respect to the design and production of weapons. The writing of such a history would require use of state-of-the-art historical techniques and knowledge of an enormous scholarly literature and would demand imaginative speculation about important matters that have not yet been investigated. No such history exists, and bringing it into being would be an enormous undertaking.

Notes

1. An earlier version of this article was published in 2001 as "Getting New Insight from Old Books: The Case of Alfred Thayer Mahan," in the *Naval War College Review*. The article is presented here in its entirety, with slight modification, and is followed by a commentary on its relevance to the discussion of spacepower.

Chapter 2:
On the Nature of Military Theory

Harold R. Winton

The quest for a theory of spacepower is a useful enterprise. It is based on the proposition that before one can intelligently develop and employ spacepower, one should understand its essence. It is also based on the historical belief that, over the long haul, military practice has generally benefited from military theory.[1] While such a conviction is generally true, this happy state has not always been realized. Faulty theory has led to faulty practice perhaps as often as enlightened theory has led to enlightened practice.[2] This does not necessarily call into question the utility of theory per se, but it does reinforce the need to get it about right. Taking the broader view, it is a trait of human nature to yearn for understanding of the world in which we live; and when a relatively new phenomenon such as spacepower appears on the scene, it is entirely natural to seek to comprehend it through the use of a conceptual construct. Thus, one can at least hope that the common defense will be better provided for by having a theory of spacepower than by not having one.

This chapter will deal only tangentially with spacepower. Its main task is to explore the nature of theory itself. First, it examines the general and somewhat problematic relationship between theory and the military profession. Next, it surveys what theorists and academics say about the utility of theory. It then seeks to determine what utility theory actually has for military institutions, particularly in the articulation of military doctrine. Finally, it offers a few implications that may be germane to a theory of spacepower.

Theory and the Military Profession

To examine the relationship between theory and the military profession, we must first assess the salient characteristics of each.[3]

Webster's definition of *theory* as "a coherent group of general propositions used as principles of explanation for a class of phenomena"[4] is a pretty good place to start. It highlights the essential task of explanation and the desirable criterion of coherence. But if we stand back a bit, we can tease out several other functions of theory. The first two occur before its explanatory function. Theory's first task is to define the field of study under investigation, or, in Webster's words, the "class of phenomena." In visual terms, this defining act draws a circle and declares that everything inside the circle is encompassed by the theory, while everything outside it is not. In the theory of war, for example, Carl von Clausewitz offers two definitions. The first states baldly, "War is thus an act of force to compel our enemy to do our will."[5] After introducing the limiting factor of rationality into the consideration of what war is, Clausewitz expands this definition as follows: "War is not a mere act of policy but a true political instrument, a continuation of political activity with other means."[6] A synthesis of these two definitions would be that war is the use of force to achieve the ends of policy. Although the utility of this definition has been argued at some length, it leaves no doubt as to what Clausewitz's theory is about.[7]

The next task of theory is to categorize—to break the field of study into its constituent parts. Here it may be helpful to visualize the subject of the theory as a spherical object rather than a circle. The sphere can be divided in many different ways: horizontally, vertically, diagonally, or, if it is a piece of citrus fruit, into sections that follow the natural internal segmentation. Again, reference to Clausewitz is instructive. War has two temporal phases—planning and conduct—and two levels—tactics and strategy—each with its own dynamics.[8] Furthermore, wars could also be categorized according to their purpose (offensive or defensive) and the amount of energy (limited or total) to be devoted to them.[9] A word about categorization is important here because it relates to the continuous evolution of theory. Theories tend to evolve in response to two stimuli: either new explanations are offered and subsequently verified that more accurately explain an existing reality, or the field of study itself changes, requiring either new explanations or new categories. An example of the former is the Copernican revolution in astronomy.[10] An example of the latter is the early 20th-century discovery of the *operation*, which emerged from the industrial revolution's influence on the conduct of war, as the connecting link between a battle and a campaign and subsequently led to the study of *operational art* as a new subdiscipline of military art and science.[11]

The third, and by far the most important, function of theory is to explain. Webster's definition cited above is correct in emphasizing theory's explanatory role, for, as Nicolaus Copernicus, Johannes Kepler, Albert Einstein, and scores of other theorists so clearly demonstrated, explanation is the soul of theory. In the military sphere, Alfred Thayer Mahan's statement that the sea is "a wide common, over which men may pass in all directions, but on which some well-worn paths show that controlling reasons have led them to choose certain lines of travel rather than others" explains the underlying logic of what are today called *sea lines of communication*.[12] Reading further in Mahan, one finds an extended explanation of the factors influencing the seapower of a state.[13] Explanation may be the product of repetitive observation and imaginative analysis, as Copernicus' was, or of "intuition, supported by being sympathetically in touch with experience," as Einstein's was.[14] In either case, theory without explanatory value is like salt without savor—it is worthy only of the dung heap.

But theory performs two additional functions. First, it connects the field of study to other related fields in the universe. This marks the great utility of Clausewitz's second definition of war, noted above. Although war had been used as a violent tool of political institutions dating to before the Peloponnesian War, Clausewitz's elegant formulation, which definitively *connected* violence with political intercourse, was perhaps his most important and enduring contribution to the theory of war.

Finally, theory anticipates. The choice of this verb is deliberate. In the physical realm, theory predicts. Isaac Newton's theory of gravitation and Kepler's laws of planetary motion, combined with detailed observations of perturbations in the orbit of Uranus and systematic hypothesis testing, allowed Urbain Jean Joseph Le Verrier and John Couch Adams independently to predict the location of Neptune in 1845.[15] But action and reaction in the human arena, and therefore in the study of war, are much less certain, and we must be content to live with a lesser standard. Nevertheless, anticipation can be almost as important as prediction. In the mid-1930s, Mikhail Tukhachevskii and a coterie of like-minded Soviet officers discovered that they had the technological capacity "not only to exercise pressure directly on the enemy's front line, but to penetrate his dispositions and to attack him simultaneously over the whole depth of his tactical layout."[16] They lacked both the means and the knowledge that would allow them to extend this "deep battle" capability to the level of "deep operations," where the problems of coordination on a large scale would become infinitely more complex. But the underlying conceptual construct—that is, what was practically feasible on a small level was theoretically achievable on a much larger scale—was a powerful notion that has only recently been fully realized in the performance of the U.S. Armed Forces in the Gulf Wars of 1991 and 2003.

But theory also has its limitations. No theory can fully replicate reality. There are simply too many variables in the real world for theory to contemplate them all. Thus, all theories are to some extent simplifications. Second, as alluded to earlier, things change. In the realm of military affairs, such change is uneven, varying between apparent stasis and virtual revolution. Nevertheless, military theory always lags behind the explanatory curve of contemporary developments. Thus, we can here paraphrase Michael Howard's famous stricture on doctrine, theory's handmaiden, and declare dogmatically that whatever theories exist (at least in the realm of human affairs), they are bound to be wrong—but it is the task of theorists to make them as little wrong as possible.[17]

This observation leads to a brief consideration of the several sources of theory. The first lies in the nature of the field of study about which the theory is being developed. As Clausewitz noted in his discussion of the theory of strategy, the ideas about the subject had to "logically derive from basic necessities."[18] These necessities are rooted in the nature of the thing itself, its phenomenology. As time passes, men accumulate experience related to the phenomenon, and this experience contributes to the refinement and further development of theory. As Mahan famously noted of naval strategy, "The teachings of the past have a value which is in no degree lessened."[19] But if theory has one foot firmly rooted in the empirical past, it also has the other planted in the world of concepts. In other words, theory draws from other relevant theory. It is no accident that Julian Corbett's instructive treatise *Some Principles of Maritime Strategy* begins with an extended recapitulation of *On War*, which might lightheartedly be characterized as "Clausewitz for Sailors."[20] Corbett was keenly aware that the theory of war at sea, while distinct in many ways from the theory of war on land, had to be rooted in a general conceptual framework of war itself. He also knew that Clausewitz provided a solid base upon which to build. But Corbett's work is also emblematic of another source of theory: dissatisfaction with existing theory. This notion of dissatisfaction runs like a brightly colored thread throughout almost all of military theory. Clausewitz wrote because he was fed up with theories that excluded moral factors and genius from war; Corbett wrote to correct Mahan's infatuation with concentration of the fleet and single-minded devotion to the capital ship; and J.F.C. Fuller railed against what he called the *alchemy of war*, whose poverty of thought and imagination had led to the horrors of World War I.[21]

To sum up, although theory is never complete and is always bound to be at least somewhat wrong, it performs several useful functions when it defines, categorizes, explains, connects, and anticipates. And it is primarily a product of the mind. There are good reasons that the world produces relatively few theorists worthy of the name. The formulation of useful theory demands intense powers of observation, ruthless intellectual honesty, clear thinking, mental stamina of the highest order, gifted imagination, and other attributes that defy easy description.[22] These are not qualities normally associated with the military profession.

Why is this so? First, war is an intensely practical activity and a ruthless auditor of both individuals and institutions. The business of controlled violence in the service of political interest demands real attention to detail and real results. Complex organizations of people with large amounts of equipment must be trained and conditioned to survive under conditions of significant privation and great stress, moved to the right place at the right time, and thrust into action against an adversary determined to kill or maim in frustrating the accomplishment of their goals. Those who cannot get things done in this brutal and unforgiving milieu soon fall by the wayside.

Second, war demands the disciplined acceptance of lawful orders even when such orders can lead to one's own death or disfigurement. A Soldier, Sailor, Marine, or Airman unwilling to follow orders is a contradiction in terms. Thus, there is an inherent bias in military personnel to obey rather than to question. On the whole, this tendency does more good than harm, but it tends to limit theoretical contemplation.

Finally, war is episodic. Copernicus could look at the movement of the planets on any clear night and at the sun on any clear day. But war comes and goes, rather like some inexplicable disease, and the resulting discontinuities make it a difficult phenomenon about which to theorize.

I do not mean to imply that the military profession is inherently antitheoretical. There are countervailing tendencies. As both Sun Tzu and Clausewitz cogently observed, the very seriousness of war provides a healthy stimulus to contemplation.[23] Its episodic nature, while restricting opportunity for direct observation, does provide opportunity for reflection. Furthermore, the very complexity of war, while limiting the ability of theorists to master it, creates incentives for military practitioners to discover simplifying notions that reduce its seeming intractability. And we would not have seen the appearance of institutions of higher military learning, societies for the study of the martial past, or a virtual explosion of military literature over the last 20 years were there not some glimmerings of intellectual activity surrounding the conduct of war.

But the larger point remains: there are underlying truths about both theory and the military profession that make the relationship between the two problematic at best. Despite this inherently uneasy relationship, there is sufficient evidence that theory has utility in military affairs to justify probing more deeply. In doing so, I would like to follow a dual track: to explore the question of what utility theory should have for military institutions and what utility it actually does have. In investigating the former, the study is confined to the opinions of theorists and educators. In the latter, it plumbs the empirical evidence. But an important caveat before proceeding: tracing connections between thought and action is intrinsically difficult. When the nature of the thought is conceptual, rather than pragmatic, as theory is bound to be, such sleuthing becomes even more challenging, and one frequently is forced to rely on inferential conjecture and even a bit of imagination to connect the deed to an antecedent proposition.

The Theorists Make Their Case

A narrow but rich body of discourse about theory's contribution to individual military judgment is densely packed in *On War*. Clausewitz's line of thought is most cogently revealed in book two, "On the Theory of War." He begins this discourse by classifying war into the related but distinct fields of tactics and strategy. He follows with a stinging critique of the theories of his day that seek to exclude from war three of its most important characteristics: the action of moral forces, the frustrating power of the enemy's will, and the endemic uncertainty of information. From this, he deduces that "a positive teaching is unattainable."[24] Clausewitz sees two ways out of this difficulty. The first is to admit baldly that whatever theory is developed will have decreasing validity at the higher levels of war where "almost all solutions must be left to imaginative intellect."[25] The second is to argue that theory is a tool to aid the contemplative mind rather than a guide for action.

This formulation leads to some of the most majestic passages of *On War*. Theory is "an analytical investigation leading to a close *acquaintance* with the subject; applied to experience—in our case, to military history—it leads to thorough familiarity with it." Clausewitz elaborates:

> Theory will have fulfilled its main task when it is used to analyze the constituent elements of war, to distinguish precisely what at first seems fused, to explain in full the properties of the means employed and to show their probable effects, to define clearly the nature of the ends in view, and to illuminate all phases of war through critical inquiry. Theory then becomes a guide to anyone who wants to learn about war from books; it will light his way, ease his progress, train his judgment, and help him avoid pitfalls. . . . Theory exists so that one need not start afresh each time sorting out the material and plowing through it, but will find it ready to hand and in good order. It is meant to educate the mind of the future commander, or, more accurately, to guide him in his self-education, not to accompany him to the battlefield; just as a wise teacher guides and

> stimulates a young man's intellectual development, but is careful not to lead him by the hand for the rest of his life.[26]

This view of theory has a particular implication for military pedagogy. It requires that education begin with broad principles, rather than an accumulation of technical details. "Great things alone," Clausewitz argued, "can make a great mind, and petty things will make a petty mind unless a man rejects them as alien."[27] But Clausewitz also makes it abundantly clear that the cumulative insights derived from theory must ultimately find practical expression:

> The knowledge needed by a senior commander is distinguished by the fact that it can only be attained by a special talent, through the medium of reflection, study, and thought: an intellectual instinct which extracts the essence from the phenomena of life, as a bee sucks honey from a flower. In addition to study and reflection, life itself serves as a source. Experience, with its wealth of lessons, will never produce a *Newton* or an *Euler*, but it may well bring forth the higher calculations of a *Condé* or a *Frederick*. . . . By total assimilation with his mind and life, the commander's knowledge must be transformed into a genuine capability. . . . It [theory] will be sufficient if it helps the commander acquire those insights that, once absorbed into his way of thinking, will smooth and protect his progress, and will never force him to abandon his convictions for the sake of any objective fact.[28]

Thus, a century before Carl Becker advanced the proposition that "Mr. Everyman" had to be his own historian in order to function effectively in daily life, Clausewitz argued that every commander had to be his own theorist in order to function effectively in war.[29] In Clausewitz's view, the essential role of theory was to aid the commander in his total learning, which synthesized study, experience, observation, and reflection into a coherent whole, manifested as an ever-alert, perceptive military judgment.

There is, however, another view of the utility of theory, most famously articulated by Baron Antoine Henri de Jomini, Clausewitz's chief competitor in this arena. Jomini indeed believed in the power of positive teaching. Although he was prepared to admit that war as a whole was an art, strategy—the main subject of his work—was "regulated by fixed laws resembling those of the positive sciences."[30] Following this point-counterpoint formula again, he conceded that bad morale and accidents could prevent victory, but:

> These truths need not lead to the conclusion that there can be no sound rules in war, the observance of which, the chances being equal, will lead to success. It is true that theories cannot teach men with mathematical precision what they should do in every possible case; but it is also certain that they will always point out the errors which should be avoided; and this is a highly important consideration, for these rules thus become, in the

> hands of skillful generals commanding brave troops, means of almost certain success.[31]

This fundamental belief in the efficacy of prescriptive theory led Jomini to formulate his theory itself much differently than Clausewitz. At the epicenter of Clausewitz's theory, we find a trinity of the elemental forces of war—violence, chance, and reason—acting on each other in multifarious ways, whose dynamics the statesman and commander must thoroughly consider before deciding whether to go to war and how to conduct it.[32] Jomini's central proposition consists of a series of four maxims about strategy that he summarized as "bringing the greatest part of the forces of an army upon the important point of a theater of war or of the zone of operations."[33] Jomini's principle-based approach to theory has had great endurance over the years. It perhaps found its most complete expression in J.F.C. Fuller's *The Foundations of the Science of War*, a treatise whose nine didactic imperatives, each expressed as a single word or short phrase, continue to resonate in contemporary doctrinal manuals.[34]

Clausewitz's and Jomini's views of theory were not mutually exclusive. Jomini addressed some of the wider considerations of policy central to Clausewitz, particularly in the opening chapter of *The Art of War*.[35] And Clausewitz occasionally engaged in formulaic statements, perhaps most notably in his observation that "destruction of the enemy force is always the superior, more effective means, with which others cannot compete."[36] Nevertheless, their two approaches—one descriptive, the other prescriptive—represent the two normative poles concerning the utility of theory.

But we find useful insights into the utility of theory from more modern observers as well. In his 1959 foreword to Henry E. Eccles's important but much-neglected work, *Logistics in the National Defense*, Henry M. Wriston, then president of the American Assembly at Columbia University, opined, "Theory is not just dreams or wishful thinking. It is the orderly interpretation of accumulated experience and its formal enunciation as a guide to future intelligent action to better that experience."[37] In this pithy and elegant formulation, Wriston captures an important truth: the fundamental social utility of theory is to help realize man's almost universal longing to make his future better than his past. The fact that the book that followed offered a theory of military logistics was but a particular manifestation of a general verity. Several years later, J.C. Wylie, a reflective, combat-experienced Sailor, developed a formulation similar to Wriston's that described the mechanics of translating theory into action:

> Theory serves a useful purpose to the extent that it can collect and organize the experiences and ideas of other men, sort out which of them may have a valid transfer value to a new and different situation, and help the practitioner to enlarge his vision in an orderly, manageable and useful fashion—and then apply it to the reality with which he is faced.[38]

In sum, there are two somewhat polar philosophies of how theory should influence practice. In the Clausewitzian view, it does so indirectly by educating the judgment of the practitioner; in the Jominian view, it does so directly by providing the practitioner concrete guides to action. Wriston and Wylie, both slightly more Clausewitzian than Jominian, provide a useful synthesis and update of Clausewitz and Jomini, rearticulating the value of theory to the military professional.

Influence of Theory on Military Institutions

In the modern age, theory has its most immediate influence on military institutions in the form of doctrine, a sort of stepping stone between theory and application. Along a scale stretching from the purely abstract to the purely concrete, doctrine occupies something of a middle ground representing a conceptual link between theory and practice. Having come much into vogue in the U.S. Armed Forces since the end of the Vietnam War and with its popularity propagated to many other institutions as well, doctrine also represents, in a sense, sanctioned theory. In other words, there are two principal distinctions between theory and doctrine: the latter is decidedly more pragmatic, and it is stamped with an institutional imprimatur. How does theory influence doctrine? Generally speaking, we would expect theory to provide general propositions and doctrine to assess the extent to which these strictures apply, fail to apply, or apply with qualifications in particular eras and under particular conditions. In other words, the intellectual influence flows from the general to the particular. But at times, the relationship is reversed. This occurs when doctrine seeks to deal with new phenomena for which theory has not yet been well developed, such as for the employment of nuclear weapons in the 1950s, or when doctrine developers themselves formulate new ways of categorizing or new relational propositions. In cases such as these, doctrine may drive theory. In seeking to examine the relationship between the two in detail, we will explore the theoretical underpinnings of the 1982 and 1986 statements of U.S. Army doctrine and the 1992 articulation of U.S. Air Force doctrine.

Our first laboratory for exploring these relationships is the Army in the aftermath of the Vietnam War. In 1976, it promulgated Field Manual (FM) 100–5, *Operations*. This manual was deliberately crafted by its principal architect, General William E. DePuy, first commander of the U.S. Army Training and Doctrine Command (TRADOC), to shake the Army out of its post-Vietnam miasma and provide a conceptual framework for defeating a Soviet incursion into Western Europe.[39] It succeeded in the first but failed in the second. DePuy definitely got the Army's attention, and he culturally transformed it from being indifferent toward doctrine to taking it quite seriously. But his fundamental concept of piling on in front of Soviet penetrations, which he referred to as the "Active Defense," did not find favor. It was seen as reactive, rather than responsive; dealing with the first battle, but not the last; and insufficiently attentive to Soviet formations in the second operational and strategic echelons. Thus, the stage was set for a new manual, a new concept, and a new marketing label.

The new manual was the 1982 edition of FM 100–5; the new concept was to fight the Soviets in depth and hit them at unexpected times from unexpected directions; and the new marketing label was "AirLand Battle." The principal authors were two gifted officers, L.D. "Don" Holder and Huba Wass de Czege. Both had advanced degrees from Harvard University (Holder in history, Wass de Czege in public administration); both were combat veterans of the Vietnam War; and both were sound, practical soldiers. The manual they produced under the direction of General Donn A. Starry, DePuy's successor at TRADOC, was clearly informed by theory as well as history. From Clausewitz came notions such as the manual's opening sentence, "There is no simple formula for winning wars"; a quotation to the effect that "the whole of military activity must . . . relate directly or indirectly to the engagement"; "The objective of all operations is to destroy the opposing force"; and another direct citation characterizing the defense as a "shield of [well-directed] blows."[40] But there was also a strong element of indirectness in the manual that one could trace to the ideas of Sun Tzu, who was mentioned by name, and Basil H. Liddell Hart, who was not. Sun Tzu was quoted to the effect that "rapidity is the essence of war; take advantage of the enemy's unreadiness, make your way by unexpected routes, and attack unguarded spots"; soldiers were adjured that "our tactics must appear formless to the enemy"; and one of the seven combat imperatives was to "direct friendly strengths against enemy weaknesses."[41] Additionally, the manual's extensive discussion of "Deep Battle," which advocated striking well behind enemy lines to disrupt the commitment of reinforcements and subject the opposing force to piecemeal defeat, drew heavily on the legacy of Mikhail Tukhachevskii, V.K. Triandafillov, A.A. Svechin, and other Soviet thinkers of the 1920s and 1930s.[42] Although it was politically infeasible to acknowledge this intellectual debt at the height of the Cold War, the apparent reasoning here was that one had to fight fire with fire. And the strong emphasis on "Deep Battle" was an outgrowth of an intensive study of Soviet military practices dating back to the earliest years of the Red Army. A further reflection of this debt was the introduction of a variation of the Soviet term *operational art* into the American military lexicon as the *operational level of war*.[43]

When the manual was updated 4 years later, a third author, Richard Hart Sinnreich, was brought into the work. Sinnreich's professional and academic credentials were just as sound as those of his two compatriots: combat time in Vietnam, an advanced degree in political science from The Ohio State University, and well-developed soldiering skills. Holder, Wass de Czege, and Sinnreich engaged in a collaborative effort that expanded and conceptualized the notion of operational art. But rather than associating the term *operational* strictly with large-scale operations, as had been done in the previous edition, the 1986 manual defined *operational art* as "the employment of military forces to attain strategic goals in a theater of war or theater of operations through the design, organization, and conduct of campaigns and major operations."[44] This depiction of operational art as a conceptual link between tactical events (the building blocks of major operations) and strategic results significantly broadened the Soviet concept and made it applicable to the wide variety of types of wars that the U.S. Army might have to fight. It also harkened back to Clausewitz's definition of strategy as "the use of an engagement for the purpose of the war."[45] The manual then ventured into some theory of its own in requiring the operational commander to address three issues: the conditions required to effect the strategic goal, the sequence of actions necessary to produce the conditions, and the resources required to generate the sequence of actions. The combination of a new definition of operational art and a framework for connecting resources, actions, and effects gave the manual an underlying coherence that made it an extremely valuable document in its day and an admirable example of the genre of doctrinal literature.

Roughly contemporaneously with the publication of the second expression of the Army's AirLand Battle doctrine, a group of Airmen with a scholastic bent was assembled at the Airpower Research Institute (ARI) of the U.S. Air Force College of Aerospace Doctrine, Research, and Education to launch a bold experiment in the formulation of Air Force basic doctrine. This effort was based on an idea put forth by the highly respected Air Force historian Robert Frank Futrell, who opined that doctrine should be published with footnotes to document the evidence supporting the doctrinal statements.[46] The ARI Director, Dennis M. Drew, a Strategic Air Command warrior who had served at Maxwell Air Force Base since the late 1970s and held an advanced degree in military history from the University of Alabama, decided to put Futrell's idea to the test. But he and his research/writing team ultimately determined to expand on Futrell's basic notion. They would publish the doctrine in two volumes. The first, relatively thin, document would contain the bare propositional inventory; the second, more substantial, tome would lay out the evidence upon which the statements in the first were based. The process involved a good deal of both research and argument; but by the eve of the 1991 Gulf War, Drew and his team had produced a workable first draft. Publication was delayed until 1992 to allow the Air Force to assimilate the experience of that war. The result was what Air Force Chief of Staff Merrill A. McPeak called "one of the most important documents published by the United States Air Force."[47] Arguably, he was correct. No other American military Service had ever mustered the intellectual courage to put its analysis where its propositions were. It was potentially, in form alone, a paradigm for a new, analytically rigorous approach to the articulation of doctrine.[48]

As one would suspect, the primary influence on the manual was empirical. Historical essays addressed issues such as the environment, capabilities, force composition, roles and missions, and employment of aerospace power as well as the sustainment, training, organizing, and equipping of aerospace forces.[49] But there was a notable conceptual cant as well. The opening pages either paraphrased or quoted Clausewitz: "War is an instrument of political policy"; "the military objective in war is to compel the adversary to do our will"; and "war is characterized by 'fog, friction, and chance.'"[50] And the notion that "an airman, acting as an air component commander, should be responsible for employing all air and space assets in the theater" was right out of Giulio Douhet and Billy Mitchell.[51] There was also, like the 1982 version of FM 100–5, a nod in the direction of Sun Tzu and Liddell Hart: "Any enemy with the capacity to be a threat is likely to have strategic vulnerabilities susceptible to air attack; discerning those vulnerabilities is an airman's task."[52] The only place that the propositional inventory appeared to be but thinly supported by underlying concepts or evidence was a page-and-a-quarter insert titled "An Airman's View," which contained a series of statements that could perhaps be summed up in a single aphorism: airpower does it better.[53] Nevertheless, the 1992 statement of Air Force basic doctrine represented a bold, promising new approach to doctrinal formulation and articulation. Given this strong dose of intellectual rigor, it is not surprising that the experiment was short-lived.[54]

Nevertheless, in summing up the actual interplay between theory and the military profession, we can conclude that the institutional relationship between military theory on the one hand and military doctrine on the other is fairly direct.

Implications for a Theory of Spacepower

Having surveyed the nature of military theory, the general relation between theory and the military profession, and the particular relationship between theory and doctrine, it remains to suggest a few implications of this analysis for the theory of spacepower.

First, great care and extended debate should be devoted to articulating the central proposition, or main idea, of spacepower theory. One that is cast narrowly to focus only on spacepower's contributions to national security will take the theory in one direction. One that is cast more broadly to acknowledge spacepower's contributions to the expansion of man's knowledge of the universe will take it in another. Within the narrower ambit of national security, the construct of the theory should be informed by its purpose, which is related to the target audience. Here, Clausewitz's admonition is germane. In this author's opinion, one should not aim at some sort of positivist teaching that will spell out in precise and unambiguous fashion exactly what some future space forces commander or policymaker influencing the development of spacepower should do in a given situation. Rather, the theory should aim to *assist the self-education* of such individuals. To do this, it should focus on *explanatory relationships* within categories of spacepower itself and among spacepower and other related fields in the military-political universe. Given the relative newness of spacepower as both an instrument of military force and a vehicle for scientific exploration, and given as well the speed at which technological developments are likely to alter the physics of relationships among space-power subfields, it should be the tenor of a spacepower theory to develop a fairly firm list of questions that will inform the development and employment of spacepower but to recognize that the answers to those questions can change both rapidly and unexpectedly and must, therefore, remain rather tentative. Finally, it would be helpful to use the five-fold functions of definition, categorization, explanation, connection, and anticipation as a heuristic device to check the work for its efficacy and relevance. Such a review will not guarantee a useful product. It may, however, help to reduce errors and to sharpen the analysis of relevant issues.

In summary, both the nature and history of military theory indicate that the task of developing a comprehensive, constructive theory of space-power will not be easy. Nor can the present attempt be considered the final word on the subject. It can, nevertheless, move the dialogue on spacepower to a new and more informed level and thus make a worthwhile contribution to the enhancement of national security and perhaps to the conduct of broader pursuits as well.

Notes

1. The terms of reference establishing the need for a theory of spacepower specifically alluded to this rationale, noting that "the lack of a space power theory is most notable to the national security sector. Military theorists such as Clausewitz, Mahan, and Douhet have produced definitive works for land, sea, and air, but there is not such comparable resource for circumterrestrial space." Thomas G. Behling, Deputy Under Secretary of Defense (Preparation and Warning), "Space

Power Theory Terms of Reference," enclosure to memorandum to President, National Defense University, February 13, 2006, Subject: Space Power Theory, 1.

2. Perhaps the most apposite example of this contrast is the difference between French and German military concepts in the years between World Wars I and II and the resultant campaign outcomes. On the French, see Robert Allan Doughty, *Seeds of Disaster: The Development of French Army Doctrine 1919–1939* (Hamden, CT: Archon Books, 1985); on the Germans, see James S. Corum, *The Roots of Blitzkrieg: Hans von Seeckt and German Military Reform* (Lawrence: University Press of Kansas, 1992).
3. The argument here begins with a discussion of theory in a general sense. However, when the word *theory* is applied to the field of war, it becomes *military theory* in the classical sense of that term—that is, a systematic, codified body of propositions about the art and science of war and war preparation.
4. *Webster's Encyclopedic Unabridged Dictionary of the English Language* (New York: Gramercy Books, 1996), 1967.
5. Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1989), 75.
6. Ibid., 87.
7. Perhaps the most spirited assault on Clausewitz's notion that war is an extension of politics is found in John Keegan, *A History of Warfare* (New York: Alfred A. Knopf, 1993), 3–60. For an equally spirited rejoinder, see Christopher Bassford, "John Keegan and the Grand Tradition of Trashing Clausewitz: A Polemic," *War in History* 1 (November 1994), 319–336.
8. Clausewitz, 128.
9. Ibid., 611–637.
10. For a fascinating description of how Copernicus developed his new view of the universe, see Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (1957; reprint, Cambridge: Harvard University Press, 1999), 134–184.
11. The roots and early study of operational art are succinctly described in David M. Glantz, *Soviet Military Operational Art: In Pursuit of Deep Battle* (London: Frank Cass, 1991), 17–38.
12. Alfred Thayer Mahan, *The Influence of Sea Power upon History, 1660–1783*, 12th ed. (Boston: Little, Brown, 1918), 25.
13. Ibid., 29–89. Mahan's factors include a country's geographical position, physical conformation, extent of territory, size of population, national character, and the character of its government.
14. Albert Einstein's lead essay in the collection *Science et Synthèse* (Paris: Gallimard, 1967), 28, cited in Gerald Holton, *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge: Harvard University Press, 1980), 357.
15. The MacTutor History of Mathematics Archive, "Mathematical Discovery of Planets," available at <www.gap.dcs.st-and.ac.uk/~history/HistTopics/Neptune_and_Pluto.html>.
16. Mikhail Tukhachevskii, "The Red Army's New (1936) Field Service Regulations," in Richard Simpkin, Deep Battle: *The Brainchild of Marshal Tukhachevskii* (London: Brassey's Defence Publishers, 1987), 170.
17. Michael Howard, "Military Science in an Age of Peace," *Journal of the Royal United Services Institute for Defence Studies* 119 (March 1974), 7.
18. Clausewitz's unfinished note, presumably written in 1830; Clausewitz, *On War*, 70.
19. Mahan, 9.
20. Julian S. Corbett, *Some Principles of Maritime Strategy*, introduction and notes by Eric J. Grove (1911; reprint, Annapolis, MD: Naval Institute Press, 1988), 15–51.
21. Clausewitz, 134–136; Corbett, 107–152; J.F.C. Fuller, *The Foundations of the Science of War* (London: Hutchinson, 1926), 19–47.
22. Holton attempts to capture the essential qualities of scientific genius in *Thematic Origins of Scientific Thought*, 353–380. His major focus in this investigation is the genius's ability to work in the mental realm of apparent opposites. Although I am not equating the ability to formulate theory with genius, I am arguing that such formulation requires many of the same qualities that Holton describes.
23. "War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin. It is mandatory that it be thoroughly studied." Sun Tzu, *The Art of War*, trans. Samuel B. Griffith (New York: Oxford University Press, 1963), 63; "War is not pastime; it is no mere joy in

daring and winning, no place for irresponsible enthusiasts. It is a serious means to a serious end," Clausewitz, 86.

24. Clausewitz, 140. In the Paret-Howard translation, the phrase reads, "A Positive Doctrine is Unattainable." The text comes from a subchapter heading, "*Eine positive Lehre ist unmöglich*." Carl von Clausewitz, *Vom Kriege*, 19th ed., ed. Werner Hahlweg (Bonn: Ferd. Dümmlers Verlag, 1991), 289. The rendering of the German Lehre as doctrine is certainly acceptable. However, in light of the very specific military connotation that the term doctrine has developed since the early 1970s as being officially sanctioned principles that guide the actions of armed forces, I have chosen to render Lehre as the somewhat more general term teaching.
25. Clausewitz, *On War*, 140.
26. Ibid., 141.
27. Ibid., 145.
28. Ibid., 146–147.
29. Carl Becker, "Everyman His Own Historian," *American Historical Review* XXXVII (January 1932), 221–236; reprinted in Carl L. Becker, *Everyman His Own Historian: Essays on History and Politics* (New York: F.S. Crofts, 1935), 233–255.
30. Baron Antoine Henri de Jomini, *The Art of War*, trans. G.H. Mendell and W.P. Craighill (1862; reprint, Westport, CT: Greenwood Press, 1971), 321.
31. Ibid., 323.
32. Clausewitz, *On War*, 89. Clausewitz's description of the three elements provides a strong indication of his lack of dogmatism: "These three tendencies are like three different codes of law, deep-rooted in their subject and yet variable in their relationship to one another. A theory that ignores any one of them or seeks to fix an arbitrary relationship between them would conflict with reality to such an extent that for this reason alone it would be totally useless."
33. Jomini, 322. The maxims themselves are found on page 70.
34. The derivation of these nine principles is laid out in Fuller, 208–229. Fuller named them Direction, Concentration, Distribution, Determination, Surprise, Endurance, Mobility, Offensive Action, and Security. The U.S. Air Force's current list of principles of war includes Unity of Command, Objective, Offensive, Mass, Maneuver, Economy of Force, Security, Surprise, and Simplicity. *Air Force Basic Doctrine: AF Doctrine Document 1*, November 17, 2003, 19–26, available at <www.dtic.mil/doctrine/jel/service_pubs/afdd1.pdf>. Contemporary joint doctrine contains precisely the same list of the principles of war as the Air Force's but adds three "Other Principles": Restraint, Perseverance, and Legitimacy. Joint Publication 3–0, Joint Operations, September 17, 2006, II–2, available at <www.dtic.mil/doctrine/jel/new_pubs/jp3_0.pdf>.
35. Jomini, 16–39. The chapter is titled "The Relation of Diplomacy to War."
36. Clausewitz, *On War*, 97.
37. Henry M. Wriston, foreword to Henry E. Eccles, *Logistics in the National Defense* (1959; reprint, Washington, DC: Headquarters, United States Marine Corps, 1989), vii.
38. J.C. Wylie, *Military Strategy: A General Theory of Power Control* (1967; reprint, Annapolis, MD: Naval Institute Press, n.d.), 31.
39. For DePuy's pivotal role in the formulation of the 1976 edition of FM 100–5 and the reaction thereto, see Romie L. Brownlee and William J. Mullen III, *Changing an Army: An Oral History of General William E. DePuy, USA Retired* (Carlisle Barracks, PA: United States Military History Institute, n.d.), 187–189, and John L. Romjue, *From Active Defense to AirLand Battle: The Development of Army Doctrine 1973–1982* (Fort Monroe, VA: United States Army Training and Doctrine Command, 1984), 3–21.
40. Department of the Army, Field Manual 100–5, Operations (Washington, DC: Department of the Army, 1982), 1–1, 1–4, 2–1, and 11–1.
41. Ibid., 2–1, 2–8.
42. Ibid., 7–13 through 7–17.
43. Ibid., 2–3.
44. Department of the Army, Field Manual 100–5, *Operations* (Washington, DC: Department of the Army, 1986), 10.
45. Clausewitz, *On War*, 76. This definition, as the drafters of the manual were well aware, was much more conceptual than Jomini's description of strategy as "the art of making war upon the map." Jomini, *Art of War*, 69.

46. Interview with Professor Dennis M. Drew, School of Advanced Air and Space Studies, March 11, 2004. In addition to an extremely detailed history of U.S. Air Force operations in the Korean War, Futrell produced a two-volume compilation titled *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force* (Maxwell Air Force Base, AL: Air University Press, 1989).
47. Department of the Air Force, Air Force Manual 1–1, *Basic Aerospace Doctrine of the United States Air Force*, 2 vols. (Washington, DC: Department of the Air Force, 1992), 1:v.
48. For a detailed assessment of this groundbreaking work, see Harold R. Winton, "Reflections on the Air Force's New Manual," *Military Review* 72 (November 1992), 20–31.
49. Air Force Manual 1–1, 2:i.
50. Ibid., 1:1–2.
51. Ibid., 1:9.
52. Ibid., 1:12.
53. Ibid., 1:15–16.
54. The subsequent statement of Air Force basic doctrine, published in 1997, reverted to the traditional format. See Department of the Air Force, Air Force Doctrine Document 1, *Air Force Basic Doctrine* (Maxwell Air Force Base, AL: Headquarters, Air Force Doctrine Center, 1997).

Chapter 3:

International Relations Theory and Spacepower

Robert L. Pfaltzgraff, Jr.

The traditional focus of international relations (IR) theory has been peace and war, cooperation and competition, among the political units into which the world is divided—principally states, but also increasingly nonstate actors in the 21st century. Until the advent of technologies for air- and spacepower, all interaction took place on the Earth's surface. With the development of manned flight, followed by our ability to venture into space, international relations expanded to include the new dimension provided by the air and space environment. Just as terrestrial geography framed the historic setting for international relations, space is already being factored more fully into 21st-century IR theory, especially as rivalries on Earth, together with perceived requirements for cooperation, are projected into space. The foundations for the explicit consideration of space exist in IR theory. In all likelihood, new theories eventually will emerge to take account of the novel features of space as we come to know more about this environment. For the moment, however, we will think about space with our theories about Earth-bound political relationships as our essential point of departure. Just as we have extended Eurocentric IR theory to the global setting of the 21st century, such theories will be tested in space. Because all IR theories either *describe* or *prescribe* interactions and relationships, space becomes yet another arena in which to theorize about the behavior of the world's political units. The assumption that theories developed for Earth-bound relationships apply in space will be reinforced, modified, or rejected as we come to know more about human interaction in space. We may theorize about IR theory as it applies to the relationships between entities in space as well as how space affects the relationship between political units on Earth. We may also speculate about the extent to which space would eliminate or mitigate conflicts or promote cooperation between formerly hostile Earthly units if they found it necessary to confront an extraterrestrial foe. Such issues open other areas for speculation and discussion, including the potential implications of IR theory as space becomes an arena in which Earthly units attempt to enhance their position on Earth and eventually to establish themselves more extensively in space.

We need not live in fantasyland to think about the extension of Earthly life to space. This could include orbiting space stations building on the achievements of recent decades as well as colonies of people whose forebears originated on Earth but who have established themselves far from Earth. The need for IR theory about space could also arise from the development of transportation and communication routes among space colonies and space stations, and between peoples living on asteroids and the Moon as well as other planets. We may think of asteroids as either fragmenting objects that could destroy or alter Earth or as a basis for extending man's reach into space. As Martin Ira Glassner points out, such activities in space environments "will inevitably generate questions of nationality and nationalism and sovereignty, of ownership and use of resources, of the distribution of costs and benefits, of social stratification and cultural differences, of law and loyalties and rivalries and politics, of frontiers and boundaries and power, and perhaps of colonial empires and wars of independence."[1] This will provide a fertile environment for theorizing about existing and potential political relationships. We will come to understand more fully the extent to which Earthly theories can be projected onto space or the need to evolve entirely new ways of thinking about space. Because space is not the exclusive domain of governments, theories will include private sector entities as well. In this respect, the present IR theory emphasis on states as well as actors other than states has direct applicability.

Colonization of the Moon, asteroids, and planets would present humans with challenges to survival in space not encountered on Earth. We would greatly enhance scientific knowledge in a setting with greater or lesser levels of gravity and potentially lethal cosmic ray exposure, to mention only the most obvious differences with Earthly life. At the same time, we would face far different circumstances related to political and social relationships. For example, the challenges to survival would probably be so great that the rights of the individual might be sacrificed to the needs of the collective, or rugged individualism and self-reliance would be essential. Space colonies would be dependent for a time on their mother country on Earth but increasingly would be compelled by vast distances and time measured by years from Earth to fend for themselves. Barring dramatic technological advances that compress such travel time, the interactive capability of space colonies, whether with each other or with Earth, would be extremely limited. A premium would be placed on independence, and leadership would be measured by the ability to adapt to new and harsh circumstances.

There are many other unknowns concerning political and social relationships in space. We literally do not know what we do not know. Would Earthly religions be strengthened or weakened by space knowledge? It cannot be known in advance whether space colonization would reinforce existing social science theory about the behavior of individuals or groups with each other or lead to dramatic differences. For example, under what conditions in space would there be a propensity for greater conflict or for greater cooperation? In the absence of such experience in space, we have little choice but to extrapolate from existing IR theory to help us understand such relationships in space. In any event, the testing of theory about interaction of humans in space lies in the future. Our more immediate goal is to gain a greater understanding of how IR theory can (and does) inform our thinking about the near-term space issues, notably how space shapes the power of Earthly states, while we also speculate about the longer term issue of social science theory and relationships within and between groups in space. Thus, we think first about the extension of capabilities of states into space as a basis for enhancing their position on Earth and only subsequently about how sociopolitical relationships might evolve between space-based entities far from Earth.

The huge expanse of space provides a rich basis for theory development about relations between the Earth and the other bodies of the solar system and ultimately perhaps between these entities themselves. If social science theorizing is based on our images about the world surrounding us, how we imagine, or develop images about, the evolution of such relationships can only give new meaning to the word *imagination* as a basis for future IR theory. What is unique about space is the fact that we are dealing with infinity. Whereas the terrestrial land mass and the seas have knowable finite bounds, we literally do not know where space ends or understand the implications of infinity for how we theorize about space. In its space dimension, IR theory will evolve as emerging and future technologies permit the more extensive exploration, and perhaps even the colonization, of parts of the solar system and the exploitation of its natural resources, beginning with the Moon and ultimately extending beyond our solar system. As in the case of Earth-bound geopolitical theorizing, the significance of space will be determined by technologies that facilitate the movement of people, resources, and other capabilities. Those technologies may be developed as a result of our assumptions about the geopolitical or strategic significance of space extrapolated from IR theory and the requirements that are set forth in our space-power strategy.

From IR theory we derive the notion, building on geography, that a new arena becomes first an adjunct to the security and well-being of the primary unit and, later, a setting to be controlled for its own sake. Airpower was first envisaged as a basis for enhancing ground operations but subsequently became an arena that had to be defended for its own sake because of the deployment of vulnerable assets such as heavy bombers. As technologies become more widely available, they are acquired by increasing numbers of actors. Such technologies proliferate from the core to the periphery, from the most advanced states to others. Space becomes first an environment for superpower competition, as during the Cold War, to be followed by larger numbers of states developing space programs. At least 35 countries now have space research programs that are designed to either augment existing space capabilities or lead to deployments in space. Others are likely to emerge in the decades ahead.

IR theory has long emphasized power relationships, including the extent to which power is the most important variable for understanding the behavior of the political units into which the world is divided. The theory addresses questions such as: How pervasive is the quest for power, and how should power be defined? Given its centrality to IR theory, power in the form of spacepower represents a logical extension of this concept. Spacepower consists of capabilities whose most basic purpose is to control and regulate the use of space. This includes the ability, in the words of the 2006 U.S. National Space Policy, to maintain "freedom of action in space" as vital to national interests. According to the National Space Policy, "United States national security is critically dependent upon space capabilities, and this dependence will grow."

All Presidents since Dwight Eisenhower have stated that preserving freedom of passage in space is a vital U.S. interest that should be protected for all of humankind. Freedom of passage through space represents a norm embodied in the 1967 Outer Space Treaty. This is analogous to sea control, which encompasses freedom of passage in peacetime and the ability to deny an enemy the use of the seas during wartime. In the future, the interests of space powers will be in assuring safe passage for themselves and for their allies, while denying such access to their enemies. In practice, this means that, like the seas, space will become an arena for both competition and cooperation as political issues, including security, are extended from their terrestrial environment into space. Because IR theory has both a descriptive and prescriptive focus on competition and cooperation, it inevitably becomes the basis for speculation and theorization about such relationships in space, including spacepower.

Definitions of spacepower focus on the ability, as Colin Gray points out, to use space and to deny its use to enemies.[2] Spacepower is a multifaceted concept that, like power in IR theory, is "complex, indeterminate, and intangible," as Peter L. Hays put it.[3] Spacepower includes the possession of capabilities to conduct military operations in and from space and to utilize space for commercial and other peaceful purposes. Such capabilities have been increasing in the decades since the first German V2 rockets passed through the outer edge of space en route to their targets in England in the final months of World War II and the Soviets launched the first *Sputnik* in 1957. These events made space a military arena. In recent decades, space has become an essential setting for precision, stealth, command and control, intelligence collection, and maneuverability of weapons systems. In addition to its military uses, space has also become indispensable to civilian communications and a host of other commercial applications. Strategies for dissuasion and deterrence in the 21st century depend heavily on the deployment of capabilities in space. As a concept, spacepower broadens the domain of IR theory from the traditional horizontal geographical configuration of the Earth divided into land and the seas to include the vertical dimension that extends from airspace to outer space.

Because spacepower enables and enhances a state's ability to achieve national security, IR theory will be deficient if it does not give space more prominent consideration. In the decades ahead, spacepower theory and IR theory will draw symbiotically on each other. It is increasingly impossible to envisage one without the other. Space is an arena in which competition and cooperation are already set forth in terms and issues reminiscent of Earth-bound phenomena. Spacepower includes assumptions drawn from IR theory. Our theories about the political behavior of states and other entities in space are extensions of our hypotheses about terrestrial power. To the extent that our theories emphasize competition on Earth, we theorize in similar fashion about such interactions in the domain of space. If we emphasize the need for regimes to codify and regulate Earth-bound relationships, we extend such thinking to the dimension represented by space. Indeed, the ongoing debates about space, including its militarization and weaponization, have direct reference points to IR theory. The inclusion of space in IR theory will evolve as we incorporate space into national security because IR theory, like social science theory in general, is contextual. As E.H. Carr has written: "Purpose, whether we are conscious of it or not, is a condition of thought; and thinking for thinking's sake is as abnormal and barren as the miser's accumulation of money for its own sake."[4] We theorize, or speculate, about relationships among the variables that constitute the world that exists at any time.

However, states in some instances work with other states to develop cooperative arrangements that govern their relationships. It is to be expected that they would undertake efforts to regulate their operations in space as they do on Earth by developing legal and political regimes based on normative standards. Cooperative arrangements are already deemed necessary to prevent the stationing of weapons of mass destruction in space. It is the goal of our adversaries to place limits on U.S. terrestrial activities, and it would be unusual to expect them to try to do otherwise in space. Space becomes another arena for states to attempt to limit the activities of other states and to develop "rules of the road" favorable to their interests and activities. Thus, we have the basis for theory that *prescribes* how political entities in space should possibly interact with each other, including the kinds of regimes and regulations states may seek to develop in space.

At this early stage in space, we have already devoted extensive intellectual energy to prescribing how such entities *should* relate to each other. According to E.H. Carr, because "purpose, or teleology, precedes and conditions thought, at the beginning of the establishment of a new field of inquiry the element of wish is overwhelmingly strong."[5] This leads to normative thinking about how we would like human behavior to evolve in space. Carr was describing IR theory as it developed in the early decades of the 20th century. However, IR theory was erected on a rich base of historical experience dating from the Westphalian state system that had arisen in the mid-17th century. There is as yet no comparable basis for developing and testing theories about political relationships in space. With this important caveat in mind, we turn first to IR theory and spacepower in its geopolitical, or geostrategic, setting and then to other efforts, existing and potential, to theorize about space and to link IR theory to spacepower. Subsequent sections deal with geopolitics, realist theory, liberal theory, and constructivism.

Geopolitics and IR Theory

The process of theorizing about space is most advanced in the area of the geopolitics of the domain. This is a derivative of classical geopolitical theory. According to Everett C. Dolman, geopolitical theory developed for the Earth and its geographical setting can be transferred to outer space with the "strategic application of new and emerging technologies within a framework of geographic, topographic, and positional knowledge."[6] He has developed a construct that he terms *Astropolitik*, defined as "the extension of primarily nineteenth- and twentieth-century theories of global geopolitics into the vast context of the human conquest of outer space."[7] Although space has a unique geography, strategic principles that govern terrestrial geopolitical relationships nevertheless can be applied. States have behavioral characteristics, notably a quest for national security, that exist on Earth but that may also govern state behavior in space, thus opening the way for consideration of those theories about national interest as states acquire interests and capabilities in space. Dolman suggests that geopolitical analysis can be folded into the realist image of interstate competition extended into space.

Geopolitical theory represents a rich and enduring part of the literature of IR theory. In fact, all IR theory is based on environing factors that are physical (geography) and nonphysical (social or cultural), as Harold and Margaret Sprout have pointed out.[8] As the Sprouts recognized, all human behavior takes place in a geographic setting whose features shape what humans do or cannot do. Although geography pertains to the mapping of the Earth's surface, its physical differentiation has important implications for the behavior of the units that inhabit the various parts of the world, for example, as land or sea powers and now space powers. Thus, geography is crucially important. However, the significance of specific aspects of geography, or geographic location, changes as technology changes. For example, technology has exerted a direct influence on how wars are fought and how commercial activity has developed. As the seas became the dominant medium for the movement of trade and commerce, port cities developed. As land transportation evolved, junctions and highway intersections shaped land values. As resource needs changed, the importance of the geographical locations of resources such as reserves of coal or oil rose. If vitally important natural resources are found in abundance in certain locations in space, their geopolitical importance will be enhanced. The exploitation of such resources may become the basis for international cooperation or competition in order to secure or preserve access.

Central in the writings of classical geopolitical theorists such as Alfred Thayer Mahan and Sir Halford Mackinder is the direct relationship between technology and power projection. As long as technology favored the extension of power over the oceans (Mahan), those states most fully able to build and deploy naval forces were preeminent. The advent of the technological means for rapid movement of large forces over land (Mackinder), and subsequently for flight through the Earth's atmosphere, transformed not only the ways in which war could be waged, but also the hierarchy of states with the necessary capabilities. Thus, there was a close relationship between technology and the utilization, both for military and civilian purposes, of the Earth's surfaces— maritime and land—as well as the surrounding atmosphere and exosphere. Such a frame of reference emerges from the analysis of historic technological-strategic-economic relationships. Similarly, the existence of technologies for the transport of formerly Earth-bound objects into outer space has implications for both military and civilian activities at least as great as those changes that accompanied the great technological innovations of the past.

Historically, geopolitical theorists tell us, technology has had the effect of altering the significance of specific spatial relationships. The advent of the airplane, and subsequently the means to penetrate outer space, provided a whole new dimension to geopolitics. As long as human activities were restricted to the Earth's surface, they were subject to constraints imposed by the terrain. Although the seas are uniform in character, human mobility via the oceans is limited by the coastlines that surround them. No such constraints exist above the Earth's surface, in airspace or in outer space. In this environment, the possibilities of unprecedented mobility and speed enable states to seek either to protect their interests or project their power. For such purposes, they may exploit opportunities for surveillance, reconnaissance, and verification, as well as the potential afforded by space as an arena for offensive and defensive operations.

Just as geopolitical theorists have set forth their ideas about the political significance of specific geographical features, comparable efforts have been made to address "geography" in space. Writing on the geopolitics of space focuses on gravity and orbits. Gravity is said to be the most important factor in the topography of space because it shapes the "hills and valleys" of space, which are known as *gravity wells*. A simple astropolitical (geopolitical) proposition has been set forth: the more massive the body, such as a planet or moon, the deeper the gravity well. The expenditure of energy in travel from one point to another in space is less dependent on distance than on the effort expended to break out of gravitational pull to get from one point to another. The geographical regions of space have been divided into near Earth orbit, extending about 22,300 miles from the Earth's surface; cislunar space, extending from geosynchronous orbit to the Moon's orbit and including the geopolitically important Lagrange libration points, discussed below; and translinear space, extending from an orbit beyond the Moon, where the gravitational pull of the Sun becomes greater than that of the Earth, to the edge of the solar system.[9]

As with the Earth, an understanding of the geopolitics of space emerges initially from efforts to delineate the physical dimensions of the space environment. We need not review in great detail the literature on this important topic. What should be immediately obvious, however, is the limited applicability of the national sovereignty concept that governs nation-state relationships on Earth. The farther one ventures into space, the more difficult it becomes to determine what is above any one point on Earth. States can assert exclusive jurisdiction within their airspace because it lies in close proximity to their sovereign territory and they are more likely to have the means to enforce their claim to exclusive jurisdiction. Of course, this calculation could be changed by the development and deployment of capabilities constituting spacepower. The Earth and its atmosphere have been likened to the coastal areas of the seas on Earth. The high sea of Earth space is accessible only after we are able to break through the Earth's atmosphere or, in the case of the high seas, to pass beyond the coastal waters.

Earth space is the environment in which reconnaissance and navigation satellites currently operate. It is the setting in which space-based military systems, including space-based missile defense, would be deployed. Beyond this segment of space lies the lunar region encompassing the Moon's orbit. It is of special importance because it contains the Lagrange libration points where the gravitational effects of the Earth and Moon would cancel each other out. As Marc Vaucher pointed out in a seminal paper on the geopolitics of space, the military and commercial importance of these points is vast.[10] They are at the top of the gravity well of cislunar space, meaning that structures placed there could remain permanently in place. Because of the effects of the Sun, however, only two of the five Lagrange libration points (L4 and L5) are regarded as stable.

Finally, as we venture from lunar space, we would enter the solar space that lies beyond the Moon's orbit, encompasses the planets and asteroids of the solar system, and exists within the gravity well of the Sun. As already noted, the asteroids are feared as objects that could eventually collide with the Earth and end life as we know it. Alternatively, they could represent the new frontier of space exploration. In this latter case, asteroids become the basis for stations in space en route to the Moon or from Earth or Moon to other planets. Asteroids are said to acquire geostrategic importance as their potential for enhancing space travel increases.

Realist Theory and Spacepower

In order to understand its implications for spacepower, realist theory can be examined in each of its three major variations. These include *classical* realist theory as set forth by Hans Morgenthau;[11] *structural* realist theory developed by Kenneth Waltz;[12] and *neoclassical* realist theory.[13] What has made realist theory as a whole such a prominent part of the IR theory landscape is its multidimensionality, including hypotheses that can be generated at each of the levels of analysis of IR theorizing: the international system, the units that comprise the international system, and the behavioral characteristics of the units themselves. Among the key variables of realist theory, in addition to power, is the concept of competing national interests in a world of anarchy, with states comprising an international system that requires them to rely extensively on their own means of survival or to join alliances or coalitions with others sharing their interests. Although realist theory does not (yet) contain an extensive emphasis on space, it is possible to derive from its variants numerous ideas as a basis for further IR theory development. We begin with national interest.

According to classical realist theory, the territorial state pursues national interest, which is defined by a variety of factors such as geography, ideology, resources, and capabilities based on the need to ensure its survival in a world of anarchy. Because international politics is a struggle for power, it can easily be inferred that spacepower is a manifestation of such a struggle. With the advent of space technologies, national interest now includes space. If international rivalries on Earth are being projected into space, theories about how states deal with them on Earth can also be extended into space. Because technologically advanced states are heavily dependent on space-based assets, the ability to defend or destroy such assets becomes a key national security concern, as in the case of the United States. Although states are the current entities that may threaten the space capabilities of other states, not-so-distant future challenges may come from terrorist groups capable, for example, of launching an electromagnetic pulse attack that would destroy or disable vital electronic infrastructures, including telecommunications, transportation, and banking and other financial infrastructures, and food production and distribution systems.[14] Such a threat would arise from a nuclear weapon detonated 80 to 400 kilometers above the Earth's surface directly over the United States or adjacent to its territory. However, those entities best able to safeguard their Earth-bound interests through the exploitation of new technologies are also likely to be able to utilize space for that purpose.

Space is a new frontier that will be exploited as part of an inevitable and enduring struggle for power. This is the obvious lens through which adherents of the realist theory would view space. More than 40 years ago, President John F. Kennedy expressed this idea when he declared, "The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in the race for space."[15] In the absence of space leadership, states will lose preeminence on Earth. In recognition of this essential fact, competition in space began as soon as technologies became feasible. During the Cold War, the Soviet Union challenged the United States in space. Such statements are fully in keeping with classical realist theory.

In the 21st century, the United States faces increasing numbers of states whose power and prestige will be enhanced by their space programs. Therefore, with the advent of space technologies, a new dimension has been added to the national interest concept of realist theory. The fact that several states have developed national space programs highlights the relevance of realist theory in helping to explain why states acquire those programs. As already noted, space has begun to be utilized in support of the national interest. That the competition characteristic of terrestrial political relationships would be extended to space as soon as technologies for this purpose became feasible is implicit in realist theory. This includes the ballistic missiles dating from World War II and satellites that had their origins in the national security needs for reconnaissance, surveillance, and communications during the Cold War. The U.S.-Soviet competition included an increasingly important space component that would only have grown more intense if the rivalry had gone on for many more years. The dependence of technologically advanced states on space, together with their resulting vulnerability to attack in and from space, contributes to the relevance of realist theory to the analysis of space and national security.

Realist theory also contains the assumption that states rely ultimately on themselves for survival in the anarchical world of international politics. As sovereign entities, states (more accurately, their decisionmakers) determine for themselves how they will ensure their survival based on perceptions of national interest. Central to such theory is independence, including capabilities that increase the latitude available to states to help themselves to survive without outside assistance. Such theory may describe well the problems that entities in space will confront, perhaps only mitigated by vast distances separating them from each other and minimizing the contact that is essential for conflict, while also rendering impossible substantial levels of outside help. What is assumed in realist theory about self-help on Earth may be amply magnified in space if and when its colonization moves forward. Nevertheless, the vast distances that separate entities in space may drastically limit the possibility of armed conflict, as we have known it on Earth, between space-based entities on distant planets or asteroids. Even to begin to speculate about such behavior is to demonstrate the great latitude for divergent perspectives about conflict and cooperation.

Because national interest can best be understood within a geographical setting, the political dimension of geography is integral to realist theory. It has been noted that IR theorizing about spacepower begins with space-related geopolitical analysis that cannot be separated from national interest. Realist theory thus provides insights into the basis for national space policies. According to realist theory, states that are able to develop vast terrestrial capabilities are likely to extend their reach into space as technologies for this purpose become available. The private sector becomes a vital source of innovation in the most advanced economies. Because developed states, and especially the United States, have greater technological capabilities to operate in space, they are likely to favor a substantial role for the private sector, together with international regimes that regulate the use of space and protect the ability of public and private sector entities to operate there. Developing countries that cannot afford to divert resources to space or simply lack such capabilities are more likely to favor the extension of the common heritage principle to space while attempting to place drastic limits on developed countries and perhaps calling for mandatory transfers of space technology to developing countries. Such countries view space through a different prism of national interest, seeking to restrict or retard more developed states from exercising full control or from maximizing spacepower. Such behavior on the part of states large and small with regard to space issues is in keeping with realist theory. Each state operates according to perceptions of national interest.

Structural realist theory offers other insights into future space relationships. According to Kenneth Waltz, the international structure shapes the options available to units (in this case, states). In particular, the international structure is key to understanding unit-level behavior. *Structure* is defined as the type and number of units and their respective capabilities. The type and number of states have changed dramatically over time. New technologies have conferred unprecedented capabilities, including interactive capacity, on the states comprising the international system. Levels of interdependence have increased greatly. The foreign policy options available to states differ between bipolar and multipolar international systems. Structure shapes how states align with or against each other. We have already begun to consider the structural characteristics of space if we assume that the planets and their lunar satellites constitute the principal units. The geography of space, including where units are strategically situated, provides an important basis for theorizing about their relative importance, first, to states and other units on Earth and, eventually, perhaps with each other. The physical sciences, including astronomy, have already provided vast knowledge about how these units of the solar system relate to each other and to the Sun. IR theories will be enriched as we move into space and develop political relationships that become the basis for theorizing about the sociopolitical entities that will comprise space-based actors. Earlier, the suggestion was made that the unique characteristics of space, including distances and other features, will shape interactive patterns within and among space-based political units. Space colonies may have to operate with great independence because they cannot rely on a Mother Earth that would be possibly light years distant. If such assertions are true, they provide insights into how structure, extrapolated from structural realist theory, would shape unit behavior in space. Perhaps this would resemble in some ways the extremely limited preindustrial interactive capacity on Earth when communications between widely separated groups were few and often nonexistent.

Compared to present terrestrial international structures, space structures are likely to remain at a very rudimentary level. As technology develops, however, it is not fanciful to anticipate that parts of the solar system will be linked in unprecedented fashion as the ability to project spacepower rises, thus giving new meaning to space structure. Like the proliferation of capabilities leading to new power centers and globalization on Earth, it is possible to envisage such an analogy in space someday. This might include space stations or capabilities in space controlled from Earth. It might also encompass space colonization and the creation of new interactive capacity and patterns in space such as those that take place among Earth-based units. In the absence of colonization from Earth as took place in the age of European expansion, structural analogies in outer space are obviously premature.

However, a major theme of this chapter is that space exploration and exploitation will create interactive patterns that in themselves become the basis for theory and its testing. What constitutes those capabilities and how they are distributed among political units will be essential to understanding space structures. This may eventually become another level of analysis supplementing the existing levels for understanding the source of unit behavior. For example, as already discussed, we have begun to factor space into IR theory about power relationships. Space control is held by many to be indispensable to power on Earth. The extent to which options available to states at one or more levels are shaped by spacepower providing for space control contributes to space as an increasingly important level of analysis in itself. According to such theory, spacepower becomes the essential basis for Earthpower. If entities are to be dominant on Earth, they must control space. If space control shapes the foreign policy options available to states on Earth, then such theorizing about space replaces or supplements the international system level as the key echelon of analysis if we move beyond the structural realist theory of Kenneth Waltz.

Structural realist theory attaches great importance to the numbers and types of actors, the distribution of capabilities among them, and their interactive capabilities. For example, to think about globalization today is to understand the growing importance of telecommunications, including the Internet and broadband. Only recently has the Earth been wired for instantaneous communications. Interactive capacity translates into greater interaction that, in turn, creates systemic relationships leading to higher levels of specialization and interdependence. Systems as the outgrowth of structures represent a major focal point of IR theory. Astronomers have accumulated great knowledge about the behavior of the units comprising the solar system, including how such units relate to each other and how they are arranged in the solar system. Our theories about the social-political behavior of such units will evolve as social or political systems. This means that space first will affect interactive patterns, as we already see, of Earthly units with each other. Subsequently, the space-based interactive patterns that will become the object of theorizing are likely to differ dramatically from those on Earth because of factors such as vast distances measured in light years. The social-political solar system will remain far more primitive in its development than Earthly international systems, barring major advances in space technologies. Nevertheless, it is possible to make use of IR theory focused on structure and system to speculate about such space relationships.

Neoclassical realist theory also provides a basis for discussing space-power and IR theory. The effort to refine neorealist theory includes an understanding of the conditions under which states choose whether competition or cooperation is the preferred option. Although its overall power and the place of the state in the international system decisively shape actor choices, foreign policy, potentially including spacepower, is the result of choices based on perceptions, values, and other domestic-level factors. Thus, the neoclassical realist literature brings together international systems and unit-level variables based on the assumption that foreign policy is the result of complex patterns of interaction within and between both levels. Neoclassical realist theory rethinks power in its offensive and defensive components, including the circumstances under which states seek security in an anarchic setting by developing military forces to deter or defend against an adversary as well as the level and types of capabilities that are deemed sufficient to ensure one state's security without threatening the other side's ability to deter or defend. Such issues are easily identifiable in discussions about spacepower.

A variant of neoclassical realist theory, called contingent-realist theory, emphasizes what is termed the *offense-defense balance*, defined as the ratio of the cost of offensive forces to the cost of defensive capabilities. Contingent-realist theory provides a theoretical basis for examining when and how states, in a self-help system, decide to cooperate as a means of resolving the security dilemma. Entirely consistent with such IR theory, space affords yet another setting for states to develop cooperative or competitive relationships. To the extent that domestic preferences shape the foreign policy of democratic states, we also come close to democratic peace theory. Domestic factors help mold foreign policy preferences, including support for cooperation or competition. Such neoclassical realist thought leads logically to a discussion about, and possible integration of, other IR theories into theory about space, including neoliberal and especially democratic peace theory.

Neoliberal Theories and Space

Just as space can be viewed as an area for competition, so can it also be the basis for cooperation. Such an assertion opens for consideration a spectrum of IR theory beyond neoclassical realist theory to be applied to our thinking about space. For example, democratic peace theory (DPT) posits that states defined as liberal democracies do not go to war with other liberal democracies. Such states are more likely to cooperate with each other in space activities than they are with totalitarian governments in space or in other endeavors—although the United States and the Soviet Union developed cooperative relationships with each other during the Cold War. Liberal democracies in disputes with other liberal democracies are likely to resolve their disagreements by means other than armed conflict. It is primarily in democracies that debates about the militarization and weaponization of space take place. Presumably, democracies that provide the basis for colonization or other interactive patterns in space would carry with them the values that could shape their behavior in space, just as the seeds of American democracy were planted by the British colonists who settled in the New World. Could we conceive of the colonization of space leading to forms of government pitting democratic colonies against those from nondemocratic states on Earth? Such is the logic of DPT extended into space. However, it is plausible to suggest that the rigors of space will test Earthly values in environments drastically different than those that exist on Earth, necessitating dramatic changes in political and social relationships. Such a suggestion is fully in keeping with the assumption that environing factors shape the options available to humans, whether on Earth or in space, just as humans make concerted efforts to alter the environment to meet their needs. The interactive process between humans and their environment has provided an enduring focal point for IR theory and other social science theory.

As they develop a presence in space as an adjunct to their terrestrial interests, democracies and other states have already begun to form regimes that codify normative standards designed to facilitate cooperation based on agreed procedures and processes as well as common interests and shared values about space-related activities. Those regimes may be formal or informal. Formal regimes may be the result of legislation by international organizations that are themselves established by democracies and other states having an interest in such arrangements. Such formal regimes may possess governing councils and bureaucratic structures. In contrast, informal regimes may be based simply on consensus about objectives and the interests of the participants. Therefore, it is possible to envisage regimes in space or on space issues based on a convergence of interests in keeping with realist theory or as the outgrowth of the cooperative values of democracies.

The liberal world vision holds that states and their actors engage in mutually rewarding exchanges, including trade based on specialization and comparative advantage. Cooperation benefits states as well as individuals and groups that become increasingly interdependent. Order emerges as self-interested units in an anarchic setting cooperate for mutual benefit. In other words, cooperation may be based on national interests, an idea that is compatible with realist theory. Liberal theory holds that cooperation in one sector may produce satisfaction that enhances incentives to collaborate in additional sectors, leading to what Ernst Haas termed "spillover" or the "expansive logic of sector integration."[16] Just as advances in technology have led to the emergence of a single global system and international society, neoliberal theory posits that the extension of man's reach into the solar system and ultimately the broader universe will enhance the need for cooperation. Both as an expression of the values of a liberal democracy set forth in DPT and as a matter of self interest, cooperation becomes an essential part of liberal IR theory about space relationships. We do not currently know whether outer space will reinforce the competitive dimension or create the need for greater cooperation within and among the emerging entities that will populate space. We may hypothesize that the demands of life in outer space may enhance the need for cooperation, but we may also consider the pursuit of clashing interests between contending groups for control of key space geopolitical positions and assets. The answer to such questions, of course, holds important implications for the relevance of one IR theory or another to space. At this point in time, however, neoliberal theory, like realist theory, has much to offer as we speculate about space relationships.

Constructivism

Another approach (and a fertile one) to theorizing about space flows from constructivism. Whereas much of IR theory usually focuses on relationships among structures that shape the behavior of units or agents, and how interactive capacity leads to interactive patterns (systems), constructivism views the world in a fundamentally different way. In the constructivist image, the building blocks of international society can be best understood by analysis of rules, practices, agents, statements, social arrangements, and relationships. Constructivism is not a theory, but instead an ontology, an understanding of the nature of being, a way of looking at the world. The world is constantly being "constructed" and therefore changed as new geopolitical, geoeconomic, or geostrategic changes take place. Such changes occur in a setting in which a "vast part of the planet [is] also changing 'internal' ways of running [its] political, economic, and social affairs. No part of the world can avoid these changes or their consequences; the entire world is continuously 'under construction.'"[17] What this means is that theories based on phenomena such as states, balances of power, anarchy, or national interest are inadequate, if not misleading, because they are abstractions that are "constructed" in our minds rather than being objects having concrete reality. Instead, human relationships are inherently social in that they are defined by the social arrangements made by individuals or groups who are endowed with free will. What is acceptable in the form of human behavior at one point in time may not be acceptable in a subsequent phase. For example, the role of women in Western society has been altered dramatically in the past century. Practices that were once commonplace are no longer deemed acceptable. People are constantly changing and redefining their relationships based on the practices and rules that they create. Therefore, they are free of the material inanimate factor termed *structure*. Translated into IR theory and space, this means that we have the ability to create, or construct, the types of arrangements that we may wish to have for space. What is important is how we think about and construct "rules rather than imaginary, artificially unified entities such as states or structures. Rules have ontological substance; they are there for anybody to see."[18]

Rules of behavior are the result of a changing intersubjective consensus that arises over time from discussions, thought, and action. Just as geopolitics addresses the physical environment, constructivism deals with the ideational setting. What we have, according to Nicholas Onuf, a leader in constructivist thought, is a continuous "two way process" in which "people make society, and society makes people."[19] As a result of such interaction, we develop rules of behavior within institutions and elsewhere. In other words, we construct reality as well as our respective individual, group, and national identities. It is not a great leap in logic to consider space as an arena in which rules of behavior, first derived from Earthly experience and subsequently evolving in light of new factors, lead to the construction of newer rules governing behavior as well as identities. According to constructivism, new values and expectations are created that become embedded in growing numbers of people and spread to broader epistemic communities, defined as elites with a shared understanding of a particular subject. Presumably, the organizers of this project and its participants fall within this category as they develop an ideational basis for thinking about and developing strategies for spacepower. Such epistemic communities create a strategy for achieving their goals and play a major innovative role. For the constructivist, the essential issue is how such a process will play itself out in sectors of importance such as space. Whoever constructs rules of behavior that can be applied to space will determine what those rules are, at least to the extent that we are dealing with political/ social relationships.

Conclusion

This chapter has briefly surveyed four major perspectives or IR theories. Greater depth and analysis are required to encompass the more extensive IR theory. This includes theories of conflict and war, deterrence and dissuasion, cooperation, integration, and political community. To what extent, for example, will the clashes that take place on Earth have counterparts in space, and what can conflict theory suggest to us about their parameters? By the same token, what can be hypothesized about the forces making for greater community and integration, including nationalism and identity, that would have direct relevance to space? Although we can only speculate about the answers to such questions, IR theory provides a useful point of departure for such an exercise.

IR theory rests on contending and contrasting assumptions about relationships between international units, including states and other actors. Even having far less knowledge of space than we have about the Earth, we have already begun to transfer beliefs about Earth-bound interactions into our thinking about the behavior of states in space. However, space has already become an arena for competition and cooperation. IR theory offers alternative explanations about international competition and cooperation. The emphasis that we place on competition or cooperation may depend on the IR theory or theories on which we choose to rely. This we already do in the case of terrestrial international relationships. To the extent that we envisage space as an arena for growing competition based on an inevitable quest for power, we will be drawn to realist theory. If we emphasize the cooperative dimension, we will likely embrace assumptions derived from liberal theory. Because the stakes are immense, how we theorize about space, drawing on existing and yet-to-be-developed IR and other social science theories, will have major implications for strategies and policies. Because no single IR theory capable of describing, explaining, or prescribing political behavior on Earth exists, we cannot expect to find otherwise in space. Therefore, it is important to recognize the inherent limitations in extrapolating from Earthly IR theory to space, while also drawing wherever possible on such theory as we probe farther into space.

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11. See especially Hans Morgenthau, *Politics among Nations: The Struggle for Power and Peace* (New York: Alfred A. Knopf, 1960), 3–15.
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15. John F. Kennedy, address at Rice University on the Nation's Space Effort, Houston, Texas, September 12, 1962, available at <www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Speeches/JFK/003POF03SpaceEffort09121962.htm>.
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Chapter 4:

Real Constraints on Spacepower

Martin E.B. France and Jerry Jon Sellers

Any discussion of the bases and tenets of spacepower must begin with a solid understanding of the governing physical laws, environment, advantages, and difficulties inherent in space systems and their operations.[1] While conferring significant advantages on those who can operate there effectively, space presents unique challenges and high development costs, both monetarily and experientially. After all, it *is* rocket science. Beyond the equations, too, there exist the complex systems definition and engineering needed to "operationalize" space and bring its effects to the user in a timely and affordable fashion. From definition of the basic need to delivery of a given capability, the variety of technical, programmatic, and acceptable risk issues that must be defined before any spacepower can be sustained or developed is daunting. Theorists and users must realize that, even on the strategic level, there are irreducible sets of knowledge, understanding, and trades that form the foundation of space competency. The purpose of this chapter is to highlight these key concepts, serving as a review for some readers, an overview for others, and (we hope) a motivation for all to continue to hone their space expertise.

Advantages of Space

Getting into space is dangerous and expensive. So why bother? The five primary advantages space offers for modern society are:

- global perspective
- clear view of the heavens
- free-fall environment
- abundant resources
- unique challenge as the final frontier.

While each of these benefits plays a role in defining a nation's space-power, they may not be equally valued.

Clearly, the global perspective provided by space is a primary motivator for deploying commercial, civil, military, and scientific systems there. Space takes the quest for greater perspective to its ultimate end, allowing access to large areas of the Earth's surface depending upon orbital specifics. Orbiting spacecraft can thus serve as "eyes and ears in the sky" to provide a variety of useful services.

The high ground, once achieved, makes possible several other capabilities that may reinforce a nation's space and economic power. Scientifically, space offers a clear view of the heavens. From the Earth's surface, the atmosphere blurs, blocks, and disturbs (scintillates) visible light and other electromagnetic radiation, frustrating astronomers who need access to all the regions of the electromagnetic spectrum to explore the universe. Spacecraft such as the Hubble Space Telescope and the Gamma Ray Observatory overcome this restriction and have revolutionized our understanding of the cosmos.

Space offers a free-fall environment enabling manufacturing processes not possible on the Earth's surface. Though certainly not exploited to date for other than experimental value, the potential to manufacture exotic compounds for computer components or pharmaceutical products exists.

Further downstream, space offers abundant resources. While spacecraft now use only one of these abundant resources—solar energy—the bounty of the solar system offers an untapped reserve of minerals and energy to sustain future exploration and colonization. In the not-too-distant future, lunar resources, or even those from the asteroids, might fuel a growing space-based economy.

Finally, space serves simply as a frontier. The human condition has always improved as new frontiers were challenged. As a stimulus for technological advances and a crucible for creating economic expansion, space offers a limitless challenge that compels national and global attention. The act of exploration—across oceans or prairies in the past, and in this case pushing back the frontiers of space—has long been a wellspring of pride and an expression of power.

Turning Need into Capability

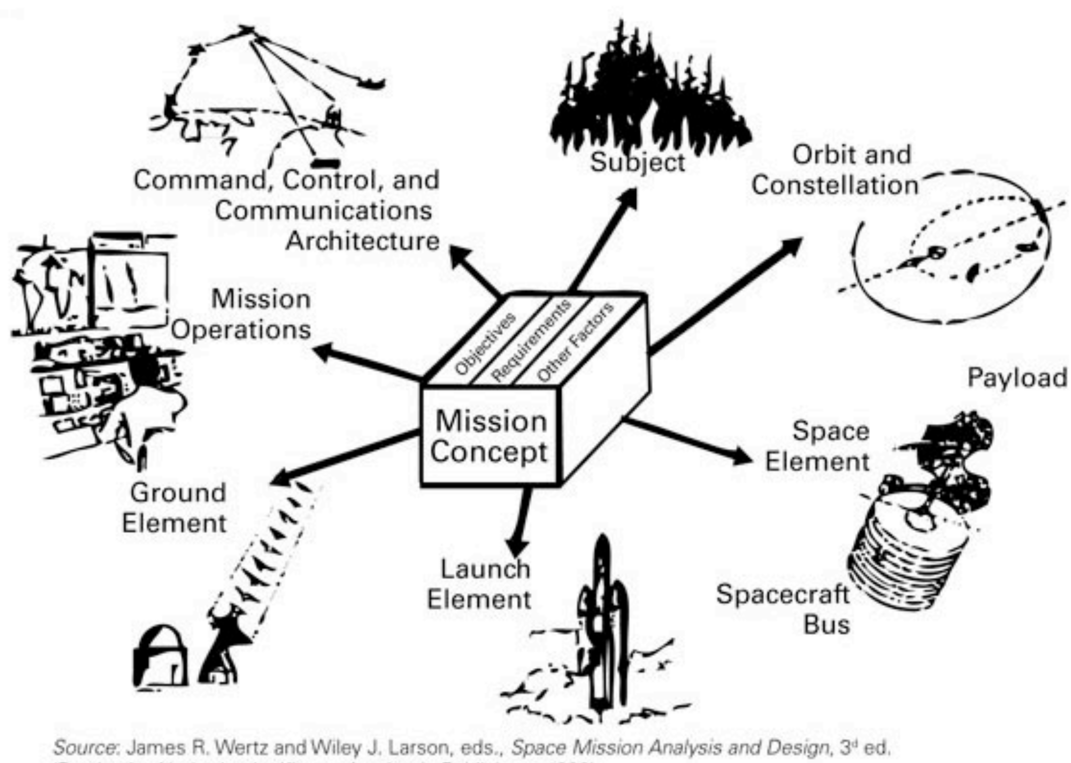
From an engineer's perspective, spacepower can be viewed as the exploitation of space-based systems (and the natural laws governing them) to achieve national political or economic ends. Maintaining and expanding a nation's spacepower hinges on the ability to define the need for new systems and turn those needs into capabilities that policymakers and war-fighters can exploit. The purpose of the space systems acquisition process is to translate those needs into capable systems. The technical foundation of space systems acquisition is systems engineering. Fundamentally, the space systems engineering process leverages one or more of the advantages of space outlined above to turn needs, as defined by policymakers and warfighters, into operational capabilities. The more clearly the needs for these systems are articulated in terms of performance, cost, and schedule goals, the better systems engineers can make realistic tradeoffs to achieve those goals with acceptable risk.

Ultimately, the intended goals and objectives of the system become defined in terms of *requirements*—single, testable *shall* statements that define what the system will be or shall do and how well. Bounding the universe of possible solutions for any problem are *constraints*. The difference between a requirement and a constraint is really a matter of perspective. One person's requirement for a given mechanical interface as defined by a specific bolt pattern becomes a constraint from the standpoint of the designer of the interface plate. Some requirements are imposed on a system for practical, political, or economic reasons and are arguably negotiable at some pay grade, while some constraints, such as the laws of physics or the real state of the art, are not subject to negotiation. The remainder of this chapter will focus on understanding the source of requirements and constraints on space systems—and thus ultimately on spacepower—that form the realm of the possible. Fortunately, this realm is vast, offering many asyet-untapped capabilities. But the better we understand the limits of this realm, the better we will manage scarce resources to achieve best systems— and hence capabilities—to enhance spacepower.

Mission Architectures

The increasing complexity and interoperability of space systems have lead to discussions of "systems of systems" or, more broadly, *mission architectures*. A space mission architecture includes all of the space and ground elements needed to make the mission successful. A mission architecture includes the spacecraft (including payload and bus), operating in a specific orbit, interacting with some subject (see figure 4–1). The spacecraft is placed into orbit by a launch vehicle and is operated using a defined communication architecture that uses ground stations and operators. At the heart of the architecture are the objectives, requirements, and other factors that define the mission concept.

Figure 4–1. Mission Architechture



Source: James R. Wertz and Wiley J. Larson, eds., *Space Mission Analysis and Design*, 3rd ed. (Dordrecht, Netherlands: Kluwer Academic Publishers, 1999).

Defining Requirements, Understanding Constraints

As stated earlier, the need desired by the policymaker or warfighter must eventually be articulated as a set of design-to, build-to, and test-to requirements by the systems engineer during the acquisition process. If we consider only technical requirements (the focus of this chapter), we can divide these requirements into a number of basic categories (similar to those specified by Military Standard-961c, "Preparation of Military Specifications and Associated Documents"). Within these broad categories, we can further define a number of typical requirements identified for military missions. These requirements are in turn specified by some number of detailed performance parameters. Finally, these parameters are constrained by a number of factors (see table 4–1). The point of this exercise is to distill the broad operational requirements normally levied on space systems down to a handful of constraining factors that affect them. The reader will notice a number of recurring themes that affect myriad types of requirements—for example, orbital mechanics. The balance of this chapter will explore these constraining factors to understand the possibilities and limits they pose on spacepower capabilities.

Table 4–1. Space Mission and Constraints

Requirement Category	Typical Requirement	Specified by	Constrained by
Performance	Resolution	Spatial resolution Spectral resolution Radiometric resolution Temporal resolution	Orbital mechanics Remote sensing physics
	Data rate	Bits per second	Communication physics
	Coverage	Latitude/longitude ranges	Orbital mechanics
	Maneuverability	Delta-V	Orbital mechanics Space launch and rocket propulsion
Interfaces	Spacecraft-to-launch vehicle	Mechanical bolt pattern, connectors pin in/out description	Space launch and rocket propulsion
	Spacecraft-to-ground segment	Data rates, frequencies, modulation schemes, encryption methods	Communication physics
	Spacecraft-to-spacecraft	Data rates, frequencies, modulation schemes, encryption methods, Doppler shifts	Communication physics
Physical Characteristics	Spacecraft mass, volume Constellation Description	Mass, volume, number of satellites, number of orbit planes, spacing of orbit planes	Spacecraft state of the art Orbital mechanics
Operational Environments	Launch environment Space environment	Vibration, thermal, acoustic, radio frequency gravitational, vacuum, neutral atmospheric, charged particles, radiation, micrometeoroid/orbital debris	Space launch and rocket propulsion Space environment
System Quality	Lifetime operability	Reliability Orbit lifetime Autonomy, interfaces	Spacecraft state of the art Orbital mechanics Space launch and rocket propulsion

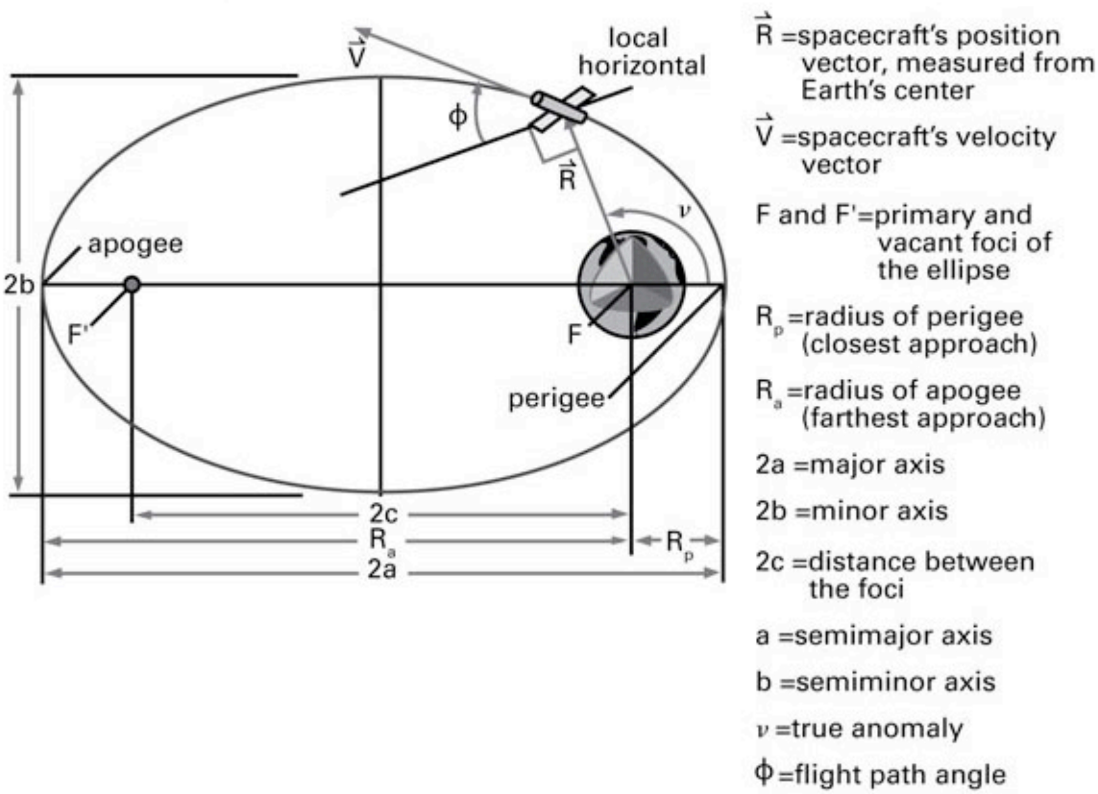
Orbital Mechanics

Simply put, an orbit is achieved when an object is moving fast enough that the Earth's curved surface is falling away from it faster than the object itself is pulled to the Earth by gravity. The velocity of the object (or spacecraft, for our purposes) and its position relative to the Earth define the specific orbit in which it moves. At ground level, an object would need a velocity of approximately 7.9 kilometers (km) per second (tangent to the Earth's surface) to effectively "fall" around the Earth—neglecting aerodynamic drag, of course. This motion is governed by Newton's second law of motion and law of gravitation and assumes that the spacecraft acts as a constant point mass, its mass is insignificant relative to the Earth's, the Earth is a perfect sphere, and no other forces (drag, thrust, solar, or lunar gravity, and so forth) are acting upon our spacecraft. These assumptions represent the requirements for the "restricted two-body problem," for which Newton's solution describes the spacecraft's location using two constants and a polar angle and represents a general relationship for any conic section (circle, ellipse, parabola, or hyperbola).

Describing Orbits

For the most useful case in this study, we consider the elliptical Earth orbit defined by the parameters shown in figure 4–2.

Figure 4–2. Elliptical Orbit Parameters



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 4–33.

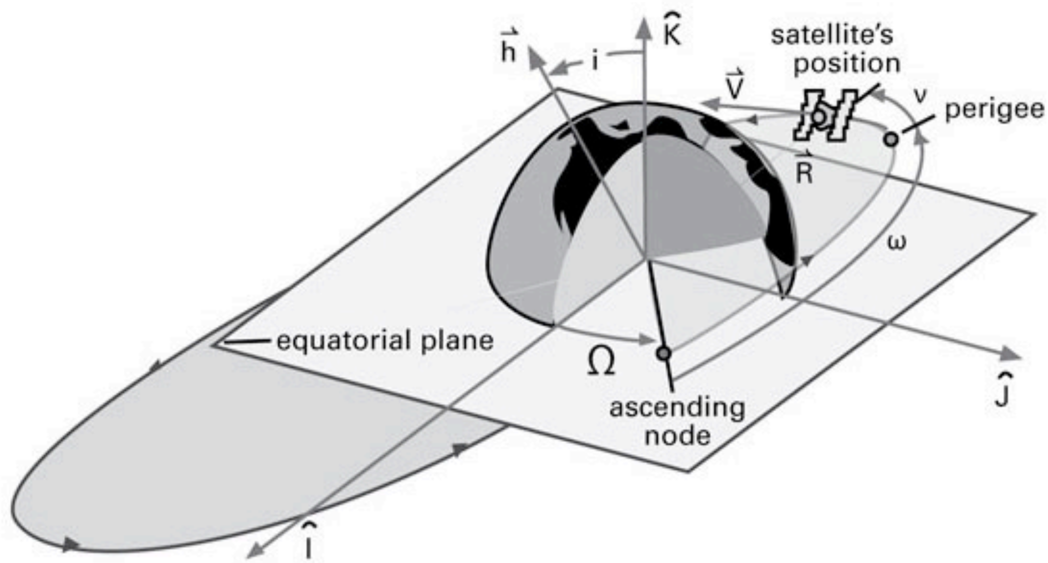
With no other forces acting upon the satellite, both total mechanical energy and angular momentum of the spacecraft remain constant throughout its orbit—consistent with Newton's laws of motion and the fact that gravity is a conservative force field. While in elliptical orbit, then, the satellite is constantly exchanging potential energy and kinetic energy, moving from apogee to perigee and back. At *apogee*—the highest point in an orbit—the satellite is moving slowest, while at *perigee*, the lowest point, it is moving fastest.

Operational orbits can be described in terms of six classical orbital elements (COEs) that describe their physical properties (see figure 4–3):

- semimajor axis, a (orbital size)
- eccentricity, e (orbital shape)
- inclination, I (orientation of the orbital plane with respect to the equatorial plane)
- right ascension of the ascending node, **Ω** (orientation of the orbital plane with respect to the Earth-centered reference frame)
- argument of perigee, **ω** (orientation of the orbit within its orbital plane)
- true anomaly, n (spacecraft's location in its orbit).

Note in the figure that *all* elliptical orbits *must* cross (or contain) the equatorial plane and have the center of the Earth at one focus of the orbital ellipse.[2] It is *not* possible to have a natural orbit that forms a "halo" above the Earth's pole or that appears motionless ("hovering") over any spot not on the equator.

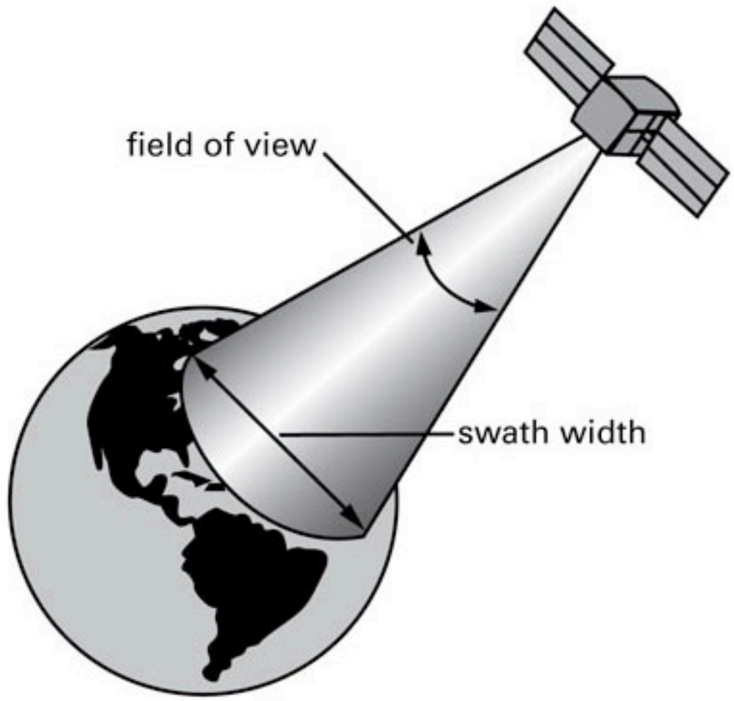
Figure 4–3. Classical Orbital Elements for Earth Orbits



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 5–9.

Earth-orbiting space missions supporting civil, commercial, and military objectives generally fall into one of four categories: communications, remote sensing, navigation and timing, and scientific. The previously presented physical laws governing spacecraft motion form the realm of the possible for which specific mission requirements can be met. The orbit's size, shape, and orientation determine whether the spacecraft payload can observe its target subjects and carry out other mission objectives. The orbit's size (height) determines how much of the Earth's surface the spacecraft's instruments can see, as well as how often it might pass overhead. Naturally, the higher the orbit, the more the total area that can be seen at once. But just as our eyes are limited in how much of a scene we can see without moving them or turning our head, a spacecraft payload has similar limitations. We define the payload's *field of view* as the cone of visibility for a particular sensor (see figure 4–4). Depending on the sensor's field of view and the height of its orbit, a specific total area on the Earth's surface is visible at any one time, with the linear width or diameter of this area defined as the *swath width*. Some missions require continuous coverage of a point on Earth or the ability to communicate simultaneously with every point on Earth. When this happens, a single spacecraft may not be able to satisfy the mission need, requiring a constellation of identical spacecraft placed in different (but often similar) orbits to provide the necessary coverage. The global positioning system (GPS) mission requirement, for example, requires a constellation of satellites because the mission requirements call for every point on Earth to be in view of at least four GPS satellites at any one time—an impossibility with only four satellites at any altitude.

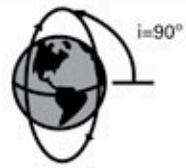
Figure 4–4. Satellite Field of View



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 1–25.

Figure 4–5 and table 4–2 show various types of missions and their typical orbits. A geostationary orbit is a circular orbit with a period of about 24 hours and inclination of 0°. Geostationary orbits are particularly useful for communications satellites because a spacecraft in this orbit appears motionless to an Earth-based observer, such as a fixed ground station. Geosynchronous orbits are inclined orbits with a period of about 24 hours. Ground-based observers above about 70° latitude (north or south) cannot see a satellite at geostationary altitude as it is actually below the horizon. A semisynchronous orbit (used by the GPS constellation) has a period of 12 hours. Sun-synchronous orbits are retrograde (westbound) low Earth orbits (LEOs) typically inclined 95° to 105° and most often used for remote sensing missions because they pass over locations on Earth with the same Sun angle each time. A Molniya orbit is a semisynchronous, eccentric orbit used for missions requiring coverage of high latitudes, those that cannot access a geostationary orbit as described above.

Figure 4–5. Types of Orbits and Their Inclinations

Inclination	Orbital Type	Diagram
0° or 180°	Equatorial	
90°	Polar	
0° ≤ i < 90°	Direct or Prograde (moves in the direction of Earth's rotation)	
90° < i ≤ 90°	Indirect or Retrograde (moves against the direction of Earth's rotation)	

Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), table 5–2.

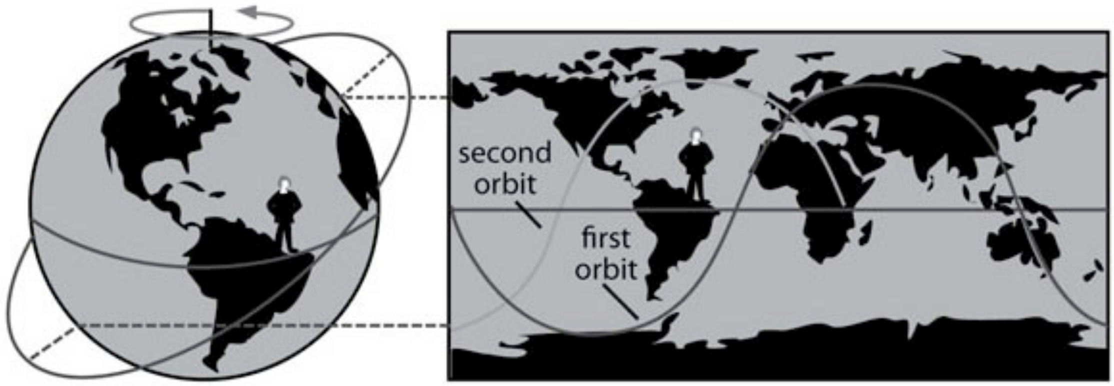
Table 4–2. Satellite Missions and Orbits

Mission	Orbital Type	Semimajor Axis (Altitude)	Period	Inclination	Other
Communication Early warning Nuclear detection	Geostationary	42,158 km (35,780 km)	~24 hr	~0°	$e \cong 0$
Remote sensing —Weather	Sun-synchronous Geostationary	~6,500–7,300 km (~150–900 km) 42,158 km (35,780 km)	~90 min ~24 hr	~95° ~0°	$e \cong 0$ $e \cong 0$
Navigation —GPS	Semi-synchronous	26,610 km (20,232 km)	12 hr	55°	$e \cong 0$
Space Shuttle	Low-Earth orbit	~6,700 km (~300 km)	~90 min	28.5°, 39°, 51°, or 57°	$e \cong 0$
Communication/ intelligence	Molniya	26,571 km (R_p = 7,971 km; R_a = 45,170 km)	12 hr	63.4°	$\omega = 270°$ $e \cong 0.7$

Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), table 5–4.

Spacecraft users often need to know what part of Earth their spacecraft is overlying at any given time. For instance, remote sensing satellites must be over precise locations to get the coverage they need. A spacecraft's ground track is a trace of the spacecraft's path over the Earth's surface while the Earth rotates beneath the satellite on its axis. Ground tracks are presented to the user on a flat (Mercator) projection of the Earth (see figure 4–6).

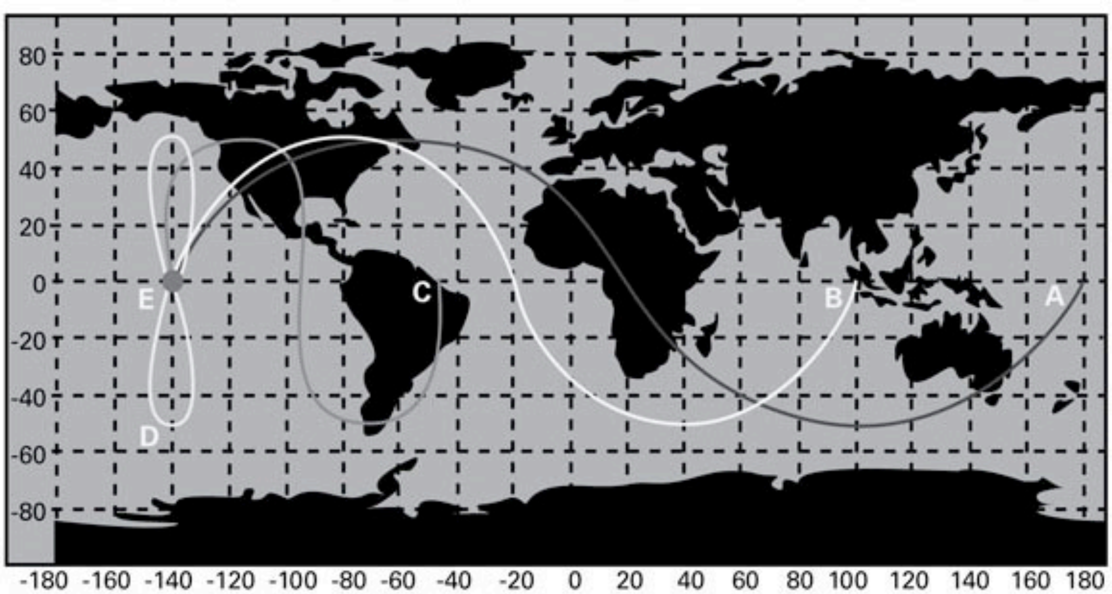
Figure 4–6. Satellite Ground Tracks



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 5–33.

The impact of variation in orbital elements such as semi-major axis, inclination, and argument of perigee is shown in figures 4–7, 4–8, and 4–9.[3]

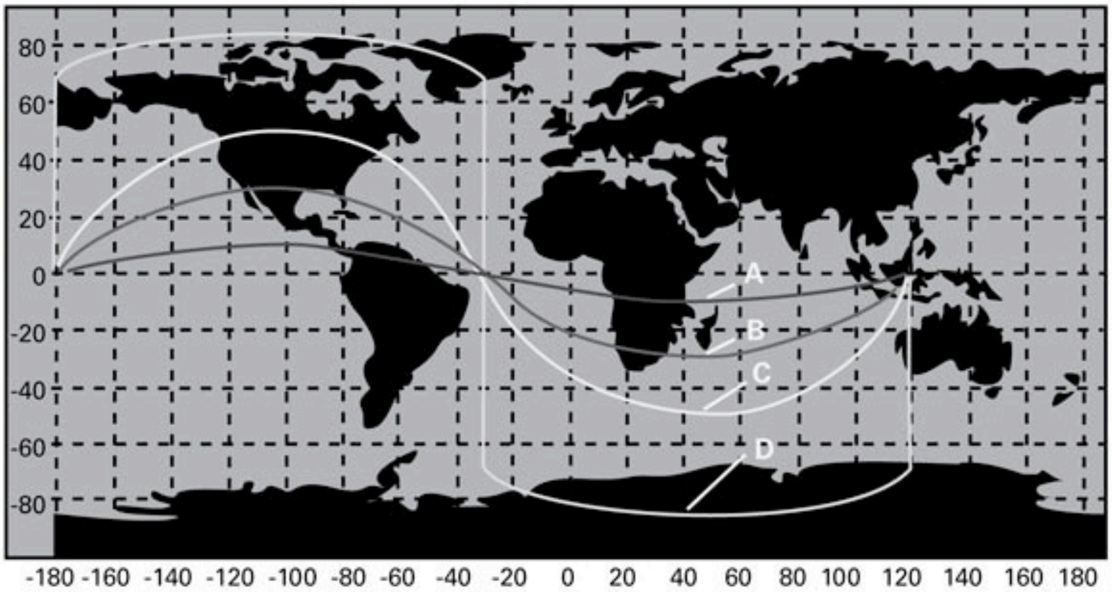
Figure 4–7. Orbital Ground Tracks with Different Periods



A = 2.67 hours; B = 8 hours; C =18 hours; D = E = 24 hours.

Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 5–33.

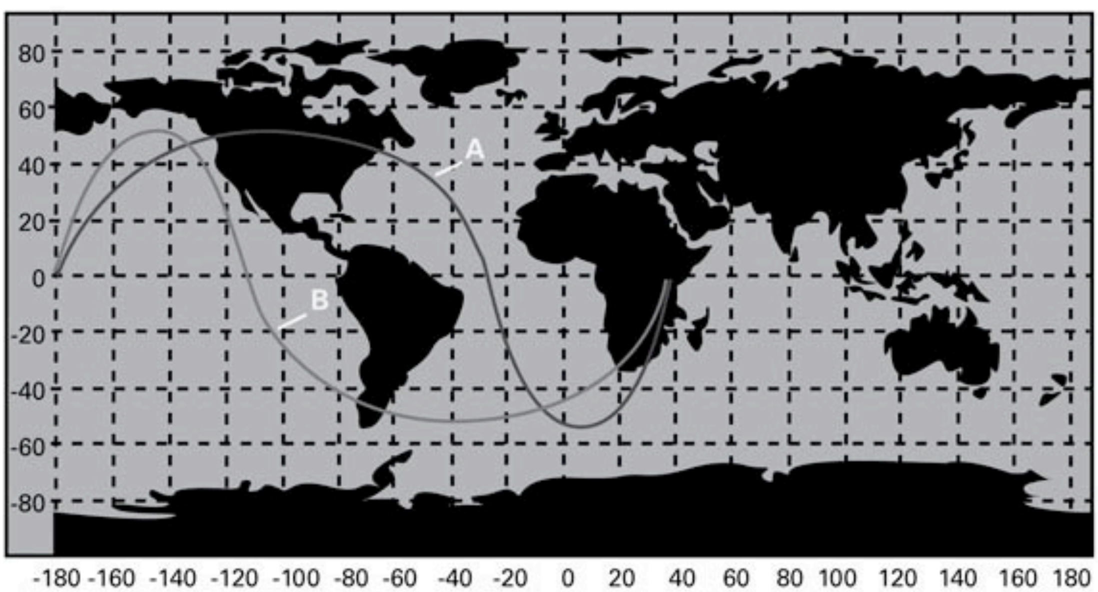
Figure 4–8. Orbital Ground Tracks with Different Inclinations



A = 10°; B = 30°; C = 50°; D = 85°.

Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 5–35.

Figure 4–9. Orbital Ground Tracks with Different Perigee Locations



Both orbits have period of 9.3 hours, inclination of 50°, highly elliptical; orbit A perigee is in Northern Hemisphere, orbit B perigee is in Southern Hemisphere.

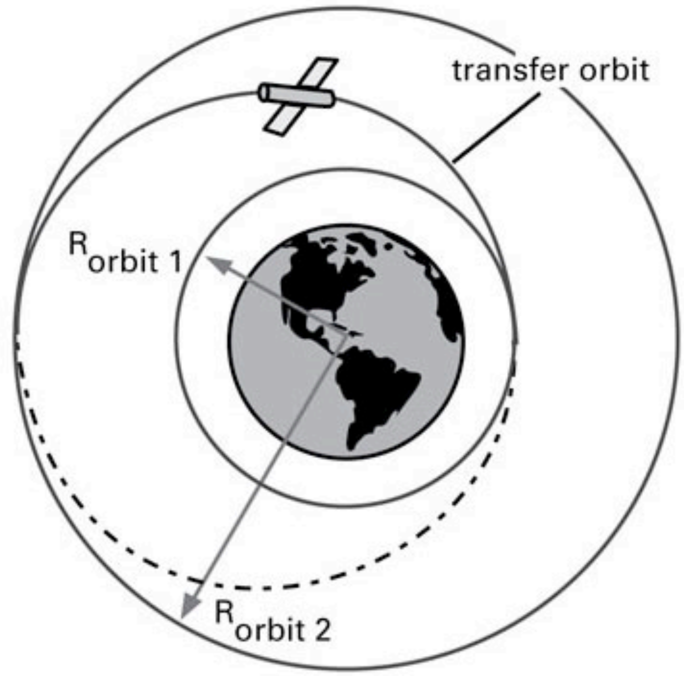
Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 5–36.

Maneuvers and Rendezvous

The ability to maintain a desired orbit and orientation within that orbit, to maneuver to possibly more useful orbits, or to rendezvous with other objects in space can be critical to overall space capability and survivability. Once a spacecraft achieves its assigned, desired orbit, it seldom remains there. Most space missions require changes to one or more of the classic orbital elements at least once. Geosynchronous satellites, for example, are sometimes first launched into a low perigee (~300 km) "parking orbit" due to launch vehicle limitations before transferring to their final orbit, requiring a large change in semi-major axis as well as shifting the satellite's inclination from that of the parking orbit to 0°. After achieving their desired mission orbit, many satellites regularly make small adjustments to compensate for small perturbations (for example, drag, solar wind, gravitational variations) to stay in that orbit. Spacecraft may also need to perform maneuvers to rendezvous with other spacecraft, as when the space shuttle maneuvers to dock with the International Space Station. The ability to maneuver in space differentiates more capable space systems from simpler buoy-like satellites with limited operational flexibility—but these extra capabilities come at some cost.

Spacecraft maneuvers, beyond simple adjustments to maintain a current orbit, can be classified as in-plane, out-of-plane, and combined, referring to the orbital plane into which the maneuver is executed. In-plane maneuvers primarily affect the semi-major axis of an orbit, enlarging or reducing the "size" of the orbit and therefore increasing or decreasing the orbit period. In either case, the spacecraft expends energy—usually in the form of burned rocket propellant. Generally, this change in energy takes the form of a change in velocity (ΔV) executed tangentially to the satellite's flight path. The most well known of these maneuvers, the Hohmann transfer, is a combination of two such "burns" that moves a satellite from one circular orbit to another using minimum energy (see figure 4–10).

Figure 4–10. Hohmann Transfer



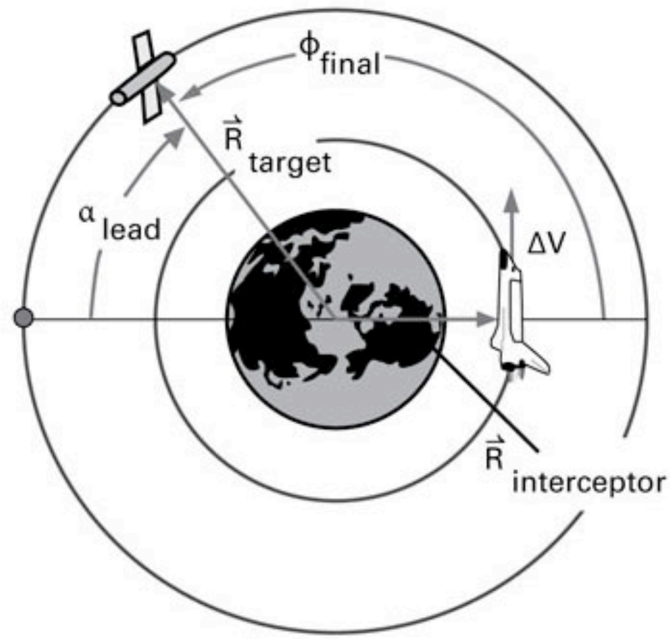
Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 6–4.

For the case where a satellite is moved from a lower to a higher orbit, the first burn (all burns are assumed to be impulsive) moves the satellite from the initial orbit to the point of perigee in the transfer orbit. The transfer ellipse's semi-major axis is the average of the semi-major axes of the initial and target circular orbits, and the ΔV needed to accomplish this first phase is the difference in the velocity at that point between the circular and elliptical orbits. Once the satellite reaches apogee of the transfer orbit, another burn is required to circularize its path into the final orbit. Again, this ΔV will be the difference between the velocity of the two orbits (transfer and final) at that point, and the total ΔV required for the mission is the sum of these two burns.[4]

Operationally, relatively small in-plane adjustments can change overhead passage time of LEO satellites by changing orbital period, can be used for collision avoidance, or can extend the on-orbit life of a LEO satellite whose orbit has slowly degraded due to atmospheric drag. Conversely, maneuvers can accelerate reentry by dropping the perigee of a satellite into a region where atmospheric drag increases, park an unused or nearly dead satellite into a safe orbit away from other operational systems, or initiate rendezvous with another spacecraft.

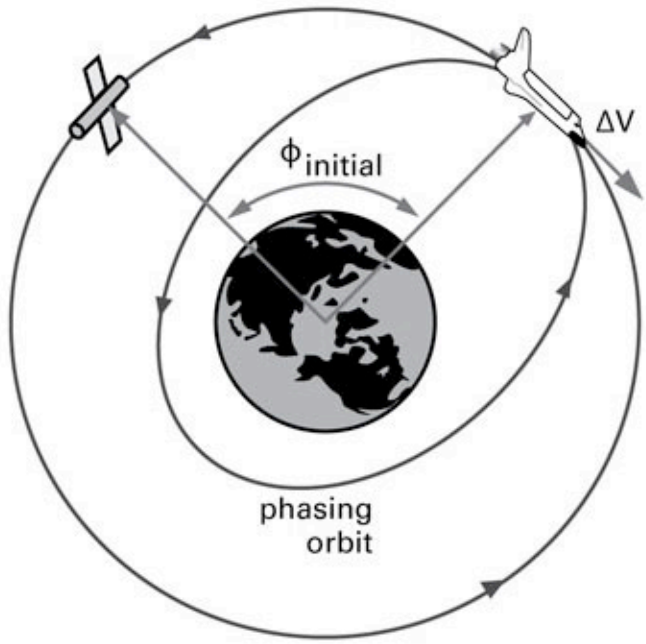
On-orbit rendezvous or interception maneuvers fall into two general categories: co-planar and co-orbital. In the former, a Hohmann transfer approach combines with appropriate phasing in order to time the burns correctly. The initial phase angle between the interceptor and target as well as the different speeds of each spacecraft in its particular orbit determines timing of the maneuver (see figures 4–11 and 4–12).

Figure 4–11. Coplanar Rendezvous



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 6–12.

Figure 4–12. Co-orbital Rendezvous

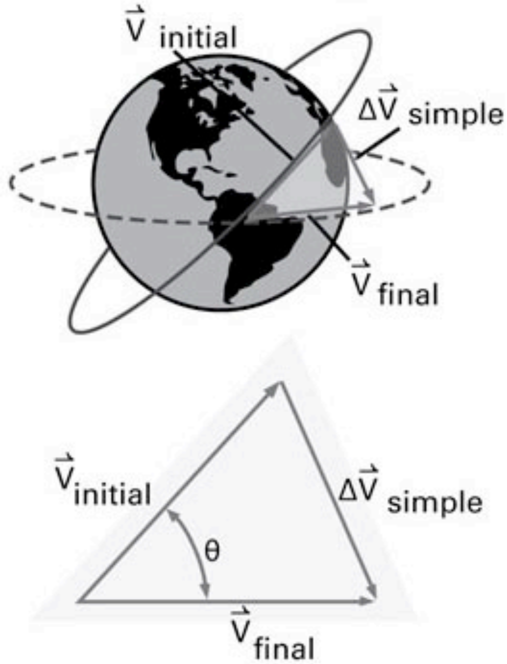


Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 6–14.

Co-orbital rendezvous occurs when both the target and interceptor are in the same orbit, though at different positions (true anomaly). In this case, the interceptor must maneuver into a phasing orbit, "speeding up to slow down" (or the converse) in order to meet the target after completing one phasing orbit. In both cases (co-planar and co-orbital), the interceptor must burn again at rendezvous to maintain its position near the target and not remain in its intercept or phasing transfer orbit.[5]

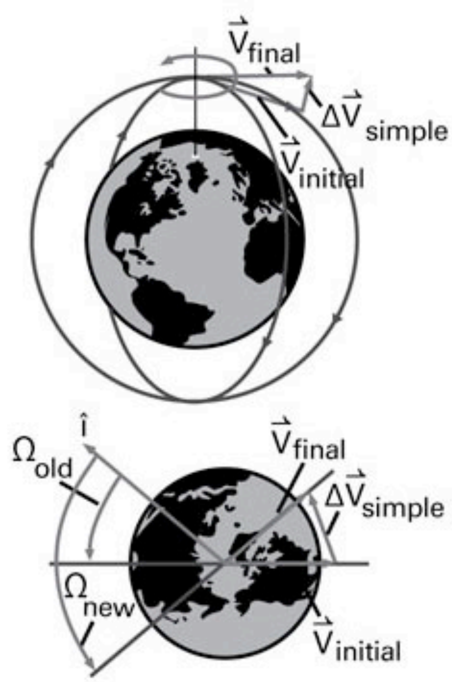
Out-of-plane maneuvers, or plane changes, occur when the satellite's direction of motion changes—usually by a nontangential burn. Operationally, plane changes to adjust the inclination of an orbit (see figure 4–13) are most commonly used when satellites launched into parking orbits from nonequatorial launch sites maneuver into geostationary orbits (a = 42,160 km, i = 0°). The plane change itself often combines with the apogee burn that circularizes the satellite's orbit at that altitude. For satellites in high inclination orbits (such as polar or Sun-synchronous), plane changes executed over one of the poles change the right ascension of the ascending node for the orbit (see figure 4–14), thus altering the overhead passage time and sun angle for that satellite. Since the burn is performed perpendicular to the spacecraft's flight path, the magnitudes of the spacecraft's initial and final velocities are identical.

Figure 4–13. Simple Inclination Plane Change



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3[d] ed. (New York: McGraw-Hill, 2005), figure 6–7.

Figure 4–14. Simple Plane Change



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3[d] ed. (New York: McGraw-Hill, 2005), figure 6–8.

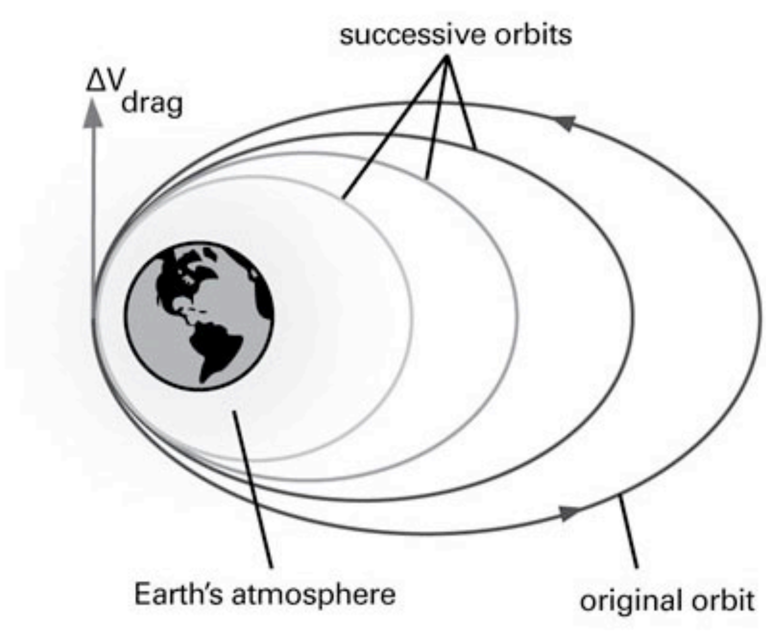
Orbit Perturbations

If some of the original simplifying assumptions for orbits are changed to include a more complete view of the forces acting on a spacecraft, COEs other than just the true anomaly will begin to change over time. The primary perturbations to simplified, classical orbital motion are:

- atmospheric drag
- Earth's oblateness (or nonsphericity in general)
- solar radiation pressure
- third-body gravitational effects (Moon, Sun, planets, and so forth)
- unexpected thrusting—caused by either outgassing or malfunctioning thrusters; can perturb orbits or cause spacecraft rotation.

While the Earth's atmosphere gets thinner with altitude, it still has some effect as high as 600 km. Because many important space missions occur in orbits below this altitude, this very thin air causes drag on these spacecraft, taking energy away from the orbit in the form of friction on the spacecraft. Because orbital energy is a function of semi-major axis, the semi-major axis will decrease over time. For noncircular orbits, the eccentricity also decreases since the drag at lower altitudes (near perigee) is higher than at apogee (see figure 4–15).

Figure 4–15. Effects of Drag on Eccentric Low Earth Orbit

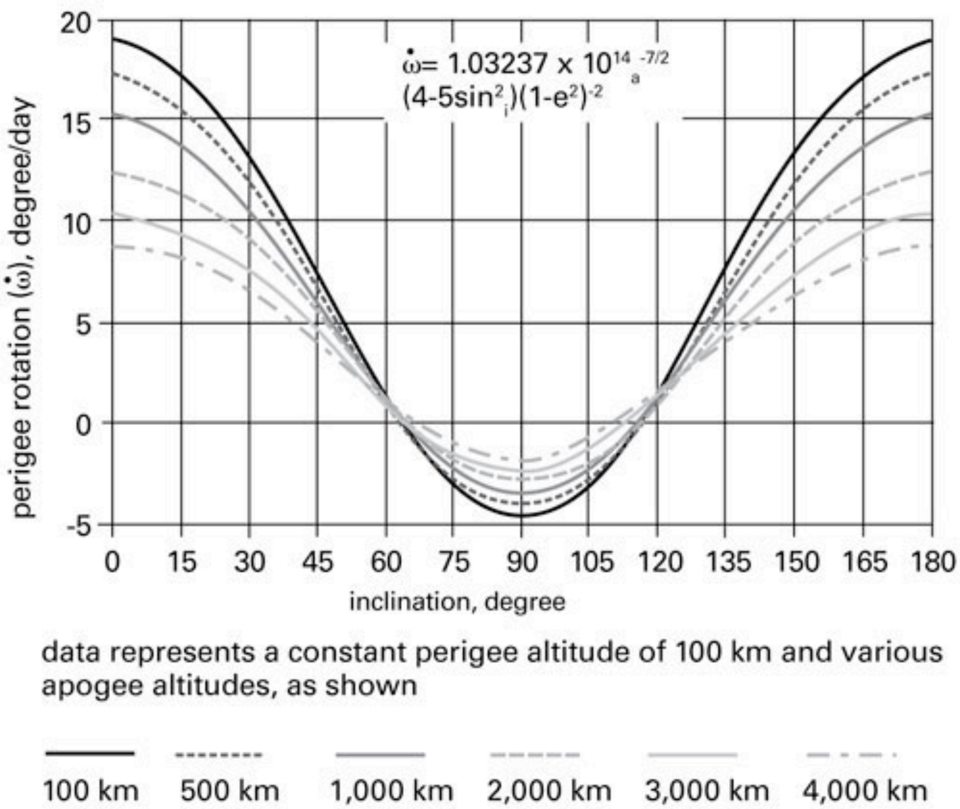


Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 8–7.

Factors such as the Earth's day-night cycle, seasonal tilt, variable solar distance, and fluctuating magnetic field, as well as the Sun's 27-day rotation and 11-year cycle for sunspots, make precise real-time drag modeling nearly impossible. Further complicating the modeling problem is the fact that the force of drag also depends on the spacecraft's coefficient of drag and frontal area, which can vary widely depending upon spacecraft orientation.

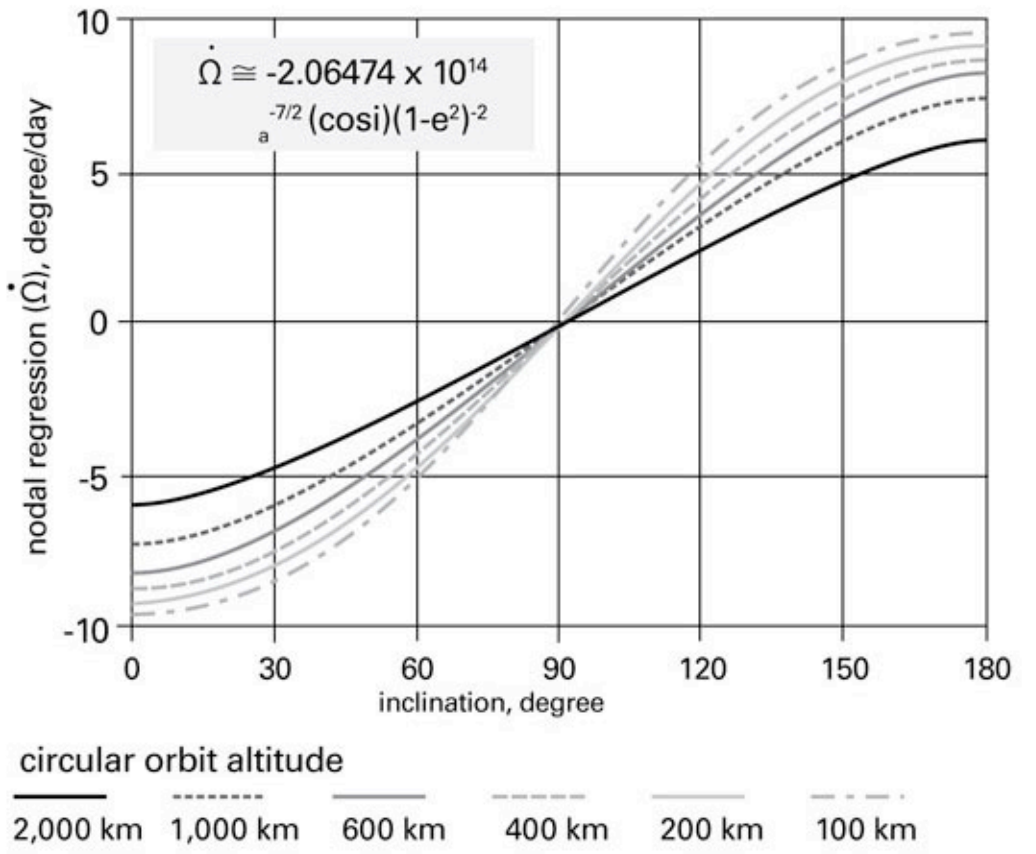
In addition, the Earth is not a perfect sphere, affecting the earlier point mass assumption. The most pronounced nonspheroidal characteristic is oblateness, meaning that the Earth bulges at the equator and is somewhat flattened at the poles, modeled using the constant J2. Unlike drag, which is a nonconservative force, the J2 effect is gravitational and does not change a spacecraft's total mechanical energy (that is, constant semi-major axis). Instead, J2 acts as a torque on the orbit since the Earth's gravitational pull is no longer directed from the Earth's exact center, causing the right ascension of the ascending node (RAAN, or **Ω**) to shift or precess with each orbit[6] and the perigee to rotate through an elliptical orbit. J2 effect is a function of orbit inclination and altitude as shown in figures 4–16 and 4–17 describing its effect on RAAN and argument of perigee.[7]

Figure 4–16. Perigee Rotation Rate



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3[d] ed. (New York: McGraw-Hill, 2005), figure 8–11.

Figure 4–17. Nodal Regression Rate



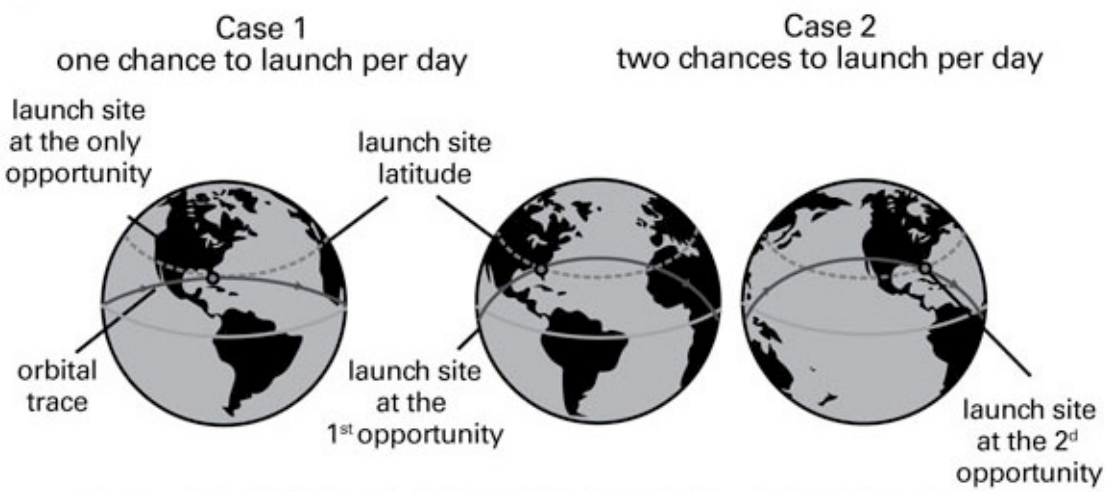
Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 8–10.

Other, smaller perturbing forces also affect a spacecraft's orbit and its orientation within it, including solar radiation pressure, third-body gravitational effects (Moon, Sun, planets, and so forth), and unexpected thrusting—caused by either outgassing or malfunctioning thrusters. The importance of each perturbation is a function of the spacecraft's mission and need for orbital and attitude accuracy.

Space Launch and Rocket Propulsion

For most space missions, the spacecraft must be placed into a specific orbit, requiring a launch at a particular time and in a specific direction. A "launch window" is a period when a spacecraft can be launched directly into its initial orbit from a given launch site, and it corresponds to the time when the chosen orbit passes over the launch site. In practice, a launch window normally covers several minutes or even hours around this exact time since mission planners have some flexibility in the orbital elements they can accept, and launch vehicles usually can steer enough to expand the length of the window somewhat. However, to launch directly into an orbit, the launch site and orbital plane must intersect at least once per day. Physically, that means that the inclination of the desired orbit must be equal to or greater than the latitude of the launch site. If the two are equal, then there will be one launch opportunity per day. If the inclination is greater than the latitude, there will be two potential opportunities since, in this case, the spacecraft may be launched toward either the ascending or descending node (see figure 4–18). However, due to practical restrictions at a given launch site, only one of these opportunities may be used. For example, launches from Cape Canaveral are restricted to the east and northeast only due to overflight considerations.

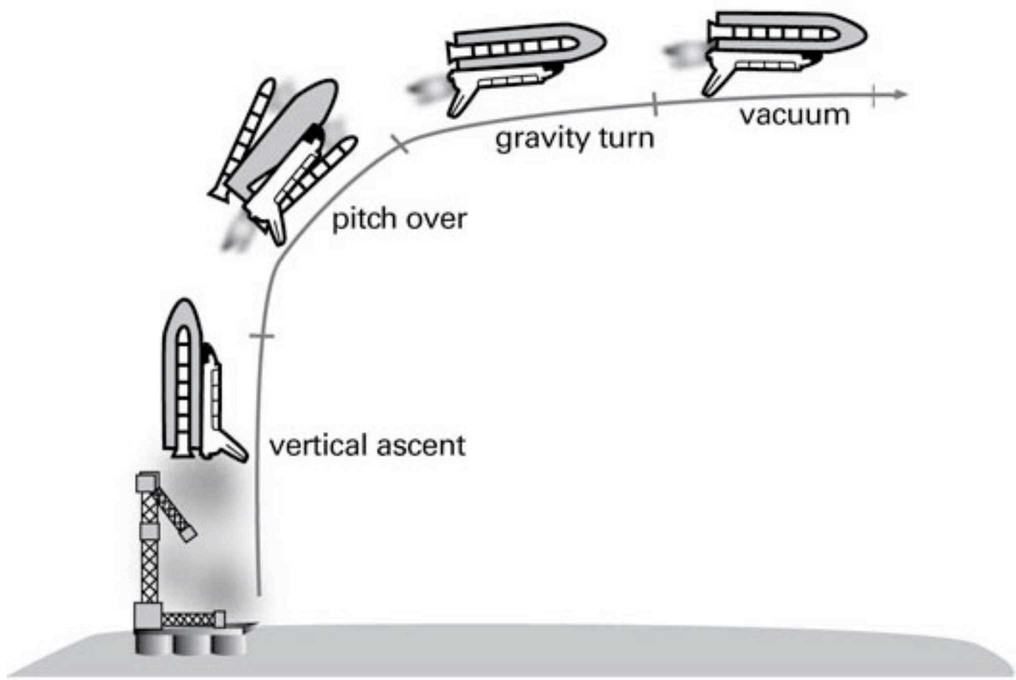
Figure 4–18. Launch Windows



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 9–7.

During liftoff, a launch vehicle goes through four distinct phases from the launch pad into orbit (see figure 4–19). During vertical ascent, the vehicle gains altitude quickly to escape the dense, high-drag lower atmosphere. The vehicle then executes a slow pitch maneuver to gain velocity downrange (horizontally), followed by a turn in which gravity pulls the launch vehicle's trajectory toward horizontal. In the final vacuum phase, the launch vehicle is effectively out of the Earth's atmosphere and continues accelerating to gain the necessary velocity to achieve orbit. The vehicle's on-board flight control system works to deliver the vehicle to the desired burnout conditions: velocity, altitude, and flight-path angle. The velocity needed to get to orbit consists of the launch vehicle's burnout velocity and the tangential velocity that exists at its launch site due to the Earth's rotation.

Figure 4–19. Phases of Launch Vehicle Ascent



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 9–14.

The closer a launch site is to the equator, the greater the velocity assist provided to the launch vehicle from the Earth's rotation when launching eastward.[8] A given launch vehicle can launch a larger payload due east from a launch site at a lower latitude. For westerly launches into retrograde orbits, this same tangential velocity reduces launch capability.

Determining the total velocity needed to launch a spacecraft is a very complex problem requiring numerical integration in sophisticated trajectory modeling programs that incorporate launch vehicle properties, atmospheric density models, and other factors. To determine the overall design velocity, the mission designer must consider velocity needed to overcome gravity and reach the correct altitude, inertial velocity needed at burnout for the desired orbit, velocity of the launch pad due to Earth's rotation, and velocity losses due to air drag, back pressure, and steering losses. The difference between the launch vehicle's actual design velocity for a specific payload mass and the design velocity is the launch margin.

Rocket propulsion is responsible for not only launching spacecraft into orbit, but also maneuvering them once they are in space and adjusting their attitude to accomplish their mission as needed (see table 4–3). While there are many forms of rocket propulsion, they all depend upon Newton's laws to apply forces (thrust) or moments (torque). Rockets operate by expelling high-speed exhaust in one direction, causing the spacecraft to accelerate in another. The only types of rockets currently in use are thermodynamic and electrodynamic. Thermodynamic rockets rely on heat and pressure to accelerate a propellant (for example, the chemical reaction of fuel and oxidizer burning, or the heat generated by electrical heating or a nuclear reaction) using converging/diverging nozzles to convert the thermal energy to kinetic energy. Examples of thermodynamic rockets include chemical (liquid, solid, and hybrid); nuclear-thermal; solar-thermal; and electro-thermal. Electrodynamic rockets use electric and/or magnetic fields to accelerate charged particles to high velocities and include ion or electrostatic, Hall effect, and pulsed plasma thrusters.

Table 4–3. Rocket Propulsion Types and Performance Comparison

Type	Propellant Examples	I_{sp} (sec)	Thrust Range (N)	Advantages	Disadvantages
Thermodynamic					
Chemical					
Liquid					
Bipropellant	LO_2/LH_2 LO_2/Kerosene Hydrazine/ Nitrogen Tetroxide	334–455	$10–10^6$	• High I_{sp} • Throttleable • Restartable	• Must manage two propellants • Requires thermal control for chamber and nozzle
Mono-propellant	Hydrazine Hydrogen Peroxide	180–240	10–1,000	• Simple • Large flight heritage • One propellant to manage	• Lower I_{sp} than bipropellant • Toxic
Solid	Ammonium Perchlorate/ Aluminum/Binder	300	$1–10^6$	• Simple, reliable • No propellant management needed • Higher thrust	• Modest I_{sp} • Susceptible to propellant grain cracks • Difficult to stop; can't restart
Hybrid	Hydrogen Peroxide/ Polyethylene	333	$10–10^6$	• Simpler than bipropellant • Safer, more flexible than solids; restartable	• Limited heritage • Modest I_{sp}
Nuclear-thermal	H_2	1,000	$1–10^6$	• Long-term energy supply • Refuelable, reusable • High I_{sp}, high thrust	• No flight heritage • Environmental/ political concerns
Electro-thermal	Ammonia (NH_3)	800	0.1–1	• Simple, reliable • High I_{sp}	• Requires large amounts of on-board electrical power • Low thrust
Solar-thermal	Ammonia	800	0.1–10	• High I_{sp} • Long-term energy supply	• Requires solar energy collection • Low thrust
Electrostatic					

In all cases, the efficiency of a rocket is measured in terms of specific impulse (I_{sp}). Specific impulse gives us an effective "miles per gallon" rating as it relates the amount of thrust produced for a given weight flow rate of the propellant. Higher I_{sp} rockets produce more total ΔV for the same amount of propellant than low Irockets. However, high Irockets (such as ion thrusters) are typically low thrust and not suited for some uses. The Rocket Equation[9] relates the initial and final masses of a spacecraft with the specific impulse of the propulsion system to determine the total ΔV available. It is the mission designer's job to determine a space mission's many propulsion needs and select the appropriate system for each phase.

The total cost of a specific spacecraft's on-board propulsion system includes several factors, in addition to the bottom-line price tag, before making a final selection.[10] These factors include mass performance (measured by I_{sp}), volume required, time (how fast it completes the needed ΔV), power requirements, safety costs (how safe the system and its propellant are and how difficult it is to protect people working with the system), logistics (system and propellant transport to launch), integration cost with other spacecraft subsystems, and technical risk (what flight experience does it have or how did it perform in testing). Different mission planners naturally place a higher value on some of these factors than on others. A complex commercial mission may place high priority on reducing technical risk—for example, a new type of plasma rocket, even if it offers lower mass cost, may be too risky when all other factors are considered.

A basic understanding of rocket propulsion informs mission planners and space experts who next consider one of the most obvious manifestations of spacepower—space launch systems. While more widely open international access to launch has provided some level of space presence and power to dozens of nations, a space launch capability defines a unique level of spacepower and is possessed by many fewer states. Requirements for an operational launch system are technical, geographic, and financial. Development of a new space launch system consumes hundreds of millions to many billions of dollars[11] and requires broad expertise in propulsion systems, avionics, logistics, manufacturing, and integration processes. Testing during system development also requires extensive infrastructure and range facilities (often consisting of thousands of square miles of controlled airspace) that can assure public safety, while operational launch facilities must also include payload processing and mission control centers.

The physical, financial, and technical difficulties of launch are evident in the relatively small number of launch vehicles developed in the world's 50 years of space launch experience. Contrasted with the first 50 years of powered atmospheric flight, today's launch vehicles represent relatively small advances in capability from the Russian and American boosters of the late 1950s and early 1960s that trace their development to intercontinental ballistic missiles of the Cold War. All based on chemical (liquid and/or solid) propulsion, today's boosters can lift little more than 4 percent of their lift-off mass to LEO and much less than half that amount to geosynchronous transfer orbit from which a final apogee burn can place a spacecraft into a geostationary orbit. All vehicles use a minimum of two stages to achieve orbit (and some as many as four) with costs on the order of $10,000 per pound to LEO and $12,000 per pound to geostationary orbit.

Several attempts to incrementally or drastically reduce launch costs and improve responsiveness have not significantly altered the status quo. The space shuttle, originally intended as a "space truck" to access space routinely and cheaply, suffered from its immense complexity, resulting in enormous per-launch cost growth. After completing its support of the International Space Station construction in 2010, it will be retired, largely due to safety and high cost of ownership. Small launch vehicles such as Orbital Sciences' Pegasus air-launched vehicle (~$22 million per launch for about 500 kilograms [kg] to LEO) have served niche markets without reducing overall costs, as have refurbished Russian and American intercontinental ballistic missiles (for example, Minotaur). SpaceX's Falcon 1 (with an advertised cost of roughly $6 million per launch as of this writing) and the larger follow-on Falcon 9 may achieve some cost savings, but nothing near the order of magnitude or greater savings that might transform space access to a more aviation-like paradigm. More exotic attempts to change the launch industry—such as the NASA-funded/Lockheed Martin–developed VentureStar single-stage-to-orbit, fully reusable launch vehicle—have not been successful beyond the PowerPoint slide.[12] In fact, current technology makes it very difficult to reduce space launch costs or turnaround time for launch vehicles or to build cost-effective reusable launch systems. With no new rocket propulsion technologies for space launch available in the foreseeable future, savings in launch costs and processing time will be incremental and depend on gains in reliability, manufacturing techniques, and miniaturization of payloads.

Whatever the state of launch, mission planners and space experts considering launch systems must consider the following factors:

- performance capability (whether the launch vehicle can take the desired mass to the mission orbit)
- vehicle availability (whether the vehicle will be available and ready to launch when needed)
- spacecraft compatibility (whether the payload will fit in the launch vehicle fairing and survive the launch environment imposed by the launch vehicle) cost.

Space Environment

Once in space, the unique environment presents several challenges to mission accomplishment, affecting not only spacecraft but also the signals received and transmitted in the course of that mission. The primary space environmental challenges are:

- free-fall gravitational conditions
- atmospheric effects
- vacuum
- collision hazards
- radiation and charged particles.

The free-fall environment gives rise to problems with fluid manage-ment—measuring and pumping—typically related to on-board liquid propulsion systems. For manned spaceflight, the physiological issues can be quite severe, marked by fluid shift within the body (lower body edema), altered vestibular function (motion sickness), and reduced load on weight-bearing tissues resulting in bone decalcification and muscle tissue loss.

In addition to the effect of drag on spacecraft (mentioned earlier as a perturbation), the upper reaches of the atmosphere contain atomic oxygen caused when radiation splits molecular oxygen (O_2). Much more reactive than O_2, atomic oxygen can cause significant degradation of spacecraft materials, weakening components, changing thermal characteristics, and degrading sensor performance.

The vacuum of space creates three potential problems for spacecraft: outgassing, cold welding, and heat transfer. Outgassing occurs when materials, such as plastics or composites, release trapped gasses (volatiles) upon exposure to vacuum—particularly problematic if the released molecules coat delicate sensors, such as lenses, or cause electronic components to arc, damaging them. Prior to launch, spacecraft are usually tested in a thermal-vacuum chamber to reduce or eliminate potential outgassing sources. Cold welding occurs between mechanical parts having very little separation between them. After launch, with the small cushion of air molecules between components eliminated, parts may effectively "weld" together. The potential for cold welding can be mitigated by avoiding the use of moving parts or by using lubricants carefully selected to avoid evaporation or outgassing. Heat transfer via conduction, convection, and especially radiation may also complicate spacecraft operation—for example, causing temperatures to drop below acceptable operating levels—and must be considered in any spacecraft design.

The chances that a spacecraft will be hit by very small pieces of debris (natural or manmade) grow with each new space mission. Twenty thousand tons of natural materials—dust, meteoroids, asteroids, and comets— hit Earth every year, and estimates of the amount of manmade space debris approach 2,200 tons.[13] Air Force Space Command, headquartered in Colorado Springs, Colorado, uses a worldwide network of radar and optical telescopes to track more than 13,000 baseball-sized and larger objects in Earth orbit, and some estimate that at least 40,000 golf ball–sized pieces (too small for the Air Force to track) are also in orbit,[14] not including smaller pieces such as paint flakes and slivers of metal.

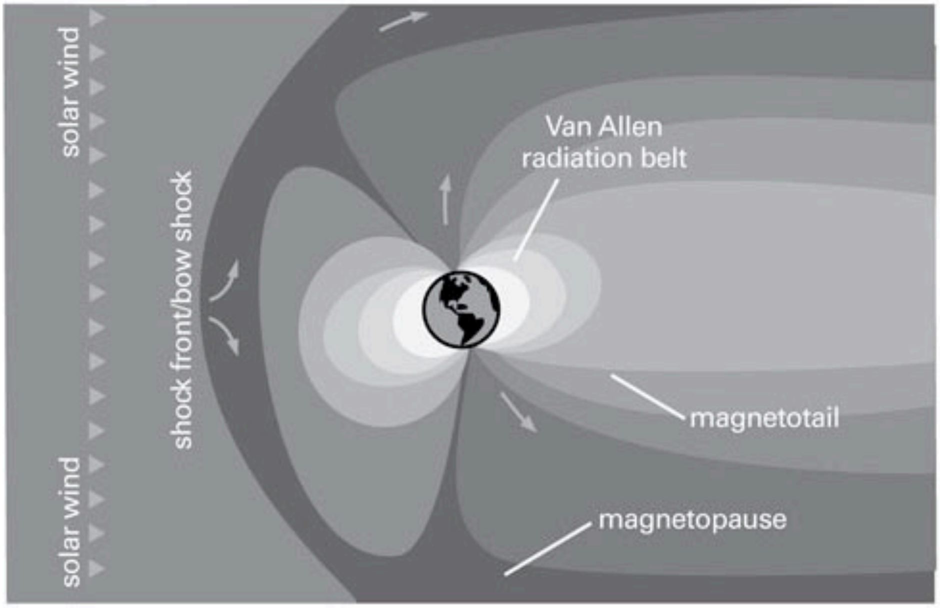
The energy of (and thus potential damage caused by) even a very small piece of debris hitting a spacecraft at relative speeds of up to 15 km per second makes the debris environment in Earth orbit a serious issue.[15] For a spacecraft with a cross-sectional area of 50 to 200 square meters at an altitude of 300 km (typical for space shuttle missions), the chance of getting hit by an object larger than a baseball during a year in orbit is about 1 in 100,000 or less.[16] The chance of getting hit by something only 1 millimeter or less in diameter, however, is about 100 times more likely, or about 1 in 1,000 during a year in orbit. The collision between two medium-sized spacecraft would result in an enormous amount of high-velocity debris, and the resulting cloud would expand as it orbited, greatly increasing the likelihood of impacting another spacecraft. The domino effect could ruin an important orbital band for decades.

Electromagnetic (EM) radiation from the Sun, while primarily in the visible and near-infrared parts of the EM spectrum, also contains significant higher energy radiation, such as X-rays and gamma rays. While solar cells generate needed electrical power from this radiation, spacecraft and astronauts well above the atmosphere face negative consequences from it depending on the wavelength of the radiation. The Sun's radiation heats exposed surfaces, which can degrade or damage surfaces and electronic components, and the resulting solar pressure can perturb orbits. Prolonged exposure to ultraviolet radiation degrades spacecraft coatings and is especially harmful to solar cells, reducing their efficiency and possibly limiting the useful life of the spacecraft they power. In addition, during intense solar flares, bursts of energy in the radio region of the spectrum can interfere with onboard communications equipment. Solar radiation pressure, though only 5 Newtons of force for 1 square kilometer of surface, can also disturb spacecraft orientation.

Perhaps the most dangerous aspect of the space environment is the pervasive influence of charged particles caused by solar activity and galactic cosmic rays. The Sun expels a stream of charged particles (protons and electrons) at a rate of 10^9 kg per second as part of the solar wind. During intense solar flares, the number of particles ejected can increase dramatically. Galactic cosmic rays are similar to those found in the solar wind or in solar flares, but they originate outside of the solar system—the solar wind from distant stars and remnants of exploded stars—and are much more energetic than solar radiation.

The solar wind's charged particles and cosmic particles form streams that hit the Earth's magnetic field. The point of contact between the solar wind and the magnetic field is the shock front or bow shock. Inside the shock front, the point of contact between the charged particles of the solar wind and the magnetic field lines is the magnetopause, and the area directly behind the Earth is the magnetotail (see figure 4–20). In the electromagnetic spectrum, many lower energy solar particles are deflected by the Earth's magnetic field, while some high-energy particles may become trapped and concentrated between field lines, forming the Van Allen radiation belts. Additionally, high-energy gamma and X-rays may ionize particles in the upper atmosphere that also populate the Van Allen belts.

Figure 4–20. Interaction between Solar Wind and Earth's Magnetic Field



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3rd ed. (New York: McGraw-Hill, 2005), figure 3–29.

Whether charged particles come directly from the solar wind, indirectly from the Van Allen belts, or from the other side of the galaxy, they can harm spacecraft in four ways: charging, sputtering, single-event phenomenon, and total dose effects. Spacecraft charging results when charges build up on different parts of a spacecraft as it moves through concentrated areas of charged particles. Discharge can seriously damage surface coatings, degrade solar panels, cause loss of power, and switch off or permanently damage electronics. Sputtering damages thermal coatings and sensors simply by high-speed impact, in effect sandblasting the spacecraft. Single charged particles penetrating deeply into spacecraft electronics systems may cause a single event phenomenon. For example, a single event upset (SEU) or "bit flip" results when a high-energy particle impact resets one part of a computer's memory from 1 to 0, or vice versa, causing potentially significant changes to spacecraft functions. Total dose effects are long-term damage to the crystal structure of semiconductors within a spacecraft's computer caused by electrons and protons in the solar wind and the Van Allen belts. Over time, the cumulative damage lowers the efficiency of the material, causing computer problems. Orbits that pass through an area of higher radiation levels known as the South Atlantic anomaly increase the total dose damage during a spacecraft's lifetime. Spacecraft shielding and the use of hardened components offer some protection for these effects, as does software coding to negate the SEU effects by storing each bit multiple times and comparing them during each read operation. But all of these steps come at a cost of increased weight, testing requirements, and development time and cost.

Spacecraft State of the Art

A spacecraft consists of a payload and its supporting subsystems, also known as the bus. Overall payload requirements are defined in terms of the subject with which it must interact, and its components are designed to make this interaction possible. Using a remote sensing example, the payload could consist of a single simple camera to detect light from some ground-based phenomenon or could include a collection of sensors, each tuned to detect a particular characteristic (such as wavelength) of that light. The number and type of sensors chosen, and how they work together to form the spacecraft's payload, determine the spacecraft's design, which in turn generates requirements for the spacecraft bus that dictate:

- payload accommodation mass, volume, and interfaces
- spacecraft pointing precision
- data processing and transmission needs
- electrical power needs
- acceptable operating temperature ranges.

Spacecraft Subsystems

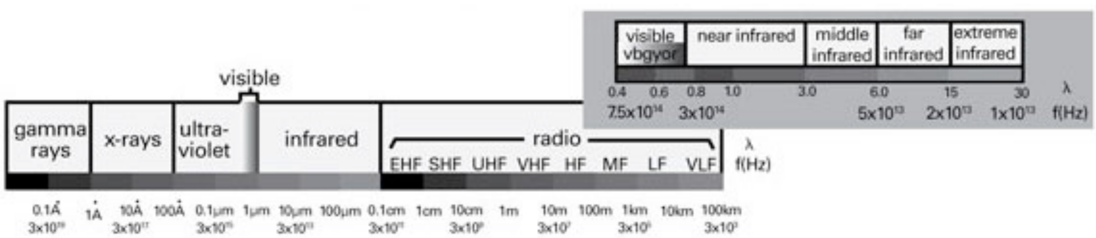
Mission designers define these requirements in terms of subsystem performance budgets such as the amount of velocity change, electrical power, or other limited resource that it must "spend" to accomplish some activity (for example, achieving operational orbit or turning on the payload). Six distinct spacecraft bus subsystems support the payload with all the necessary functions to keep it healthy and safe:

- space vehicle control: "steers" the vehicle to control its attitude and orbit, attaining and maintaining its operational orbit as well as pointing cameras and antennas toward targets on Earth or in space; on-board rockets control the orbit, while rockets and other devices rotate it around its center of mass to provide stability and precise pointing
- communication and data handling: monitors payload activities and environmental conditions, tracks and controls spacecraft location and attitude, communicates with ground controllers or other spacecraft, and warns of anomalies; communication requirements analysis produces a link budget that specifies communications parameters and the data rate
- electrical power: converts and conditions energy sources (such as solar) into usable electrical power and also stores energy to run the entire spacecraft; electrical power requirements for each of the other bus subsystems determine the total electrical power budget
- environmental control (and life support for manned missions): regulates component temperatures for proper operation, transferring or eliminating heat energy as needed; for manned missions, astronauts must be protected from the harsh space environment; provides a breathable atmosphere at a comfortable temperature, humidity, and pressure, along with water and food to sustain life
- structure and mechanisms: protect the payload and subsystems from high launch loads; deploy and maintain orientation of spacecraft components (such as solar panels and antennas)
- propulsion: produces thrust to maneuver the spacecraft between orbits and control its altitude; highly dependent on altitude and orbital control needs.

Remote Sensing and Communications Physics

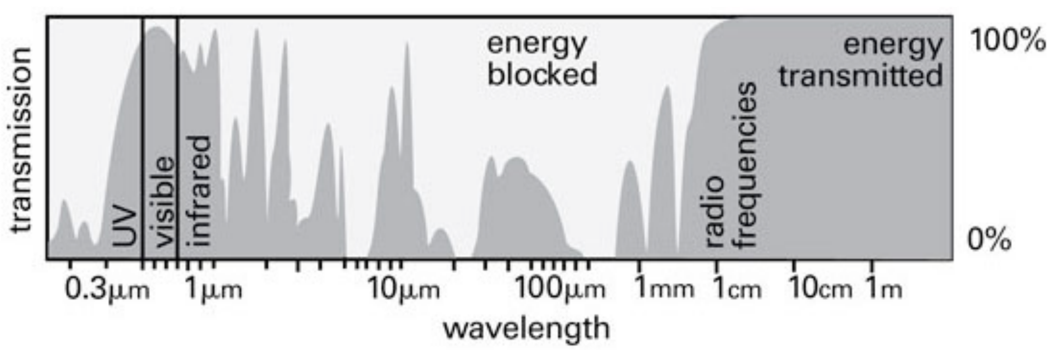
The most common general categories of spacecraft payloads perform remote sensing and communications missions and, as such, represent the variety of technical and operational trades and constraints typically found in space mission design. Remote sensing systems collect EM radiation reflected or emitted from objects on the Earth's surface, in the atmosphere, or in space—including space-based astronomy and space surveillance. Radio waves (also EM) are used to communicate to and from the Earth's surface, through the atmosphere, and between objects in space. For missions involving Earth sensing or communications, then, the transmission characteristics of the Earth's atmosphere—which frequencies are blocked, attenuated, or pass freely—drive payload performance and design decisions. Figures 4–21 and 4–22 describe the electromagnetic spectrum (in terms of EM wavelength and frequency) and the transmission of that spectrum through the atmosphere.

Figure 4–21. Electromagnetic Spectrum



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 11–29.

Figure 4–22. Atmospheric Windows



Source: Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), figure 11–32.

While some wavelengths (such as visible light) are completely transmitted, others are almost completely blocked. Spacecraft instruments have access to Earth from space through various atmospheric windows—wavelength bands in which 80 to 100 percent of the available energy is transmitted through the atmosphere. The most notable atmospheric windows are the visible, infrared, and radio wavelengths.

Passive remote sensing systems depend on reflected or emitted EM radiation passing through the atmosphere to the space-based sensor. Because objects reflect different wavelengths of EM radiation, measuring the amount and type of radiation can describe characteristics such as soil properties, moisture content, vegetation types, and many other important details. Objects also emit EM radiation at different wavelengths depending on their material properties and temperature. The relationship between temperature and wavelength of peak emission is well known,[17] and coupled with knowledge of the total energy output from the target object,[18] payload sensors can be designed to sense particular phenomena.

Given the physics of EM radiation, a workable sensor can then be designed. To observe an object, however, the spacecraft sensor must be able to point the sensor at the target, collect EM radiation from the target, transform the detected radiation into usable data, and process the usable data into usable information. First, the object must fall within the sensor's field of view—defined as the angular width within which the sensor can see. Projected onto the Earth's surface, the field of view translates into the swath width, the size of which is determined by the sensor's field of view and the spacecraft's altitude (as shown in figure 4–4). Next, the resolution of the sensor—the size of the smallest object it can detect—is a function of the wavelength of the radiation sensed, the sensor's aperture diameter, and the distance between the sensor and the target.[19]

Active remote sensors such as radar transmit their own radiation that reflects from the target and returns to the sensor for processing. Space-based radar, for example, permits accurate terrain measurement of features to construct a three-dimensional picture of a planet's surface. Because resolution relates directly to the wavelength of the transmitted and reflected signal, shorter wavelengths yield better resolution than longer wavelengths. Optical sensors measure EM wavelengths on the order of 0.5 micrometers (mm), while radar systems operate at about 240,000 mm. Thus, for optical and radar systems with the same size aperture, the optical system has almost 500,000 times better resolution. For conventional radar to have the same resolution as an optical system, the size of the radar's aperture must be increased.[20]

Space communications systems serve as the backbone for all other space missions in addition to being a mission in their own right. The primary goal, of course, is to get data to the users, whether that means relaying remote sensing data obtained from space sensors to ground systems and users, sending and receiving command and control data between spacecraft and ground control centers, or acting as a relay to receive and then transmit data from one point on the globe (or in space) to another. Communications payloads use a transmitted EM signal to carry data to a receiver. The communications link—what happens between the transmitter and the receiver—is the critical feature of any communications systems and is characterized by several critical parameters:

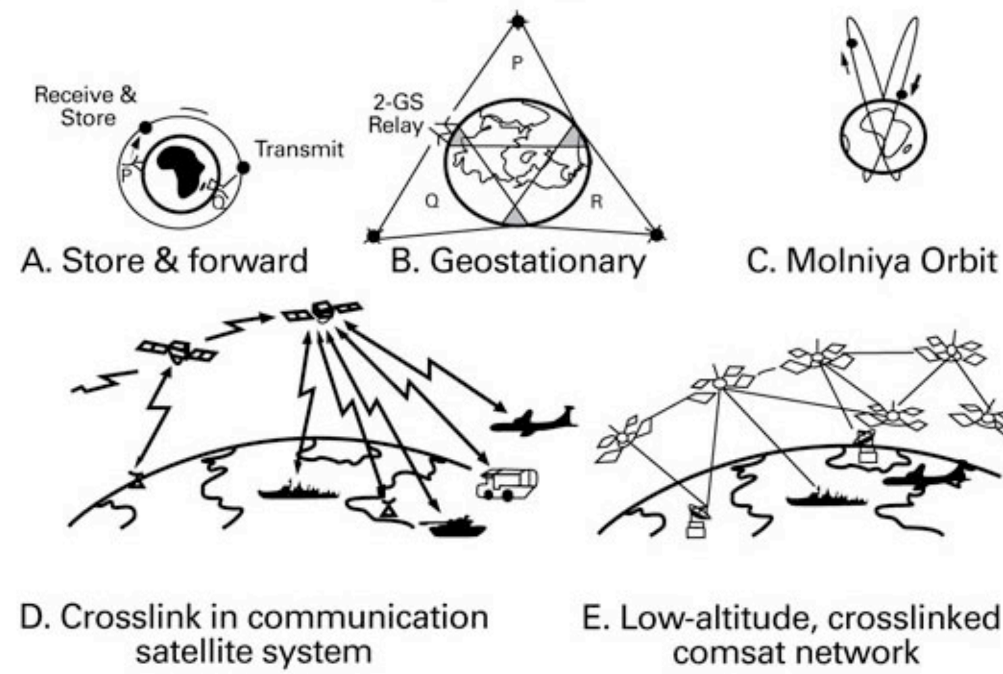
- signal-to-noise ratio

- bit error rate (signal quality)
- coverage
- data rate
- signal security.

The signal-to-noise ratio (SNR) is a function of transmitter power and gain, receiver bandwidth, temperature and gain, signal wavelength, and range between transmitter and receiver. For effective communication, SNR must be greater than or equal to one.[21] The bit error rate (BER) defines the likelihood of misinterpreting bits in a data stream, typically expressed in terms of single bit errors per power of 10 bits.[22] Increasing signal strength improves BER and can be accomplished by increasing transmitter power and antenna size, increasing receiver antenna size, improving receiver characteristics, using higher frequencies, or reducing the distance between the transmitter and the receiver. All of these factors impact the overall cost of the system. The system designer must investigate all available alternatives to obtain the desired signal-to-noise ratio at minimum system cost.

Coverage directly affects communications availability and is a function of satellite altitude and orbit, elevation angle of communicating satellites, satellite constellation configuration (number of satellites, orbital planes used, and so forth), ground station (receiver) location, and cross-linking capability. The simplest satellite communications architecture uses a "store-and-forward" approach (figure 4–23, case A) whereby it transmits or receives data only passing overhead of a single ground station. Between passes, it stores any collected data to be transmitted at the next pass. Adding well-placed ground stations improves coverage, as does adding satellites with a cross-link capability that would forward data to one or more ground stations, effectively increasing the frequency of overhead passes (figure 4–23, case D). Geostationary architectures employ three or more satellites along with terrestrial ground sites and cross-linking for global coverage (except for high latitudes) (figure 4–23, case B), while Molniya orbits with two or more satellites can provide stable, continuous coverage of polar regions (figure 4–23, case C). At low altitudes, larger numbers of cross-linked satellites in a properly arranged constellation can provide continuous coverage of the Earth (figure 4–23, case E), with the most well-known example being the Iridium satellite telephone system.

Figure 4–23. Satellite Coverage Strategies



Source: James R. Wertz and Wiley J. Larson, eds., *Space Mission Analysis and Design*, 3d ed. (Dordrecht, Netherlands: Kluwer Academic Publishers, 1999).

Data rate is the number of bits per second of information that must be transferred over the communications link and is a function of the signal frequency—higher frequency signals can better support higher data rates. Enhanced capabilities to support global operations such as unmanned aircraft systems, video teleconferencing, or simply providing Super Bowl broadcasts to deployed troops create greater demand for higher and higher data rates. Signal security and availability include communications security—disguising the actual transmitted data and typically including data encryption—and transmission security—disguising the transmitted signal, usually by generating security keys and variables that support spread spectrum techniques. Availability, on the other hand, depends upon the environment's effect on the transmission channel. Communications links are typically designed to create an SNR that produces the required BER for the anticipated environment (no hostile effects on the transmission channel). Link margin is then added to compensate for other expected (and unexpected) operating conditions. Signal jamming is an intentional means of corrupting the otherwise benign environment by introducing noise into the communications path, resulting in an SNR of less than one. Of course, simple interference from other systems operating at the same frequency may have a similar, less sinister effect on communications, making frequency deconfliction an important factor in insuring effective communications.

All of these factors will impact the overall cost of the system. The system designer must investigate all available alternatives to obtain the desired signal-to-noise ratio at minimum system cost. Current trends in space communications focus on using more power, higher frequencies, and phased-array antennas to point the beam more precisely to make the signals less susceptible to jamming and interference and to increase data rates.

Conclusion

Space offers society advantages that have revolutionized modern life since the launch of Sputnik 50 years ago and has motivated scientific investigation and dreams of adventure for millennia. The global perspective has allowed worldwide communications and remote sensing (in many forms) and transformed navigation and timing for civil, military, and industrial uses. The challenge of space as a final frontier has lured huge investments by nations seeking to increase their international stature while improving their ability to provide services to their citizens, motivating the technical progress and patriotism of those same citizens, enlarging their international economic influence, and, in many cases, increasing their military power. The clear view space provides causes astronomers and other scientists to dream of future discoveries about the fundamental nature of life and our universe, while the unlimited and largely untapped wealth of space tantalizes citizens of the Earth, who are increasingly aware of finite terrestrial resources.

Realizing these advantages and leveraging the power conferred on those who best exploit them, however, require an appreciation of the physics, engineering, and operational knowledge unique to space, space systems, and missions. It is precisely because so few citizens of Earth have first-hand experience with space—unlike previous terrestrial, maritime, and aeronautical "frontiers"—that we must stress some technical understanding of these characteristics of space. This chapter may serve as a summary or review of some of the key concepts necessary for a firm understanding of the realm of space. Further in-depth study, beginning with the references cited within, is de rigueur for anyone interested in a better understanding of space policy and power and is especially important for space decisionmakers. Making policy and power decisions without this understanding would be akin to formulating a maritime strategy using a team of "experts" who had never seen the ocean or experienced tides, had no concept of buoyancy, or seen sail or shore.

Notes

1. For in-depth development of the concepts introduced in this chapter, refer to Jerry J. Sellers et al., *Understanding Space: An Introduction to Astronautics*, 3d ed. (New York: McGraw-Hill, 2005), from which much of this material has been excerpted or summarized. The classic text in this field is Roger R. Bate, Donald D. Mueller, and Jerry E. White, *Fundamentals of Astrodynamics* (New York: Dover Publications, 1971). Another excellent reference geared toward those not technically trained is David Wright et al., *The Physics of Space Security: A Reference Manual* (Cambridge: American Academy of Arts and Sciences, 2005).
2. Kepler's First Law applied to Earth-orbiting satellites: the orbit of each planet is an ellipse with the Sun at one focus.
3. Sellers et al., 182–184.
4. A simple example: to move a satellite from a circular orbit at an altitude of 300 km (a = 6,678 km, V total= 7.726 km/sec) to a higher, 1,000 km altitude orbit (a = 7,378 km, V = 7.350 km/sec) requires a ΔV total of 378 m/sec. For a 1,000 kg satellite (initial mass on orbit), this would require approximately 155 kg of fuel using a common monopropellant rocket propulsion system.

5. The same process can be used to disperse several satellites placed into an initial, identical orbit by a single launch vehicle—the effective reverse of a rendezvous maneuver. The satellites each perform well-timed "speed up and slow down" maneuvers to establish a constellation of equally spaced satellites (in time and angle) that might provide near-continuous coverage over the Earth.
6. RAAN precession occurs westward for direct orbits (inclination < 90°), eastward for retrograde orbits (inclination > 90°), and zero for polar orbits (inclination = 90°) and equatorial orbits (inclination = 0°).
7. Earth oblateness gives rise to two unique orbits with very practical applications: sun-synchronous and Molniya. The first case uses the eastward nodal progression when i > 90°. At i ≈ 98° (depending on spacecraft altitude), the ascending node moves eastward at the same rate as the Earth around the Sun (about 1° per day), keeping the spacecraft's orbital plane in the same orientation to the Sun throughout the year such that the spacecraft will always see the same Sun angle when it passes over a particular point on the Earth's surface. This is important for remote-sensing missions (such as reconnaissance) because observers can better track long-term changes in weather, terrain, and manmade features. The Molniya (in Russian, *lightning*) orbit is usually a 12-hour orbit with high eccentricity (e ≈ 0.7), perigee location in the Southern Hemisphere, and i = 63.4. At this inclination, the perigee does not rotate, so the spacecraft "hangs" over the Northern Hemisphere for nearly 11 hours of its 12-hour period before it whips quickly through perigee in the Southern Hemisphere. Molniya orbits can provide communication coverage to areas of high latitude that could not practically use geostationary orbits.
8. For example, the European Space Agency's launch site at Kourou (4°N latitude) gives launch vehicles an assist of 0.464 km/sec versus 0.4087 km/sec for the Kennedy Space Center at 28.5° latitude.
9. $\Delta V = I_{sp} g_o \, ln \text{ mi/mf}$ where g_o is the gravitational acceleration constant (9.81 m/sec^2); m_i is the initial mass of the spacecraft (fully fueled); and m_f is the final mass (fuel empty).
10. Jerry J. Sellers et al., "Investigation into Cost-Effective Propulsion System Options for Small Satellites," *Journal of Reducing Space Mission Cost* 1, no. 1 (1998).
11. Recent bounding examples in the United States are Space Exploration (SpaceX) Incorporated's Falcon I vehicle (~1,000 pounds to low Earth orbit) on the low end and the two families of Evolved Expendable Launch Vehicles (EELV), Lockheed-Martin's Atlas V and Boeing's Delta IV. While exact figures on these are not available, low estimates for Falcon I are probably $100 million, while EELV developmental funding was several billion dollars.
12. The VentureStar program was canceled in March 2001 after NASA canceled the suborbital X–33 technology demonstrator meant to reduce risk for full VentureStar development. NASA expenditures for X–33 totaled $912 million.
13. Sellers, *Understanding Space*, 84.
14. James R. Wertz and Wiley J. Larson, eds., *Space Mission Analysis and Design*, 3[d] ed. (Dordrecht, Netherlands: Kluwer Academic Publishers, 1999).
15. The French Cerise spacecraft became the first certified victim of space junk when its 6-meter gravity-gradient boom was clipped during a collision with a leftover piece of an Ariane launch vehicle in 1996.
16. Wertz and Larson, 1999.
17. Given by Wien's Displacement Law, λm=2898/T, where λ_m is the wavelength of maximum output in micrometers (mm) and *T* is the object's temperature in degrees Kelvin.
18. Given by the Stefan-Boltzmann equation, $q_A = \varepsilon\sigma T^4$, where q_A is the object's power per unit area (W/m^2), ε is the object's emissivity (0≤ε≤1), s is the Stefan-Boltzmann constant (5.67 x 10^{-8} W/m^{2}K^4), and *T* is the object's temperature in degrees Kelvin.
19. Resolution = 2.44λh/D where λ is the wavelength of the sensed radiation, *h* is the distance between the sensor and the target, and *D* is the instrument's aperture diameter.
20. A conventional radar operating at a wavelength of 240,000 mm would need an aperture of more than 480 km (298 miles) to get the same resolution as an optical system with a mere 1-meter aperture! Fortunately, signal-processing techniques that enable synthetic aperture radar—effectively enlarging the radar aperture—can achieve much higher effective apertures and thus higher resolutions.

21. $SNR=(P_tG_t/kB)/(\lambda/4\pi R)/(G_r/T)$ where *P* is transmitter power, G_t is transmitter gain, *k* is Boltzmann's constant, *B* is the receiver system's bandwidth, λ is the signal wavelength, *R* is the range to receiver, G_r is the receiver gain, and *T* is the receiver system's temperature.
22. For example, a bit error rate of 10–3 implies an error rate of 1 bit out of every 1,000 bits; typical bit error rates are ~10–5 for voice and ~10–14 for data.

Chapter 5:
Commercial Space and Spacepower

Henry R. Hertzfeld

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It is increasingly apparent that commercial opportunities for using space to make money by selling goods and services to governments and private customers are growing. Over the past 50 years, the United States has been the technological and commercial world leader in space. U.S. space policies, as reflected particularly in Presidential Directives but also in legislation and in regulations, reflect this leadership role. From the very first space policies in the Dwight D. Eisenhower administration to the present, policy documents assume that the United States is the world leader, attempt to ensure that role continues, and reserve the right to use the necessary means to protect space assets.

Until the 1980s, private companies in the United States were contractors and suppliers to the government space program and projects. They did not offer space services to the public. The one exception to this was in the important area of telecommunications. From the very beginning of the space age, U.S. private companies (in particular, AT&T) designed, built, and operated communications satellites and sold services to the public under strict government regulations and supervision.

Today, the landscape has changed. Companies in the United States are in direct competition with many foreign entities in space in almost all areas: launch vehicles, remote sensing satellites, telecommunications satellites of all kinds (voice, direct TV, fixed and mobile services), and navigation services.The technological capability to build and operate sophisticated space equipment has spread worldwide.

All evidence points to a continuation of this trend. Space has become a global enterprise with the number of nations and firms with space goods and services growing rapidly. And not only are more people involved in space but also the unique advantages of the space environment have contributed greatly to the growing trend toward globalization through its almost universal coverage of populated areas with communications and observation products and services.

In turn, an increase in globalization can stimulate the further growth of commercial space by making even larger markets with corresponding sales potentially available to companies. Globalization must be viewed as a summation of various components (political, business, and cultural). Space capabilities and technologies contribute differently to each component, and the extent of meaningful globalization must be analyzed by its components, not in the aggregate. This chapter will discuss the long-run trend toward globalization and how the growth of multinational companies and the global marketplace has influenced commercial space and spacepower.

Although no other nation spends as much on space as the United States, the ability of the U.S. Government to influence the rest of the world in space policy and in the use of space has greatly diminished over time. In some ways, space has become just another commodity. But government policy and security aspects of space do not treat commercial space as they treat automobiles, soap, or furniture. Because of the strategic value of space as well as the huge dependence of almost every industry on the space infrastructure, space commands special importance and has become a critical national resource.

This chapter will also review the process by which the U.S. Government has developed official policies toward space that have fueled the technological lead and put the United States at the forefront of space activity, while at the same time transferring some of the responsibility of this lead from purely government programs to the domestic commercial sector. However, other policies of the U.S. Government have had the opposite effect, encouraging foreign nations to develop similar and competitive space capabilities.

Questions without clear answers are the degree to which U.S. policy has sped up foreign space capabilities and what the effect has been on spacepower. Of course, not all foreign space programs can be attributed to U.S. policy actions. Because of the obvious advantage of using space for global monitoring, communications, and other activities, other nations naturally have had the desire and have developed independent space assets and capabilities.

Spacepower

Spacepower can be viewed from a commercial perspective in two ways. The first is economic: encouragement of commercial U.S. space ventures to be dominant in the world marketplace, either through creation of a monopoly or by sheer market dominance. The latter often makes competitors follow the leader's standards and practices, which in turn practically assures that others will adopt systems compatible with those of the market leader.[1] The second is by a show of strength: aggressively denying others access or interfering with the operations of foreign space assets.

This chapter will focus on policies of commercial market dominance. Therefore, spacepower will be discussed without the notion of military control or aggressive action to protect space assets or deny others the ability to operate in space. A truly competitive commercial world assumes that companies can operate on a level playing field and that the deciding factor is the ability to make a profit rather than the ability to take out a potential competitor by military action.[2]

Looking to the future growth of commercial space companies and the multinational aspects of commercial space raises an interesting question regarding spacepower. Specifically, will it be possible for commercial interests to supersede other national interests in space? The short answer is *no*. Besides the clear dual use of all space products, space law, as defined by current United Nations treaties on outer space, makes nations responsible for the actions of their citizens in outer space. To get to space and to do anything there, a company will need the formal approval of a parent nation. Since each nation may be both jointly and separately liable for certain types of damage from space objects, it will be difficult, if not impossible, for a company to operate in space without supervision. Therefore, unless the major legal tenets of space activity change, commercial interests will be subservient to national interests in space and will face major regulatory controls.[3]

Globalization and the Changing International Economic Environment

Globalization is the process of human interaction characterized by the ease of transcending national borders for variously defined ends.[4] There are many different aspects of globalization occurring at any given point in time. It is important to distinguish between geopolitical globalization, multinational economic globalization, and cultural/information networks that have become global.

Figure 5–1. Degrees of Globalization

Figure 5–1 illustrates the range of possible degrees of globalization. As one moves to the left of the diagram, the degree of interaction among nations increases. At the other extreme, nations may choose to isolate themselves and raise barriers to global interactions. The concept of regionalization is intended to meet a middle ground where select groups of nations agree to form alliances. Since the overall concept of globalization is the combination of the different elements suggested above, it is instructive to look at the relative position on the continuum for each major element. In general, economic and cultural globalization today has moved toward the left of center, while geopolitical globalization is somewhere to the right of that.

Some of the most visible trends in today's world are the growth of multinational firms, the ease of financial transactions internationally, and the spread of ideas, culture, and entertainment through the advances in communication technologies. The availability and advantages of satellite communications have greatly contributed to these trends through both global coverage and the opening of the global communications services and markets to all nations.

Globalization is not a new phenomenon, nor is it inevitable.[5] Decreases in barriers to trade—most recently through the North American Free Trade Agreement and the World Trade Organization, but through other bilateral agreements in the past as well—and better coordination among nations characterized the decade of the 1990s. Similar eras of increased interaction among people have existed before the most recent times but have then been followed by wars, economic depressions, or other occurrences, which slowed or stopped the trend toward globalization. Even in the first few years of the 21st century, the changed policies and attitudes toward international travel and security because of the events of September 11 have, at least temporarily, slowed the rapid globalization pace established in the 1990s.[6]

Other influences may also slow economic globalization. As described by Rawi Abdelal and Adam Segal, the speed of globalization may become less rapid in the upcoming years for the following reasons: politicians are more nervous about letting capital goods and people move more freely across borders, energy is the object of intense resource nationalism, and bilateral agreements appear to be replacing multilateral agreements (particularly with the United States skeptical of "global rulemaking").[7]

As impressive as the economic and cultural spread of ideas and interactions has been during the past several decades, it has been balanced by the decided lack of geopolitical globalization. With the important exception of the European Union (a limited form of primarily economic globalization on a regional basis), nations have not changed their approach to territorial rights.[8] These rights are jealously guarded and are strong limits to true international geopolitical globalization.

Although there has been a trend toward multinational firms and a global economic regime, history has shown that there is no assurance that this trend will continue on a smooth path. Current economic globalization is dependent on nations moving toward a free market–based economy that also implies some form of democratic government. Economic globalization also depends on the establishment of a relatively uniform regulatory system that is predictable, fair, and enforceable.

Space is a global industry. Within limits established by the political system, companies compete for launch services internationally. Satellite manufacturing, once heavily dependent on U.S. companies, is now an industry with companies located around the world. Space services are also available internationally. However, because of the dual-use nature of many space activities, there are regulatory and legal limits on the degree of international trade that can occur in this industry.

There are many good economic reasons that explain why commercial space needs to be global in nature to survive in a competitive world. Primarily, it is the satellite capability to connect to ground stations anywhere in the world and to transmit data and information globally (or, if not to all nations, to a vast majority of the world's populated areas). To make a profit on an investment that has high technological risk and very high up-front demands, a large market is essential. The additional cost of adding a new ground station is small in comparison to the cost of the space system. Since satellites can have global coverage, having a global market becomes an attractive profit potential. It can be easily argued that many space services are "natural monopolies." That is, one large provider can have the ability to serve all customers much more inexpensively than can multiple providers.[9]

However, in economic government regulatory policy, a monopoly of any sort is counter to a free market competitive philosophy. It should be noted, though, that early U.S. policy encouraged a U.S. monopoly in international telecommunications, not for reasons of economic efficiency, but for U.S. control and security (see the discussion below on U.S. telecommunications policy).

Globalization can have both positive and negative effects on the growth of the space sector and on the development of specific space applications. On the positive side, privatization of space assets would be possible if markets were large enough to be profitable for some space activities. If this were to occur, governments would have to be willing to relinquish some control of space activities. Applications that involve very large international markets—such as launch services, remote sensing, distance learning, and telemedicine—would benefit.

Globalization also would mean rising per capita income among most nations (although at different rates of growth), which would create the potential for more markets for space (and other) goods and services. New and larger markets might open opportunities for the expansion of currently profitable consumer space-related services such as global positioning system (GPS) navigation equipment and telecommunications (information-based) services, and perhaps the use of space for entertainment services (such as real-time distribution of movies and new music delivery services).

On the negative side, globalization and economic growth are likely to stimulate a backlash among some in society who will push for a "simpler" life and are against using new technology. A cultural backlash can also be expected that, coupled with the spread of highly advanced communications and space technology, is likely to encourage countermeasures by advocates wanting to block or reduce the influence of alien cultures.

Security and defense issues will be of major governmental concern. Space applications will be used to monitor and control these activities, and this should be a growth sector for government programs using new satellites. However, this can easily lead to a decline in market-based commercial space applications as government demands and regulations supplant the development of private market opportunities.

In the financial community, commercial space activities would have to be shown to have a greater opportunity cost and return on investment (ROI) than other high-technology and high-risk investments. As with other "negative" aspects of globalization, the availability of sufficient private capital for space investments will depend more on opportunity costs and the expected ROI of specific projects than it will on globalization. When dual-use technologies are involved, a lack of private capital will necessitate government subsidies.

Regionalization

The effects of regionalization are likely to be similar to those of globalization on space, although at somewhat lower levels of activity due to:

- less harmonization among nations in areas of regulation
- possibility of more regional conflicts

- lower per capita income growth
- less convergence of growth rates in general.

Nevertheless, satellite capabilities will be used for additional security concerns and for global monitoring. There is likely to be less private sector investment in space under this scenario than under the globalization scenario. However, regional markets may be large enough to support sizable space investments by the private sector. Other than the European Union, regional cooperation in space has not been a market or security issue to date.

Crisis/Independence

If nations increasingly choose to develop independent space systems, defense and other government uses of space will become more important with governments discouraging private investment in space because of the potential dangers of dual-use technologies in the hands of companies and other nations. Since each nation will attempt to develop its own space systems, the duplication and oversupply of both hardware and space products will act to discourage commercial space investments. Technological progress in areas such as space science and exploration would be hurt greatly by the divergence of funds to more immediate problems.

Finally, private investment in space will be even more challenged, but governments may opt to purchase space services directly from domestic commercial private firms. These firms may be precluded by regulation or contract from offering services to customers in the general marketplace.

Globalization and Spacepower

Globalization is not an inevitable outcome of current and past trends, but some very important aspects of globalization are on a steadily expanding path that is unlikely to be deterred. They include multinational business and financial connections and networks as well as cross-border information, cultural, and entertainment products and services. Space assets provide a key enabling infrastructure component of both of these developments.

The commercial space activities that are profitable today are those that serve these sectors by providing rapid worldwide communications. Whether it is navigation and timing services of the GPS satellites, or direct TV broadcasts, or very small aperture terminal links of the credit card companies, or electronic financial trading, the global economic system is now linked via satellites and space capabilities. If it were not for the existence of a large and well-funded global market for these services, the satellite systems serving them would likely not be profitable. What has developed over time is a circular dependence: technologies create new economic opportunities, and large markets create profitable infrastructure investments with subsequent multiplicative terrestrial businesses.

However, this evolution of satellite services (from the early space years when governments provided and controlled the telecommunications satellites) has created dilemmas. No longer can a nation such as the United States even rationally plan for control of the systems or capabilities. In time of conflict, it would be almost impossible to interrupt services because businesses and governments as customers depend on them. In fact, the government is one of the major users of commercial communications networks.

Another dilemma is that satellite signals do not cleanly begin and end at national borders. Some nations are increasingly incensed at their inability to censor or control economic and political messages received by their populations. Similarly, some cultures are attempting to resist the intrusions of Western values that are predominant in the business and entertainment sectors. This is creating political and regional isolationist sentiments that may someday result in attempts to interrupt certain satellite transmissions. Such attempts make the issue of spacepower integral to both the growth of globalization and the continued development of large world markets for satellite services that can create profits and new commercial space endeavors. The nation that leads in commercial space will have a larger share of economic growth and be able to dictate industry standards, an important tool for future economic dominance as well as for space security.

Thus, if globalization continues its rapid advance, then a nation's commercial spacepower is of greater importance; if globalization stalls, dedicated national security and military uses of space will increase, and a nation's ability to garner larger market shares for commercial services will be more limited.[10] Spacepower may then be determined more by military power than market power.

U.S. Government Approach to Commercial Space over Time

This brief review of U.S. Government space policy documents as they relate to commercial space activities clearly shows a changing attitude and increasing dependence on private space activities. U.S. Government space policy, however, is very complex and is not adequately or comprehensively reflected in any one document or even any one series of documents (such as Presidential Decision Directives [PDDs] on Space Policies). When viewed from a commercial space perspective, even analyzing only unclassified policies yields a set of guidelines that is sometimes inconsistent. At any given time, one can point to both documents in which the government provides incentives for commercial space to develop and mature and ones in which significant barriers to commercial space exist. Sometimes these incentives and barriers are erected purposefully and sometimes they are inadvertent, being unintended byproducts of other government priorities and initiatives Several categories of government policies will be described below. First, trends in PDDs that have direct implications for commercial space are analyzed. Second, PDDs and documents concerning the satellite communications sector are described. Third, major legislative changes that have had an impact on the development of commercial space and regulations imposed on commercial space endeavors over time are reviewed. Fourth, other government policies such as the deregulation of many industries and the decision of the Department of Defense (DOD) to encourage the consolidation of aerospace companies are discussed.

A summary of government policy toward commercial space produces a confused set of signals to the industry and to foreign governments and potential competitors. The reasons for the contradictions include:

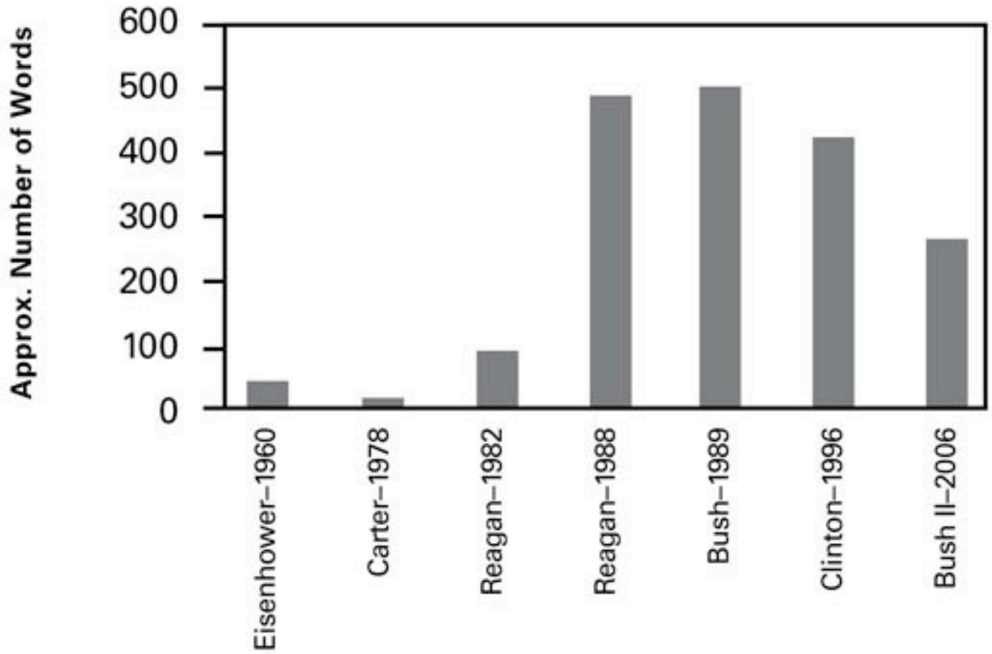
- the important role of space in national security and a goal of reserving some space capabilities, whether commercially or government owned, for national purposes
- a rapidly changing industry that has not yet reached commercial maturity
- the use of space assets for international political purposes
- changes in government policy over time concerning competition and deregulation.

Finally, it should be noted that most other nations have developed space capabilities and space programs to encourage and subsidize economic growth through cutting-edge technological developments (as well as to create jobs).[11] The charters of most foreign space agencies specifically state this as one goal.[12] That provides a basis for an overt and active "industry policy" toward space. The United States has a government philosophy of not having an industry policy for any economic sector, therefore making it more difficult for the government to find a unified way of providing incentives to any industry, aerospace included.[13]

Presidential Space Documents and Decisions

Since 1960, there have been seven major Presidential documents on space policy. Changes over time to the policies have never been radical but have reflected changing technological, political, and economic conditions. The following discussion will broadly summarize the approach over time of the various administrations to commercial space and will analyze the significance of those changes to the U.S. economy and to how commercial space plays a role in spacepower.[14] It is clear from the very rudimentary count of words in these documents that the economic and commercial aspects of space only became important policy considerations in the 1980s (see figure 5–2).

Figure 5–2. Commercial Space in Presidential Space Policy



Space policy emerged from the Cold War as a security, political, and technological endeavor for the United States. Early space policies focused on ensuring the security of the United States through winning the technological race with the former Soviet Union. In addition, there were concerns and issues of nuclear proliferation and deterrence in those early space policies, reflecting the capabilities of launch vehicles to deliver weapons. The economic capabilities of the United States were mentioned in the Eisenhower Policy but more as a general recognition that the design and development of space equipment would stimulate the economy. That is, jobs would be created and possible spin-off products would enter the economy. The Eisenhower Policy also recognized the future potential economic aspects of two civilian applications of space technologies, communications and meteorology, but these technologies were not discussed in detail in this overall policy document.[15]

It is also interesting to note that the Eisenhower Policy called for international cooperation in civilian space exploration, but at the same time space was to "demonstrate an over-all U.S. superiority in outer space without necessarily requiring the United States supremacy in every phase of space activities."[16]

The beginnings of change were apparent in the 1978 National Space Policy of the Jimmy Carter administration that focused on remote sensing; it called for a study and report on private sector involvement and investment in civil remote sensing systems.[17]

The official encouragement of commercial space did not occur until the 1980s.[18] Several different domestic factors, as well as several international developments, were responsible. First was the beginning of the maturation of the Earth observation satellites and the growth of a private value-added industry selling specialized products based on

Landsat imagery. Second was the successful partial commercialization of the upper stages of launch vehicles (the Payload Assist Modules). Third was the *Challenger* accident in 1986 that suddenly changed the launch scenario for commercial satellites (mostly telecommunications).[19]

On the international scene, the 1980s were marked by the success of the French Ariane launch vehicle and Spot remote sensing satellites. Both were designed to directly compete with U.S. systems and were marketed by private companies but were essentially vehicles funded through government sources. Other nations were also beginning to design and build competitive commercial space systems and satellites.

Therefore, on both the domestic and foreign fronts, commercial companies that had been solely government contractors for space equipment were branching into independent offerings of space components and systems. The industry was beginning to mature and, at the same time, the United States was entering an era of overall policy shifts toward economic deregulation of all industry. Although space would never be "deregulated," the philosophical shift meant more attention to commercial capabilities and opportunities along with the recognition that the government could be a customer for rather than a producer of some space goods and services.

The Ronald Reagan administration policies of 1982 and 1984 further extended the mandate for the government to both "obtain economic and scientific benefits through the exploitation of space, and expand United States private-sector investment and involvement in the civil space and space-related activities.[20] Collectively, these policies emphasized that the space systems were to be for national economic benefit and that the U.S. Government would provide a climate conducive to expanded private sector investment and involvement in civil space activities with due regard to public safety and national security. It also called for a regulatory and supervisory system.

It should be noted that all policies that encouraged private sector space activity and commercialization of space also contained caveats that required the consideration of national security. Thus, any commercial space venture had, and still has, investment risk that is subject to deliberately vague government rules and possible decisions on what might constitute a breach of national security.[21]

The George H.W. Bush administration expanded these commercial policies.[22] Collectively, they called for the active encouragement of commercial investments in space as well as for the promotion of commercial space activities. There were even directions in the policy of 1991 to study the possible disposition of missiles by converting them into commercial launchers. (This was subject to a number of security and economic caveats.) Also of significance was the mandate for the government not only to promote commercial remote sensing, but also to "not preclude" private sector remote sensing activities.

The Bill Clinton administration took further steps to encourage commercial space. In particular, remote sensing again was the focus of attention, with not only the previous security limits on the resolution of imagery that could be made public greatly relaxed, but also with specific policies on remote sensing that were to support and enhance U.S. global competitiveness in the international remote sensing market. Success in this type of commercial activity was viewed as contributing to our critical industrial base.[23]

Another Clinton policy directive called for the private sector to have a significant role in managing the development and operation of a new reusable space transportation system. The National Aeronautics and Space Administration (NASA) was directed to "actively involve the private sector."[24] Although this system (the X–33/VentureStar Project) was begun but never completed, it was one of the first major initiatives in space for a public/private partnership in the research and development (R&D) of a new launch system.

By the mid-1990s, the GPS military navigation satellites, which had a free and open signal, had stimulated a rapidly growing private sector market for ground receivers. A policy directive issued in 1996 clearly recognized that the private sector investment in U.S. GPS technologies and services was important for economic competitiveness, and the policy encouraged continued private activity in this area, subject to issues of national security.[25]

The George W. Bush administration issued a set of space policies dealing with specific issues (Earth observations, transportation, navigation, and the vision for exploration) as well as the final policy document that covers overall space policy.[26] The commitment to promoting and encouraging commercial activity is continued in all of these policies. However, in the overall policy document issued in August 2006, there is a noticeable decrease in references to commercial objectives and a noticeable increase in references to national security issues.

This should not be interpreted as a retreat from supporting commercial space endeavors. In fact, there are more companies involved in entrepreneurial space activities than ever before in the United States and the rest of the world. And the U.S. Government is actively promoting commercial ventures, both independently of and with government support, in programs such as NASA's commercial-off-the-shelf initiative. In addition, NASA is actively seeking foreign national and commercial partnerships and initiatives for future activities on the Moon.

But this new policy should also serve as a sobering warning that national security will supersede commercial issues, if necessary, adding a significant risk to commercial investments on one hand, and insuring that U.S. commercial interests in space will be backed by some form of government protective action if they are threatened.

In summary, overall space policy directives have slowly been transformed from a Cold War emphasis that marginalized the economic and commercial implications of space activities into a truly integrated policy that recognizes the maturity of many space applications, sophisticated industrial capabilities, the globalization of space technologies, and the importance of the space infrastructure to both civilian uses and security concerns.

It is important to recognize that events in the past 6 years in the United States have led to a new space policy that continues to recognize and encourage commercial space, but with a greater emphasis on security and on the protection of both public and private U.S. space assets.

In the early years of space, the dominance of the United States in its technology permitted spacepower to be practically a given, rivaled only by the competition with the Soviet Union. Today, the reality is that the Nation is still the leader in space expenditures but no longer dominates or controls developments in many space applications. Spacepower, as it might be measured by dominance in economic or commercial space activity, is broadly spread around the globe. There are only limited ways the United States can use commercial space for maintaining elements of control over the industry. One is to have the largest market share in any sector, which encourages others who may want to compete to adopt compatible standards for interoperability. The other is to be the leader in developing new technology and establish dominant control over particular markets by protecting that technology. Both methods are risky, expensive, and do not necessarily guarantee success.

The only other way the United States can assert spacepower in the commercial sector is by using nonmarket (political, diplomatic, or military) actions to discourage or deny others access to commercial space. It is highly unlikely in today's world that such measures would be successful. Other nations have independent access to space and space assets. Many companies using space for commercial purposes are multinational enterprises, often with significant U.S. corporate investments and components. And the U.S. Government itself depends not only on U.S. commercial space goods and services but also on foreign systems.[27] Therefore, at this time, disrupting the fragile market and price system that is developing for space commercial assets would not be in the best interests of the United States.

GovernmentPolicytowardTelecommunications Satellites

Until the 1990s, most space policy topics were covered in overall policy statements.[28] Telecommunications was handled separately from the very beginning of the space era, mainly because in the 1950s and 1960s, its relevance to security and its obvious commercial potential were much further developed than other space applications. In addition, telecommunications was truly a public/private endeavor, mainly developed in the private sector by AT&T. As early as the mid-1950s, comparisons were made that showed the tremendous capacity increases that could be available through satellite telephone calls when compared to the capacity of the transatlantic cable at that time.[29]

The change in 1961 from the Republican Eisenhower administration to the Democratic John F. Kennedy administration also signaled a change in attitude toward the telecommunications satellite system. In the Eisenhower era, it was accepted that AT&T was the monopoly provider of long-distance telephone service, and having the company expand into satellite service was not disputed. In fact, there was a clear recognition that a U.S. monopoly in satellite communications would be advantageous from many perspectives, ranging from control over the world system (and also, therefore, increasing the military and economic power of the United States) to cost efficiencies from scale economies of operation.

The Kennedy administration altered this perspective and encouraged competition in the United States for privately funded satellite systems by awarding contracts for the development of new communications satellites by several firms. AT&T launched the Telstar system of two satellites in 1962, NASA awarded a competitive contract to RCA for the Relay satellites, also first launched in 1962, and Hughes received a sole-source NASA contract for the Syncom satellites, launched first in 1963.

As the need for a world satellite communications system developed, COMSAT was formed in 1962 as a U.S. public corporation with shares held by both the communications companies as well as the general public. It was not only the manager for the International Telecommunications Satellite Corporation (Intelsat), but also was its U.S. official representative. Intelsat was formed in 1964, and its first satellite, Early Bird, was launched the next year. As early as 1969, there was global coverage, with agreements in place for ground stations across the world.

In 1965, the Lyndon Johnson administration approved National Security Action Memorandum 338, which clearly stated the U.S. policy toward foreign communications capabilities.[30] The essence of this policy was to encourage a single global commercial communications satellite system. It stated that the United States should refrain from providing assistance to other countries that would significantly promote, stimulate, or encourage proliferation of communications satellite systems. It went on to say that the United States should not consider foreign requests for launch services in connections with communications satellites (except for those satellites that would be part of the international system).

The European (French-German) Symphonie satellite program begun in 1967 presents an interesting case study. This was the first European-built telecommunications satellite, and the Europeans requested a launch to geosynchronous orbit from NASA. The United States, as a matter of policy, would not guarantee them a launch opportunity for Symphonie as an *operational* satellite. (Eventually, the United States did launch the satellite in 1974 under the policy exception that the satellite was an *experimental* one.) This U.S. refusal to launch a foreign, and possibly competing, satellite was one of the main factors prompting the development in Europe of the Ariane launch vehicle so that Europe would have an independent capability to launch its own operational satellites.[31]

What this example illustrates is that a policy of spacepower (denying others access to space while attempting to create a U.S.-led monopoly) can backfire by providing incentives for others to be able to ignore U.S. policies by building and operating their own systems. As is well known, the Ariane launch system was optimized to capture the launch market for commercial telecommunications satellite launches to geosynchronous orbit. It became a huge tactical and market success, capturing over 60 percent of the commercial launch market by the 1990s and effectively eliminating any hope of U.S. "control" of the launch vehicle market, particularly for telecommunications satellites.[32]

Over time, with the trend in the United States toward deregulation, the telecommunications industry monopolies have disappeared. At the same time, many nations have built and launched domestic telecommunications satellites. COMSAT became a private company and has now disappeared after being sold to Lockheed-Martin. Intelsat (and Inmarsat) are now privately operated. Many firms around the world are able to build new telecommunications satellites, and the U.S. position in this industry has changed from a virtual monopoly to a large, but by no means dominant, competitor.

Other Government RegulatoryActions

Besides the official administration PDDs on space activities, there are numerous other social, technological, budget, political, and economic actions that are decided by all branches of the government—executive, legislative, and judicial. Some are related to space issues but are handled through other venues. Antitrust reviews, for example, done by the Department of Justice and the Federal Trade Commission, often have far-reaching space and spacepower implications when dealing with firms engaged in space activities. The list of direct and tangential actions with an impact on spacepower would span almost the entire spectrum of government activities, from securities regulations to decisions from the courts.

Examples

Below, some examples are listed.[33] The major issue for consideration in the context of spacepower, however, is that many actions taken by the government for very valid purposes that are unrelated to space may create conditions that negate the ability to carry out space policies as proscribed in PDDs and/or create incentives for other nations or the companies in other nations to more aggressively develop systems in direct competition with U.S. capabilities. Taken collectively, many of these actions may make any attempt at a U.S. policy that emphasizes economic spacepower very difficult, if not impossible, to carry out. And looking historically, many of these nonspace policies and actions may have created and sped up the development of robust space capabilities in other nations, which, in turn, has weakened U.S. economic leadership in space and diluted the Nation's power in space systems development as well as in the technology and use of space applications.[34]

Overall U.S. Government philosophy toward economic deregulation of industry.Deregulation, along with policies to avoid developing government enterprises, is oriented toward letting the market and price system allocate resources more efficiently than government fiat can do. This works well in a truly competitive industry with many producers and many consumers. Unfortunately, space is an industry characterized by only a few producers and with governments as the major purchasers. What has occurred is a shift in power and human resource capability from governments to large corporations. Whether this is advantageous to either the development of space commerce or to U.S.

spacepower is a matter of empirical analysis and further research, neither of which has been done as yet.[35]

Overall government attempts to privatize and outsource functions.Examples such as the attempted privatization of remote sensing satellites, first in the late 1970s and again in the mid-1980s, were premature and not very successful. In fact, the suggestion that the satellite weather service be privatized resulted in Congress declaring that meteorology and weather systems were a "public good" and would not be privatized. Essentially, the private market for space goods and services has never developed as rapidly as was expected, and most of these proposals have not happened due mainly to a lack of a sizable nongovernment market as well as to the large up-front investments.

DOD incentives for mergers and combinations of firms since the 1990s.As discussed below, this has encouraged a more oligopolistic space industry in the United States. It also encouraged similar combinations abroad as the only way other nations could compete with U.S. companies. Lower-tier suppliers have been subsumed under larger companies, and the result has been a different type of competition than existed before these developments in the space sector. It has also created more powerful and capable foreign competition.

Examples from Space-related Decisions

Imposition of strict export controls on space systems and high-technology products. Both U.S. and foreign industries as well as foreign governments have complained bitterly about the strict enforcement of export control laws since the late 1990s. It is increasingly more difficult to share R&D information, to sell U.S. space goods and services abroad, and to cooperate with foreign nations, even on government projects. The hardest hit space industry has been satellite manufacturing in the United States, where foreign competitors have built and are selling equipment worldwide at the expense of a market that formerly was controlled and dominated by U.S. firms.

Sunset provisions on indemnification of space third-party liability.Although perhaps of a lesser economic disadvantage to the United States in providing competition in launch services, most foreign launch companies fully indemnify their domestic industry from the unlikely, but possibly very expensive, liability claims that could accrue if there were a major disaster from a space object destroying property or taking lives upon reentering the Earth's atmosphere. The United States requires private insurance and indemnifies firms (with a cap) on claims above what insurance would pay. That is a reasonable policy, but it has never been made permanent. Congress has consistently put a sunset provision into that authorizing legislation and therefore has increased the risk of investment for U.S. launch firms compared to our foreign competitors.

Decision in the 1970s to put all commercial payloads on the space shuttle and not fund R&D for expendable vehicles. The economic results of the *Challenger* disaster in 1986 clearly highlighted the potential problems with this policy. In particular, Arianespace, the French/European launch vehicle company, was developing a series of vehicles mainly designed for the commercial market in geosynchronous telecommunications satellites. As a result of the United States falling behind in R&D and manufacturing of expendable rockets and the change in policy toward commercial space shuttle launches after *Challenger*, Arianespace was able to capture up to 60 percent of the launch market. The United States needed over a decade and a major policy shift toward stimulating commercial launch developments before being able to regain some of the lost market share.

Decision not to authorize launches of foreign operational telecommunications satellites on U.S. launch vehicles. As with other restrictive policies, nations were given the incentive to develop independent capabilities. With the ensuing maturation of launch and satellite technologies, they were able to build very competitive and capable equipment without U.S. components or assistance.[36]

DOD decision to retain governance of GPS. Even though GPS was funded, designed, built, and operated by DOD, it had provided an unencrypted free signal for worldwide use as part of the program. Use of this signal has grown into a multibillion-dollar industry very quickly. Receivers are manufactured in many nations, and the system has become one of the important infrastructure services offered from space. It is important now to both the military and to civilian communications and timing systems. From the mid-1990s to today, it has been the only fully operating space navigation system. That is about to change as Europe, Russia, and possibly China develop their own systems. Nobody questions the integrity or value of the U.S. global positioning system, but partially because it is controlled by DOD without any inputs from other nations, there are incentives to invest billions of dollars abroad to duplicate the capability. From a military viewpoint, not giving up control of a critical technology is understandable, but from a practical and economic perspective, the United States likely could have maintained a monopoly position, or at least greatly stalled foreign developments, if the government had been able to compromise on this policy.

Delayed decision to allow release of higher resolution images from Earth observation satellites for civil and commercial purposes. By the early 1990s, when the restriction was lifted on releasing or permitting private U.S. companies to collect or sell imagery with a resolution of less than 10 meters, France had been selling such imagery on the open market, as had Russia. Again, nations with aggressive economic and industry space policies were able to capture market shares from U.S. companies hindered by policies designed for security, not commercial purposes.

The United States and the Changing International Space Environment

In the early days of space activity, the United States and the Soviet Union were alone in having a full range of space capabilities. National security, particularly with respect to fear of the use and/or spread of nuclear weapons, and Cold War–era jockeying for both economic and technological supremacy were the driving forces behind the space race. Private sector initiatives and the commercialization of space were concepts and ideas far from being realized. Even telecommunications through satellites was in its infancy and, at least in the United States, involved private companies but only under careful economic regulatory supervision. Essentially, there was no commercial or economic issue of any great magnitude for the government to be concerned about. And where it might be possible, the United States had a virtual lock on competition.

Today, just about everything has turned around. There is no technological race with another superpower. Nuclear technology has spread across the world despite remaining under strict controls. Likewise, space capabilities ranging from launch vehicles to satellites are available to almost any nation with the money and inclination to purchase them. Space technical and manufacturing capability exists in just about every developed region of the world, and nations are not dependent on the United States. The world economy has become far more interconnected, and U.S. dependence on international trade in goods and services has grown from approximately 5 percent of the gross domestic product in the 1960s to about 20 percent.

The issue that confronts U.S. space policy in regard to economic and commercial spacepower is whether *any* policy that attempts to put the United States in a dominant economic role in space will be effective. The above discussion has amply illustrated that most such policies have backfired. They have encouraged other nations to invest in competitive systems so as to develop and maintain their own independent capabilities in space. Although worldwide competition in space infrastructure as well as space-related products and services may have many benefits, it does severely limit the amount of control any one nation might have on important dual-use technologies in space.

Economic competition does encourage the development and deployment of new products and services, but not all of them may be of domestic origin. However, some U.S. policies, such as those that have encouraged the merger of many companies involved in space and defense work into an oligopolistic framework, have led to an interesting new economic structure where competition is among a few giant firms rather than among many providers. It also has led to similar conglomerations of firms abroad. This type of competition may not yield the same advantages (particularly to consumers—including the government as a purchaser of services) that usually are attributed to true competitive industries.

In summary, for a variety of reasons, the United States cannot return to the space era and space policies of the 1960s. It can be and is a leader in space technology, but it is not the leader in all aspects of space. Spacepower through commercial prowess is likely to be shared among spacefaring nations. Policies aimed at isolation and at protection of commercial industries only encourage others to develop similar (and sometimes better) products. The only policy that can now be effective in developing a larger and more powerful economic competitive engine for space products is one that encourages R&D investments by space firms. The introduction of new and more advanced products will create a larger global market for the United States. A policy emphasizing offense rather than defense would be advantageous for stimulating spacepower through space commerce.

Conclusion

Economic and commercial spacepower is about market dominance and control. When the United States has a monopoly or near-monopoly in space goods or services, control is not a problem, and it can dictate (and has done so) to the rest of the world what it was willing to sell and provide. History has amply illustrated that this is a short-term phenomenon and that, given the value of space technologies to many sectors and to domestic security, nations with the ability and resources will develop their own independent capabilities.

When other nations have similar capabilities, control becomes a problem assuming, as is the case with space, that control is also a critical issue in security. Options for control through spacepower change and become more limited. Once lost, it is almost impossible to regain economic control; therefore, spacepower may revert to issues of bargaining and negotiating power and/or military might.

Exerting spacepower may be inconsistent with expanded commercial developments in space, raising investment risks and creating incentives for foreign competitors. At the same time, spacepower is highly correlated with increased dual-use government purchases of space services as well as with other security issues in space activities.

Economic investments are made on the basis of expected rates of return. Expanding potential market opportunities is one of the prime motivators for private investment. The government may be a large customer for commercial goods and services. The economic question is whether it is better for a firm to invest in space because there are expanding private markets resulting from growth in global opportunities or because of expected domestic government sales, primarily for dual-use and security services.

To the extent that the global market opportunity is denied by restrictive commercial policies, spacepower from a purely international economic competitive perspective is diminished. As encouraging as the U.S. commercial space policies are in Presidential documents over the past 20 years, they have been unintentionally undermined to a large extent by other policies. In the United States, security almost always trumps commerce.

The United States is still the largest investor in space in the world and the technological and commercial space leader in many areas. This leadership is being challenged. From an economic standpoint alone, it will become increasingly important for the United States to stimulate its industry to develop better and less expensive space products in order to maintain its competitive position. A strong commercial space industry can and will contribute to spacepower. It must be recognized that space is no longer the province of one or two strong nations and that other nations will continue to enter the market and continuously challenge this leadership.

Notes

1. The advantage is twofold: it encourages purchases of technical components from the market leader, and it gives the market leader a military advantage in understanding the technological workings of others' systems.
2. The police power to ensure a status quo (or improvement) is recognized as an important component of a level playing field. For this chapter, the purpose is to isolate economic and business arguments from military and security issues.
3. Even international nongovernmental organizations, such as the European Space Agency, that have independently agreed to the principles of the United Nations (UN) Treaties on Outer Space cannot make claims for liability directly to a nonmember offending nation or to the UN. They are required to make such claims through one of their member nations that has ratified the treaties.
4. This section is based on a working paper by Henry Hertzfeld and Michel Fouquin, "Socioeconomic Conditions and the Space Sector," Organisation for Economic Co-operation and Development, Working Paper SG/AU/SPA (2004) 3, May 12, 2004.
5. See Stanley Fischer, "Globalization and Its Challenges," *American Economic Review Papers and Proceedings* 3, no. 2 (May 2003), 3.
6. Some actions such as the tightening of visa requirements for entrance to the United States have had a definite effect on the number of foreign students in U.S. universities. These actions have also made it more difficult for professionals to attend conferences and workshops in the United States, both evidence of a slowing of at least some global communications links. Globalization is also closely tied to overall economic growth trends. The early 2000s were marked by a slowdown in growth that may have temporarily slowed globalization trends. The 9/11 events had a particularly strong influence on U.S. policies. It is unclear how much those policies affected other nations.
7. Rawi Abdelal and Adam Segal, "Has Globalization Passed its Peak?" *Foreign Affairs* 86, no. 1 (January–February 2007), 103–114.
8. Even in the European Union, nations have retained jurisdiction over many areas, including telecommunications policy. It is important to note the failure of a popular vote on establishing a European constitution.
9. That does not guarantee that the prices charged to customers will necessarily be lower than if the industry were competitive (that is, if multiple providers had been offering services to the same customers). Economic theory tells us otherwise. Monopoly means higher prices and less quantity offered on the market. Regulatory licensing, oversight, and enforcement can compensate for this. The trade-off in the case of space is one of avoiding duplication of expensive assets coupled with the space-power inherent with a monopoly that is owned by a company within the United States and under the supervision of U.S. laws. Arguments that the space sector should be "competitive" and respond fully to market prices sound persuasive but fail to recognize the reality that space economic activity is, at best, the province of a handful of companies and is beholden to large purchases from governments—both factors clearly denying space enterprise from fitting any textbook definition of a price-competitive sector. Competition in the space sector has to be viewed as a goal, not a reality.
10. This is because there will be a combination of more satellites serving only one nation or region, and there will also be restrictions on sales of services within particular nations and market areas.
11. The former Soviet Union is the obvious exception to this. Its goals were very similar to those of the United States in the space and technological race of the 1960s through the 1980s, but because of the socialist nature of the government it did not seek commercial involvement during those years.
12. See, for example, article VII of the European Space Agency Charter, SP–1271(E), March 2003.
13. Not having an industry policy is, in itself, an industry policy. And in spite of that overall philosophy, the United States has provided many specific incentives and subsidies to the aerospace industry. For example, the Independent Research and Development funds that are part of many Department of Defense research and development contracts to commercial funds provide incentive for new commercial technological development. The Export-Import Bank provides loans to industry to encourage trade. Import restrictions on some products protect domestic industry. And the largest incentive is the sales to the U.S. Government of equipment and services.
14. National Security Space Project, "Presidential Decisions: NSC Documents," ed. Stephanie Feyock and R. Cargill Hall (Washington, DC: George C. Marshall Institute, 2006). This volume (along

with its supplement) is a collection of all of the unclassified and declassified Presidential Decisions on space. That document is the source of the information in this section.

15. Telecommunications, meteorology, and remote sensing have all been subjects of separate policy documents over time.
16. National Security Council (NSC) 5918/1, "Draft Statement of U.S. Policy on Outer Space," December 17, 1959.
17. Presidential Decision Directive (PDD)/NSC–37, "National Space Policy," May 22, 1978, available at <http://fas.org/spp/military/docops/national/nsc-37.htm>.
18. The exception was telecommunications satellites, which are discussed in separate policy documents.
19. With an operational shuttle, the U.S. Government had adapted two related policies: one was to put all commercial U.S. payloads on the shuttle, and the second was to stop performing advanced research and development on expendable launch vehicles. After the *Challenger* accident, it was clear that the United States needed both capable expendable vehicles and the shuttle. The commercial launch sector was at this point mature enough to manufacture and sell launches of expendable vehicles to both the government and private customers. The 1984 Commercial Space Launch Act was significantly amended in 1988 to encourage government purchases of launch vehicles and licensing of U.S. vehicles for commercial satellite launches rather than having the government be the intermediary between the commercial firms and the vehicle manufacturers.
20. National Security Decision Directive (NSDD)–42, "National Space Policy," July 4, 1982, available at <www.hq.nasa.gov/office/pao/History/nsdd-42.html>; NSDD–94, "Commercialization of Expendable Launch Vehicles," May 16, 1982, available at <www.fas.org/irp/offdocs/nsdd/nsdd-094.htm>; "Fact Sheet: National Space Strategy," August 16, 1984; and NSDD–254, "United States Space Launch Strategy," December 27, 1986, available at <www.fas.org/irp/offdocs/nsdd/nsdd-254.htm>.
21. One could argue that any commercial venture in any industry might be subject to a similar constraint. However, given the dual-use nature of all space activities, along with the history of the space industry, this constraint is of a more direct and significant importance for most activities in space.
22. NSDD–30 (National Security Presidential Directive [NSPD]–1), "National Space Policy," November 2, 1989, NSPD–4, "National Space Launch Strategy," July 10, 1991, available at <http://fas.org/spp/military/docops/national/nspd4.htm>; NSPD–5,"Landsat Remote Sensing Strategy,"February 13, 1992, available at <www.au.af.mil/au/awc/awcgate/nspd5.htm>; NSPD–6, "Space Exploration Initiative," March 13, 1992, available at <http://fas.org/spp/military/docops/national/nspd6.htm>.
23. PDD/NSC–23, "Statement on Export of Satellite Imagery and Imaging Systems," March 10, 1994.
24. PDD/National Science and Technology Council (NSTC)–4, "National Space Transportation Policy," August 5, 1994, available at <www.fas.org/spp/military/docops/national/launchst.htm>.
25. PDD/NSTC–6, "U.S. Global Positioning System Policy," March 29, 1996, available at <www.fas.org/spp/military/docops/national/gps.htm>.
26. George W. Bush, "U.S. Commercial Remote Sensing Policy," Section VI, "Foreign Access to U.S. Commercial Remote Sensing Space Capabilities," April 25, 2003, available at <http://ostp.gov/html/Fact%20Sheet%20-%20Commercial%20Remote%20Sensing%20Policy%20-%20April%20 25%202003.pdf>; George W. Bush, "A Renewed Spirit of Discovery: The President's Vision for Space Exploration" (Washington, DC: The White House, January 2004), available at <http://ostp.gov/html/ renewed_spirit.pdf>; "Fact Sheet: U.S. Space-Based Positioning, Navigation, and Timing Policy," December 15, 2004, Background, §II; "Fact Sheet: U.S. Space Transportation Policy," January 6, 2005, available at <http://ostp.gov/html/Space_Transportation_Policy05.pdf>, U.S. National Space Policy, August 31, 2006.
27. This is particularly important for the purchase of communications bandwidth as well as for Earth observation imagery. In addition, there are many scientific and meteorology satellites that provided data that are shared with many nations and are important for U.S. security as well.
28. Today, remote sensing, navigation, transportation, and NASA's "vision" are all enumerated in separate policy documents. The administration's overall space policy addresses general issues and direction, as well as topics not dealt with in the separate policy documents.

29. The brief summary in this paper is based on information in David J. Whalen, "Communications Satellites: Making the Global Village Possible," available at <www.hq.nasa.gov/office/pao/History/ satcomhistory.html>, and in Joseph Pelton, "The History of Satellite Communications," in *Exploring the Unknown*, ed. John M. Logsdon (Washington, DC: National Aeronautics and Space Administration, SP–4407, 1998). It is also interesting to note that the most profitable private use of satellites has changed and is now in the broadcast of direct-to-home television. Technology has changed and cop-per-wire cables have been superseded by fiber optic cables, which now carry the majority of voice communications, although they cannot serve point-to-multipoint transmissions as effectively as satellites. The U.S. Department of Defense, in addition to having its own communications satellites, also purchases a large amount of bandwidth from private satellite providers.
30. Reproduced in Pelton, *Exploring the Unknown*, 91.
31. M. Bigner and J. Vanderkerckhove, "The Ariane Programme," *Philosophical Transactions of the Royal Society of London* A312, no. 1519; "Technology in the 1990s: The Industrialization of Space" (July 26, 1984), 83–88, available at <http://links.jstor.org/sici?sici=00804614%2819840726%29312%3A1519%3C83%3ATAP%5BD%3E2.0.CO%3B2-A>.
32. See below for a brief discussion of the remote sensing industry and the navigation space sector. In both cases, subsequent to the telecommunications experience, Europe (led by France) developed, launched, and successfully operated a competitive remote sensing system (Spot) and is actively engaged in a competitive navigation system (Galileo).
33. A full analysis of this issue is far too lengthy and complex for this chapter but would be a useful topic for further research.
34. Given the overall maturity of parts of the space industry and the very obvious advantages of having space systems, foreign technological and economic development of competing systems is inevitable and advantageous in many cases. However, the argument given above relates to unilateral U.S. actions that have created unusually strong incentives for foreign development of competing systems and resulted in a competitive disadvantage for U.S. industry.
35. A hint of the effects might be found in the telecommunications sector where COMSAT as the U.S. monopoly representative to Intelsat was supposed to do advanced telecommunications research and development (R&D). After COMSAT was formed, the government did not fund much new basic research in that area. However, COMSAT, as a private company, had other research objectives, mainly developing new products rather than doing more fundamental R&D. NASA, with great political difficulty, finally did establish a new R&D program in telecommunications (the Advanced Communications Technology Satellite program) in the 1980s to attempt to catch up to other nations that had continued government funding in that area.
36. See discussion of the French-German Symphonie satellite above.

Chapter 6:
The Commercial Space Industry: A Critical Spacepower Consideration

Joseph Fuller, Jr., Jeffrey Foust, Chad Frappier, Dustin Kaiser, and David Vaccaro

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Spacepower is a function of multiple factors including military, civil, and commercial space capabilities. Without considering all three capabilities, formulation of thought on spacepower would fall short of reality. The commercial space industry is an evolving part of global space activity and is driving innovative technologies and applications in conjunction with government missions. It is critical to understand the major characteristics of the commercial space market, not only because the size of the industry and its technical applications have a great effect on the global economy, but also because the assets and services of commercial space are often used by government customers.

Two major industry themes exist that affect issues of national interest. First is the interdependence between commercial industry and government space. Without the activities of one, the other would be operationally deficient. A second theme is the existence of government incentives and impediments that influence the landscape of the commercial space industry and its contributions to national goals. These themes will be examined in this chapter.

The following sections provide insight into the space industry and activity in the commercial market for space products and services. The commercial industry, although an interconnected whole, is defined by four major components: satellite services, satellite manufacturing, launch services, and ground equipment. Breaking down the industry by sector provides a better understanding of the major trends and wide-ranging components that make up commercial space. An explanation of market activity, major players, and other critical characteristics of each sector is provided, followed by an outlook for the future commercial space industry and its implications for spacepower.

Historical Overview

Aerospace and other companies have been involved in the space industry since the beginning of the space age, initially as contractors to government programs. However, the commercial space industry did not emerge in its current recognizable form until the 1980s. Growing demand for satellite communications, particularly television broadcasting, provided new business for satellite manufacturers and led to the creation of new companies to provide satellite services. At the same time, changes in U.S. national space policy in the wake of the space shuttle *Challenger* accident, as well as the emergence of competition from Europe's Ariane launch vehicle, stimulated the development of a domestic commercial launch industry.

The commercial space industry continued to grow through the 1990s, in part due to increasing demand for broadcasting and other communications services, but also because companies sought to branch out into other areas, from mobile communications to remote sensing. This growth, fueled by billions of dollars of investment in new ventures such as Globalstar, Iridium, and Teledesic, created optimistic forecasts for continued future expansion into the next decade and led to investment in new commercial launch ventures, including companies that planned to develop reusable launch vehicles that would greatly reduce the cost of space access. However, by 2000, many of these new ventures were struggling: new communications companies found it difficult to compete with low-cost terrestrial alternatives, deterring other ventures from starting up and causing a ripple effect that reduced demand for satellite manufacturing and launch services. The industry retrenched for several years, falling back on its core, relatively mature satellite communications markets. However, entrepreneurs continue to explore new commercial space markets, with suborbital and orbital space tourism now one of the leading areas of interest.

Industry Sectors: Satellite Services

Market Overview

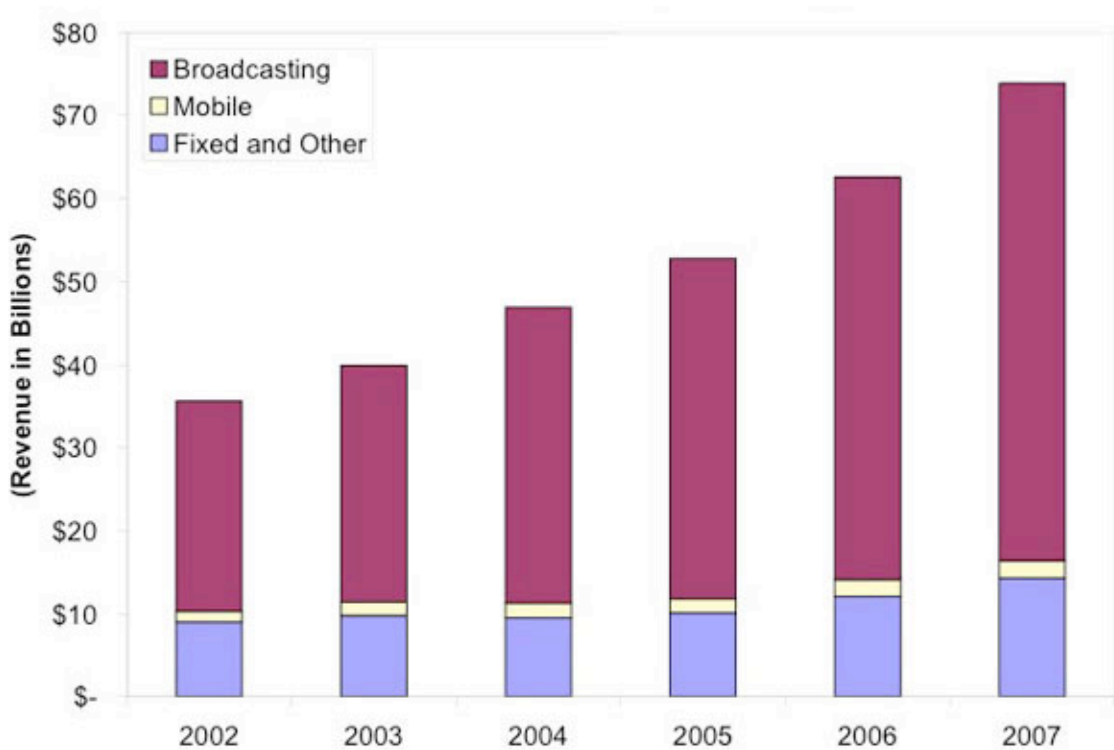
The satellite services sector refers to communications and remote sensing provided by commercially owned or operated satellites. Three categories define the sector, based upon the type of service being offered: fixed satellite service, mobile satellite service, and direct broadcast service. These categories include lease and purchase agreements for on-orbit transponders, retail or subscription services (such as direct-to-home [DTH] television and digital audio radio service), and commercial satellite remote sensing.

Since the earliest stages of the space age, commercial companies have provided services through the satellites they own or operate. In the early 1960s, the first satellite communications systems for commercial use were developed. The Telstar program produced the first active communications satellite, launched in 1962, that was developed using government-industry cooperation between the National Aeronautics and Space Administration (NASA) and AT&T. In 1965, the first commercial communications satellite was launched, the Communications Satellite Corporation's Early Bird, which acted as a line-of-sight communications repeater between North America and Europe. This satellite demonstrated the feasibility of geosynchronous satellite communications, which is the mainstay of the satellite services sector today. Satellite operators have proliferated worldwide and provide satellite communications capabilities in nearly every part of the globe while developing innovative technologies that expand available services.

Commercial satellite remote sensing operators have also developed a presence in many parts of the world and have continually improved satellite imagery services. Growth in this market has not been as significant as in communications. Remote sensing providers serve the geospatial information services market and supply overhead intelligence to governments worldwide.

The satellite services sector is larger than any other sector in the commercial space industry and has experienced sustained growth from 2002 through 2007. As figure 6–1 shows, estimated worldwide revenues earned by satellite service providers grew from 2000 to 2005, despite increasing global deregulation that has increased price competition, resulting in decreasing revenues per transponder during this period.[1]

Figure 6–1. World Satellite Services Revenue by Service Type, 2002-2007



Regulation plays a significant role in shaping the satellite services sector. The industry is licensed by regimes that differ according to the type of service provided and the geographical location of the company or of the service provided. Individual countries have the responsibility to allocate bandwidth and regulate the use of particular satellites within national borders (or *landing rights*) in the communications and remote sensing sectors. In the United States, the Federal Communications Commission regulates satellite communications, while the National Oceanic and Atmospheric Administration in the Department of Commerce regulates commercial satellite remote sensing operators. Two documents that provide the foundation of regulatory guidance in the United States are the Communications Satellite Act of 1962 and the 1992 Land Remote Sensing Policy Act.

Similarly, other countries have regulatory entities that levy rules on commercial service providers within their jurisdiction. Because regulatory regimes vary from country to country, this creates additional complexity and potential difficulty for companies seeking allocated bandwidth and landing rights in a given country.

Key Satellite Service Providers

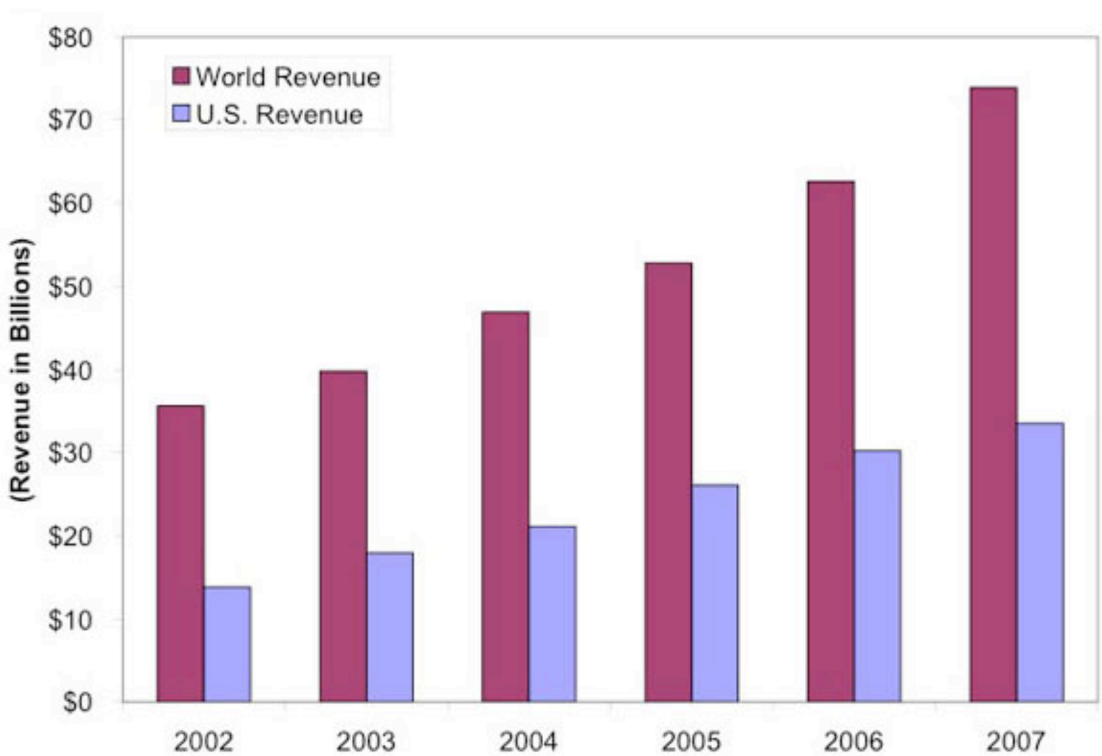
The satellite services sector is composed of numerous global and regional companies providing various services to most regions of the world. Select companies with the greatest impact on the market for different types of services are listed in table 6–1. The services are an integral part of personal and business activity globally, as well as government communications and intelligence collection. For this reason, commercial satellite assets are critical infrastructure that promote economic growth, sustain well being, and enhance security.

Table 6–1. Significant Worldwide Satellite Services Companies

FSS	MSS	DBS	DARS	Remote Sensing, U.S.	Remote Sensing, Non-U.S.
Eutelsat	Globalstar	DirecTV	Sirius Satellite Radio	DigitalGlobe	ImageSat International
Intelsat	Inmarsat	DishTV	WorldSpace	GeoEye	Infoterra
SES Americom/New Skies	Iridium	EchoStar	XM Satellite Radio		MDA Geospatial Services
Telesat	Thuraya				RapidEye
					Spot Image

The size of this sector, in terms of worldwide revenues by satellite services companies, exceeded $70 billion in 2007. Companies based in the United States play a significant role in this sector: about 45 percent of 2007 revenue can be attributed to U.S. companies (see figure 6–2).Moreover, from 2002 to 2007, these U.S. companies maintained a relatively steady percentage of all satellite services revenue, ranging a low of 39 percent to a high of 49 percent in 2007.[2]

Figure 6–2. World versus U.S. Satellite Services Revenue, 2002-2007



In addition to the companies that own and operate satellites, private equity firms are playing an increasingly important role in this sector. This trend is particularly the case in the U.S. market; the effect of private equity in the sector varies by location. Private equity firms are purchasing satellite assets at an increasing pace, which could potentially affect the future landscape of the entire industry. The long-term nature of satellite planning is in conflict with the short-term business nature of the private equity planning horizon. Absent the traditional longer term technology development focus, this could affect the procurement of future satellites if there is insufficient attention to recapitalization and investment in physical assets. In this case, the business environment of commercial services could affect whether there is sufficient capacity available to government and nongovernmental customers.

Industry Sectors: Satellite Manufacturing

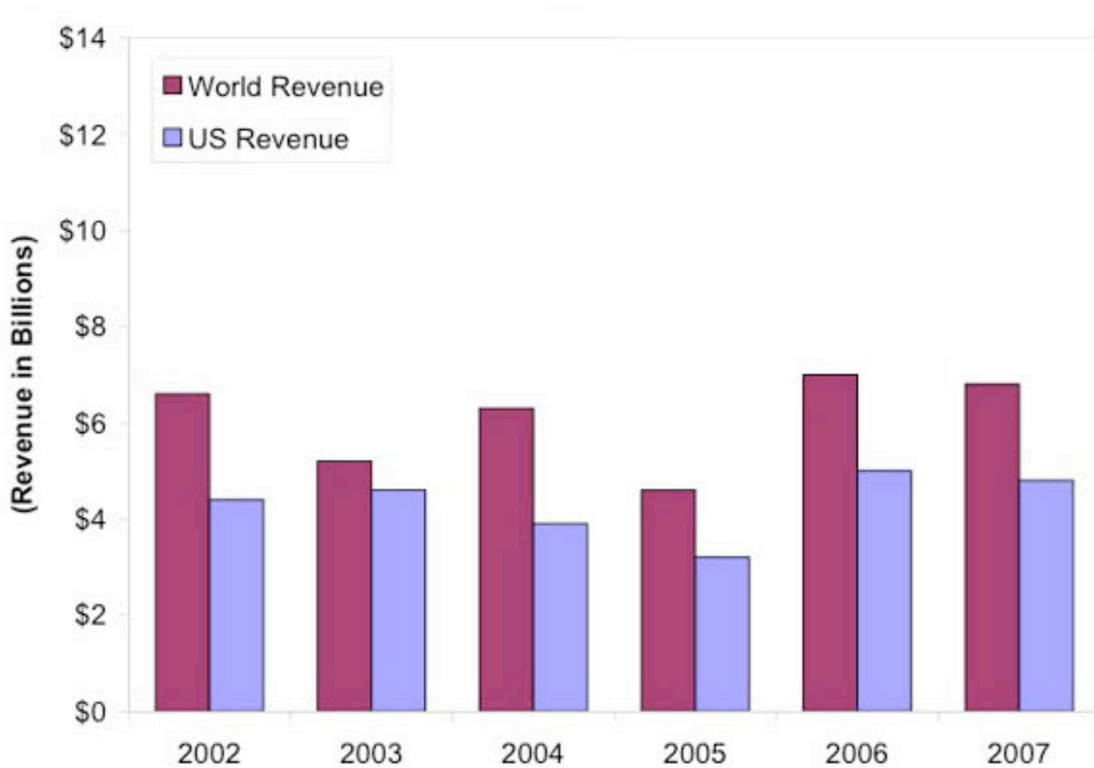
Market Overview

The commercial satellite manufacturing sector, historically dominated by a handful of American and European firms, has diversified both geographically and technologically in the past decade. A host of Asia-Pacific companies has entered the market. Meanwhile, European companies have partnered to take advantage of market opportunities created by U.S. export regulations, which are generally perceived to have precipitated a decline in the U.S. share of the market. Established and new satellite manufacturers, both in the United States and abroad, have sought competitive advantages in technologies such as small satellites, customizable modular bus designs into which standardized interoperable payload components can be inserted according to the desired function of the satellite (known as *plug-and-play* modular buses), and advanced remote sensing, imagery, and communications instrumentation.

One driving force behind this internationalization and specialization of the satellite manufacturing sector has been the changing levels of demand.Traced over the past decade (1999–2008), the financial performance of the satellite manufacturing sectors forms a U-curve:a marked decline, a period of leveling, followed by a resurgence.In the late 1990s, surging Internet usage and the need for increasingly sophisticated, globally available communications services fueled expectations that many fleets of new satellites would be needed. Instead, the telecom bubble burst, and satellite manufacturers have since competed for a limited number of contracts. Non-geosynchronous orbit (NGSO) communications ventures such as Globalstar and Iridium experienced financial failures and both underwent extensive restructuring before returning to their current operational status.During this period, geosynchronous Earth orbit (GEO) commercial providers ordered fewer replacement satellites, opting instead to consolidate their fleets and to invest only in maintaining or replacing spacecraft as required to preserve their current constellations.However, after several years of shrinking demand, beginning in 2006, satellite manufacturing revenues began to rebound.After falling from $11 billion in 2002 to $7.8 billion in 2005, satellite manufacturing revenues rose sharply to $12 billion in 2006.This trend was sustained in 2007 with satellite manufacturing revenues of $11.6 billion recorded.

Importantly, the slight drop between 2006 and 2007 was due not to fewer satellites being produced for launch but rather to the decrease in the average mass of the satellites launched in 2007.This highlights another trend in the satellite manufacturing market, the growing importance of small satellites, or *smallsats*, which will be discussed later in this section (see figure 6–3).[3]

Figure 6–3. Worldwide Satellite Manufacturing Revenues, 2002-2007



Despite the recent resurgence in satellite manufacturing revenues, the deep global recession that began in 2008 and continued in early 2009 will likely impact the satellite manufacturing sector. There is typically a period of many months, often extending to years, between completion of a satellite manufacturing contract and delivery of the satellite. This gap means satellite manufacturers usually have a backlog of contracts. When the recession began, satellites manufacturers were building spacecraft ordered before the global downturn; many had very high backlogs in late 2008 and early 2009. The duration of the recession can create a risk that fewer new satellite orders will be placed overall, despite the ability of some major players to accelerate purchases opportunistically during this period of market contraction. For this reason and the ongoing difficulties in the credit markets, satellite manufacturing could suffer from a delayed recession impact, leading to a potential contraction in manufacturing revenues in 2010 and beyond.

In response to this tightening market, manufacturers in China, India, and other Asian countries have sought to compete on a price basis. Asian manufacturers benefit from a large pool of skilled low-cost labor and maintain considerable, but nontransparent, collaborative relationships with government-funded space agencies and science institutes in their home countries. These factors keep costs low and create mechanisms for leveraging public sector research and development resources toward commercial ends, enabling Asian manufacturers to offer satellite buses on the world market at comparatively lower rates.

Meanwhile, U.S. companies, stimulated partly by government-sponsored responsive space and other initiatives, have pursued a technological edge. They have invested in facilities to develop smallsats, which can offer the same functionality as larger satellites at a fraction of the cost. Interest in smallsats has also prompted U.S. manufacturers to explore plug-and-play technology.

The global market has been slower to adopt the smallsat concept, and despite the technical advances, U.S. manufacturers have experienced declining market share since the beginning of the decade. In 2000, 51 percent of worldwide satellite manufacturing revenues went to U.S. companies. By 2007, this proportion had decreased to 41 percent. The industry consensus is that a significant portion of this decline has been caused by U.S. Department of State International Traffic in Arms Regulations (ITAR) controls, which make it difficult and sometimes impossible for U.S. manufacturers to build satellites for or provide components to foreign clients.

The application of ITAR regulations has become a subject of consternation in this U.S. commercial space sector. From component suppliers to bus providers and payload integration companies, all tiers of the American satellite manufacturing sector have seen their global market potential reduced by ITAR restrictions. As American firms have explored state-of-the-art technologies to gain a market advantage, European, Russian, and other international firms have specialized by marketing satellites that are not subject to ITAR controls. These export control rules, which were designed to protect U.S. technology, have created a market based solely on avoidance of the controls. Among the most prominent examples is the case of Chinasat-8, a communications satellite serving the China Satellite Communications Corporation (Chinasat) of Beijing. In 1998, Loral Space and Communications, a U.S. manufacturer, completed construction of Chinasat-8 but was prevented by ITAR rules from exporting it for launch aboard a Chinese Long March vehicle. The satellite remained in storage for 6 years while Loral sought export approval from the Department of State. Loral's efforts were ultimately unsuccessful. As a result, Chinasat awarded a $145-million manufacturing contract for the follow-on satellite, Chinasat-9, to Alcatel Alenia Space (now Thales Alenia Space), a European company not subject to ITAR. Thales Alenia has meanwhile also taken the lead in developing an "ITAR-free" satellite whose components are supplied wholly by manufacturers outside the United States. Similar collaborations among international satellite manufacturers in this market space were in various stages of progress as of early 2009.

Cases like Chinasat-8 have prompted a consensus among American satellite manufacturers that by disadvantaging U.S. firms in the global marketplace, ITAR rules harm the national interest more than help it. However, others continue to cite the need to limit technology transfers to possible adversaries. It is important to consider that, now, there are non–U.S. companies providing the international market with technology of equal or better quality than U.S. technology. Against this backdrop of foreign competition and dual-use issues, the debate continues over how best to balance American commercial and security interests as they pertain to satellite manufacturing.

Key Satellite Manufacturers

Five companies currently dominate the commercial satellite manufacturing sector: The Boeing Company, Lockheed Martin Commercial Space Systems, and Space Systems/Loral in the United States; and Alcatel Alenia Space and EADS Astrium in Europe. Together, these companies have won approximately three-fourths of announced GEO commercial payload manufacturing contracts in the past decade. The remaining contracts were distributed among a handful of smaller players: Orbital Sciences Corporation in the United States; Khrunichev State Research and Production Space Center, NPO PM, and Energiya in Russia; Mitsubishi Electric in Japan; and the Chinese Academy of Space Technology (CAST).

In addition to commercial GEO satellite contracts, a number of companies manufacture NGSO satellites as well as GEO satellites whose contracts are not openly competed on the commercial market. Other U.S. satellite manufacturers include Northrop Grumman Corporation, Aero Astro, Ball Aerospace, General Dynamics, and several firms specializing in small satellites, such as Instarsat, Microsat Systems, SpaceDev, and Swales Aerospace.

Beyond Thales Alenia and EADS, Europe is also home to smaller satellite manufacturers. Two significant smaller manufacturers are Germany's OHB–System AG and Britain's Surrey Satellite Technology Ltd., one of the world's foremost smallsat builders. Like American firms, European satellite manufacturers often partner and subcontract with one another. Unlike American firms, European manufacturers are not subject to ITAR restrictions, enabling them to collaborate more easily with firms abroad. While European manufacturers are subject to some export controls, European Union rules are not as strict as those of its U.S. counterparts. This has allowed collaboration with Russian and other international firms, including a 2005 accord between EADS Astrium and Antrix, the commercial arm of the Indian Space Research Organization, to jointly address the commercial market.

In Asia, Japanese companies such as Nippon Electric Corporation and Mitsubishi were for many years the only satellite manufacturing market contenders. But in the past decade, Chinese and Indian firms have emerged. In addition to producing a steady flow of payloads for Chinese government and commercial purposes, CAST has contracted to build satellites for the Venezuelan and Nigerian governments and has established ties with Thales Alenia to cooperate in addressing the satellite export market. India's Antrix is pursuing a similar path, building satellites for domestic Indian clients while enhancing its focus on international customers. The success in February 2006 of the joint EADS Astrium-Antrix bid to manufacture the Eutelsat W2M communications satellite marked India's first major international satellite manufacturing contract. China and India are positioning themselves to compete primarily on a cost basis. If satellite demand begins to stagnate or decline due to the current recession, the price advantages both countries can offer may prove decisive in a tightening market.

Finally, a collection of other international satellite manufacturers occupies small niches within the market. Israel Aircraft Industries and Elbit Systems together manufacture sophisticated remote sensing satellites for Israeli military use. Iran is seeking to build a similar indigenous satellite capability via Shahid Hemmat 1G, a government-funded manufacturer about which little information is known. In South America, Argentina's INVAP, a research incubator sponsored by the government, has attempted to foster a national commercial satellite manufacturing industry with little success thus far. The Korean Aerospace Research Institute has pursued the same goal in South Korea, but despite these efforts, that country has not yet joined China and India as a contender in the commercial satellite manufacturing marketplace. Finally, Canada's MacDonald, Dettwiler, and Associates is seeking to enhance its payload manufacturing offerings.

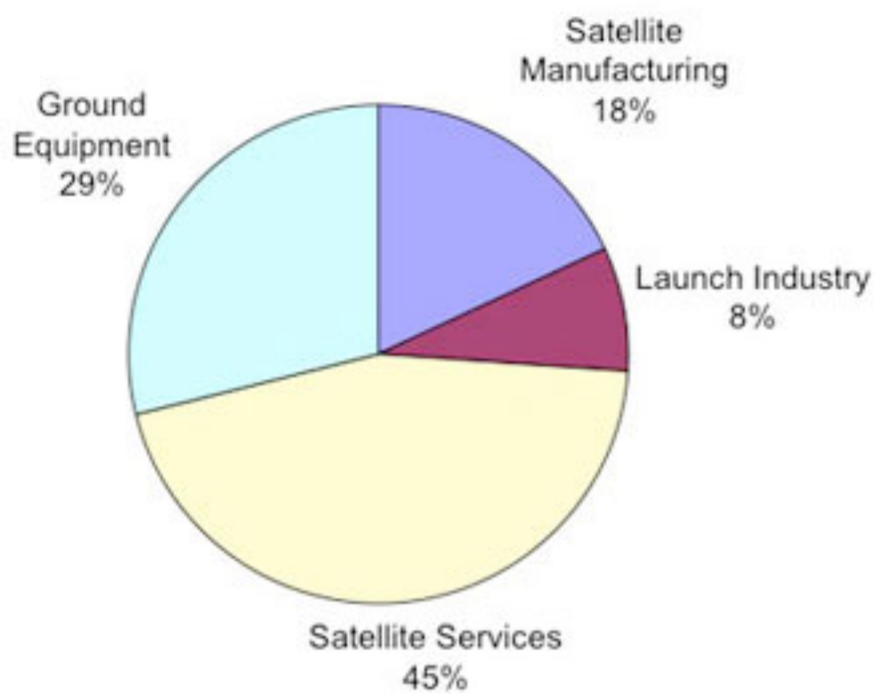
Satellite Technologies and Trends

Small satellites are a key emerging technology area in the satellite manufacturing sector. The ability to conduct functions currently handled by larger satellites using smaller, lighter payloads promises to increase payload versatility while reducing manufacturing and launch costs. While smallsats promise advantages due to their launch and operational flexibility, their strategic value has not yet been demonstrated in operational scenarios. The U.S. military has funded the building and test launch of several smallsats, and numerous universities worldwide have designed 1-kilogram cube-shaped satellites for similar experimental missions. These have been used mainly for technology development rather than commercial applications. While there will continue to be military, scientific, and nonprofit interest in smallsat technologies, the manufacturing tempo of small satellites appears unlikely to increase significantly until their commercial viability has been demonstrated.

Other satellite technologies under development also have strategic implications. Several U.S. and international satellite manufacturers continue to produce intelligence, surveillance, and reconnaissance satellites. More recent models of these satellites feature technologies such as synthetic aperture radar, which allow satellites to analyze ground images despite interference from low light and cloud cover, and high-resolution cameras and imagers. Meanwhile, the U.S. global positioning system (GPS) constellation and other navigation systems programs are seeking to bolster future satellites with advanced positioning, navigation, and timing technologies. These technologies will increase the overall accuracy of the satellite navigation systems they serve—including a diverse array of critical military, commercial, and civil applications. Other technologies will be applied to space surveillance, situational awareness space asset defense, and possibly offensive counterspace.

Despite these high value-added technology developments, the satellite manufacturing sector now contributes proportionately less to the overall economic valuation of the commercial space industry than it did at the beginning of the decade (see figure 6–4). In 2000, revenues from the satellite manufacturing sector constituted 18 percent of worldwide space industry revenues. By 2007, the proportion had shrunk to 9 percent.[4]

Figure 6–4. Composition of Worldwide Space Industry Revenues, 2002



Given these market dynamics, the satellite manufacturing sector will likely face growing pressures to adapt to a tightening market in the 2010 timeframe and beyond. Although government requirements will continue to generate demand for new satellites and satellite technologies, the ongoing recession suggests that the recent rebound in the satellite manufacturing sector might be short-lived. The sector appears poised to enter another period of change in which satellite manufacturers with the most diverse portfolios of satellite hardware offerings and capabilities will likely benefit from comparative advantages over their counterparts.

Industry Sectors: Launch Services

Launch Market Overview

Commercial payloads have created demand for launch services since the early communications satellites of the 1960s. Initially, those launches were provided by government organizations, such as NASA. By the 1980s, a commercial launch industry had emerged with the rise of Arianespace, the European company that markets launches of the Ariane launch vehicle family, and the 1986 decision by President Ronald Reagan to move commercial and many government payloads from the space shuttle to expendable launch vehicles intensified these developments. Competition increased in the 1990s with the introduction of the Chinese Long March and various Russian vehicles to the global market.

The commercial launch sector has experienced wide variations in activity in the last 10 years (see figure 6–5). In the latter half of the 1990s, commercial launch activity surged primarily because of the launch of a growing number of GEO communications satellites, as well as the deployment of three low Earth orbit (LEO) communications systems: Globalstar, Iridium, and ORBCOMM. However, after the telecommunications boom ended in 2000 and the LEO satellite operators filed for bankruptcy protection, launch activity dropped precipitously. Forecasts for launch activity through the middle of the next decade, as generated by the U.S. Federal Aviation Administration's (FAA's) Office of Commercial Space Transportation and the Commercial Space Transportation Advisory Committee, do not foresee a return to the peak levels of the late 1990s, although launch activity is projected to remain above the early 2000s nadir, in part because of efforts to replace the original LEO satellite constellations with new generations of spacecraft (see figure 6–6).[5]

Figure 6–5. Composition of Worldwide Space Industry Revenues, 2007

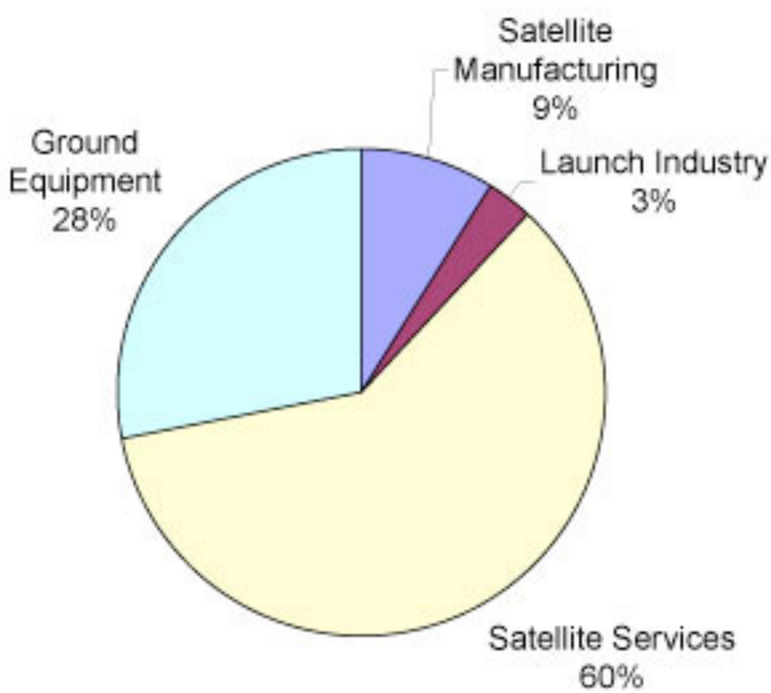
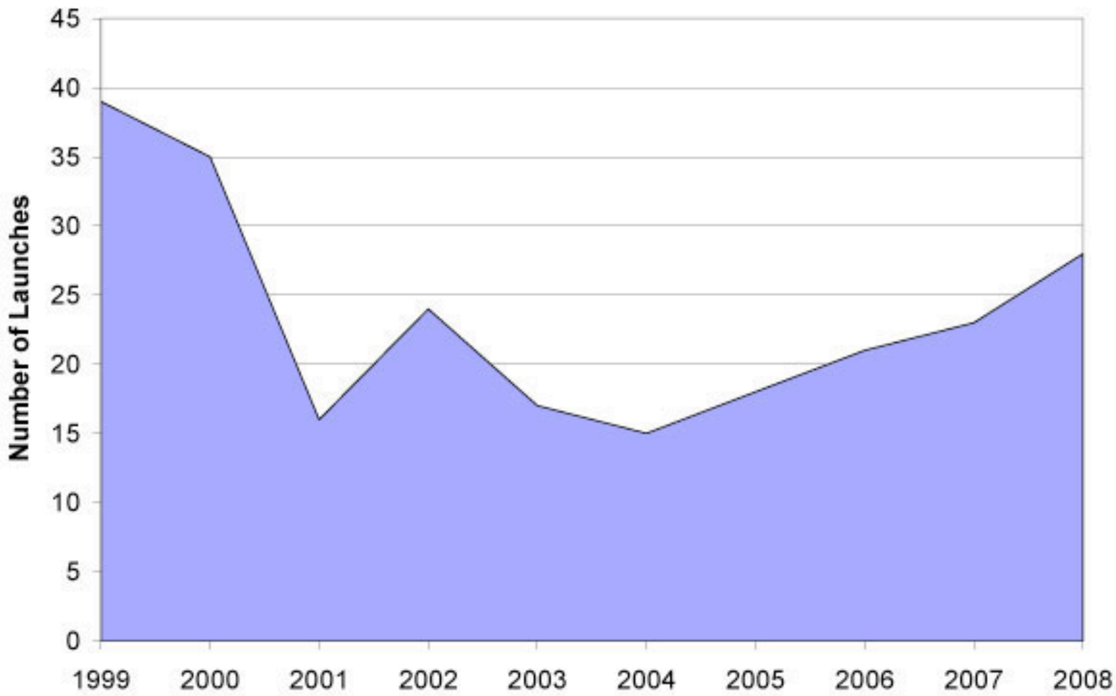
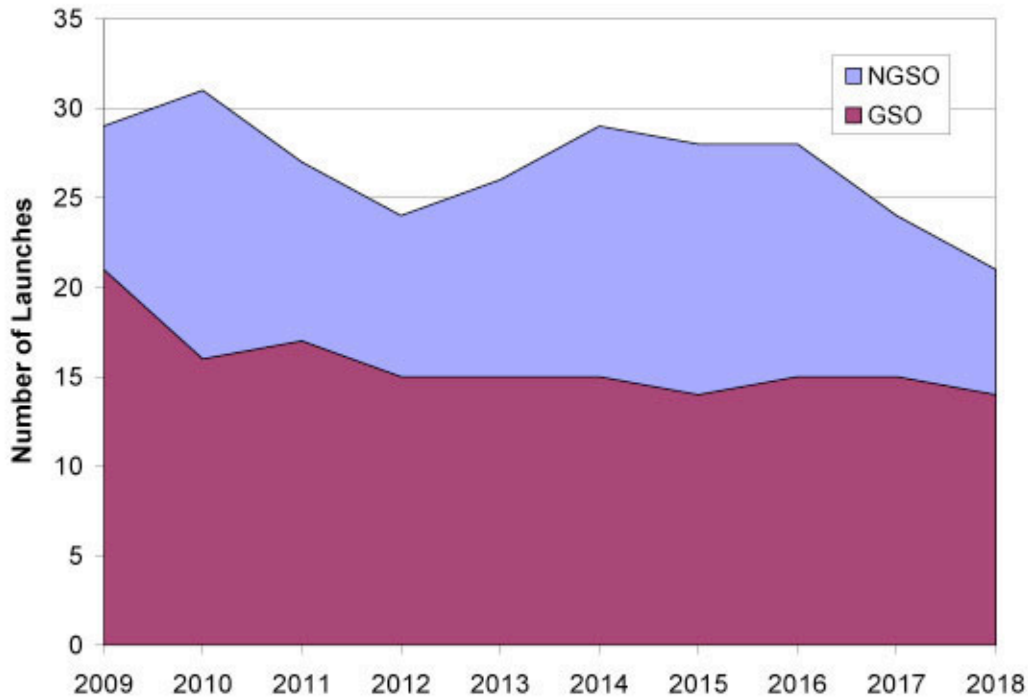


Figure 6–6. Worldwide Commercial Launches, 1999-2008



Translating launch activity into revenue for the industry has been notoriously difficult because of the lack of independently verifiable pricing data. Launch services providers, with rare exceptions, do not publish prices for either individual launch contracts or vehicles in general. Anecdotal data suggest that launch prices have varied considerably in the last decade, falling early in the decade because of considerable oversupply in the market but later recovering somewhat because of an increase in demand and short-term supply constraints. By early 2009, there was some evidence of a renewed decline in launch prices, at least by some launch providers. Figure 6–7 provides an approximation of launch services revenue, based on FAA-approved estimates of commercial launch prices.

Figure 6–7. Commercial Launch Forecast, 2009-2018



From 1999 to 2008, the U.S. share of the global commercial launch market significantly declined. The United States held a de facto monopoly on the commercial market prior to the entry of Arianespace in the 1980s and maintained a significant share of this market through much of the 1990s.The U.S. share of the commercial launch market fell significantly this decade, however, and has declined even more in recent years (see figure 6–8). Much of the decline has to do with price: while individual purchase decisions are not especially price sensitive (since the cost of launch is only a fraction of the overall cost to build and deploy a large commercial GEO communications satellite), non–U.S. launch vehicles on the market have proven to be both equally reliable and less expensive, providing better service to commercial customers.One U.S. company, Space Exploration Technologies (SpaceX), is attempting to reverse this trend with its Falcon line of launch vehicle that can launch spacecraft at prices significantly below not just other U.S.–built vehicles, but international competitors as well.

Figure 6–8. Estimated Worldwide Commercial Launch Revenues, 1999-2008

Key Launch Service Players

Three providers currently dominate the commercial launch services market. Arianespace, a French company, provides the Ariane 5 launch vehicle, the only vehicle that offers dual-manifesting for large GEO satellites. Arianespace is also now selling launches on the Russian-built Soyuz rocket, which will begin flights out of the European spaceport in Kourou, French Guiana, in 2010. Sea Launch is a multinational venture led by a U.S. company, Boeing, and includes companies from Ukraine, Russia, and Norway. It offers flights on the Zenit-3SL, a Ukrainian-built launch vehicle with a Russian upper stage that is launched from a mobile launch platform on the Equator in the Pacific Ocean to maximize its performance. A version of the same vehicle, designated Zenit-3SLB, entered service in 2008 from the Baykonur cosmodrome in Kazakhstan under the Land Launch brand.

International Launch Services (ILS) formed in 1995 as a joint venture between Lockheed Martin, Khrunichev, and Energiya. It originally sold commercial launches on the Atlas family of vehicles and the Proton. In October 2006, Lockheed sold its majority stake in ILS to a new venture, Space Transport, and retained commercial marketing rights for the Atlas 5. Space Transport sold its stake in ILS to Khrunichev in 2008. ILS continues to offer the Proton and plans to offer its eventual successor, the Angara, once it enters service.

Boeing withdrew the Delta 4 vehicle from the commercial market in 2003, citing poor market conditions, but continues to sell the smaller Delta 2 commercially for launches of NGSO spacecraft, such as commercial remote sensing satellites. Lockheed Martin offers only the Atlas 5 commercially, having retired older variants of the Atlas family earlier in the decade. SpaceX successfully flew its small Falcon 1 launch vehicle in 2008 and plans to launch the larger Falcon 9 for the first time in 2009.

Several companies also offer smaller launch vehicles intended for NGSO communications and remote sensing satellites as well as government spacecraft whose launches are procured commercially. These companies include U.S.-based Orbital Sciences Corporation, which offers the Pegasus and Taurus; Eurockot, a German-Russian joint venture that markets the Russian-built Rockot; and Kosmotras, a Russian company that offers the Dnepr, a converted SS–18 intercontinental ballistic missile. Arianespace also plans to market the Vega small launch vehicle currently under development by the European Space Agency (ESA).

Several other countries are interested in entering or reentering the commercial launch market. China, which offered commercial launches on its Long March family of boosters through 2000, exited the market when U.S. export control changes made the transfer of satellites to China for launch effectively impossible. China hopes to be able to reenter the market by providing launches for so-called ITAR-free satellites being developed by European manufacturers, notably Thales Alenia Space, and has won several launch contracts for such spacecraft in the last few years. Japan has expressed an interest in making its H–2A vehicle available to commercial customers. India has sold one commercial launch on its Polar Satellite Launch Vehicle to the Italian space agency for a small astronomy satellite and is seeking commercial orders for its larger Geosynchronous Satellite Launch Vehicle.

Suborbital launch services have traditionally been limited primarily to government markets, from scientific research to missile defense development. However, there has been renewed interest in commercial suborbital spaceflight, primarily for the emerging personal spaceflight (better known as space tourism) industry. SpaceShipOne, a piloted reusable suborbital spacecraft built by Scaled Composites, won the $10-million Ansari X Prize in 2004, helping generate interest in this market. Virgin Galactic has licensed the SpaceShipOne technology and is working with Scaled Composites to develop SpaceShip Two, which is beginning flight tests in 2009 Other entrants in this field include Armadillo Aerospace, Rocketplane Global, and XCOR Aerospace in the United States; PlanetSpace, a joint U.S.-Canadian venture; and Starchaser Ltd. in the United Kingdom.

Industry Sectors: Ground Equipment

Market Overview

Satellite ground equipment is an important component in the provision of satellite services. In the early days of satellite communications, ground equipment consisted of dishes dozens of feet in diameter supported by rooms filled with electronics, requiring budgets in the millions of dollars to build, maintain, and operate. Present-day technologies, such as very small aperture terminals (VSATs), miniaturized antennas, and microelectronics, have made DTH television and Internet services and satellite phones affordable and useful to a wide range of users. In the future, advanced technologies such as laser links and conformal array antennas will bring new capabilities to commercial and defense applications alike.

Ground equipment includes a broad array of devices and components used for satellite communications. Ground equipment can be divided into three major categories: Earth stations, VSATs, and consumer electronics. Earth station components include the equipment required for uplinking and downlinking transmissions to and from satellites and the equipment required to control satellites on orbit. Earth stations usually utilize large aperture satellite dishes capable of high bandwidth data transmission. VSATs provide businesses and other relatively high bandwidth users with flexible, transportable, and cost-effective satellite communications. Consumer electronics include devices employed by end users to receive satellite services for both mobile and fixed applications. In addition, GPS devices are also a part of this sector, using the military satellite signals for positioning by a varied user group. Table 6–2 describes these market segments and their applications.

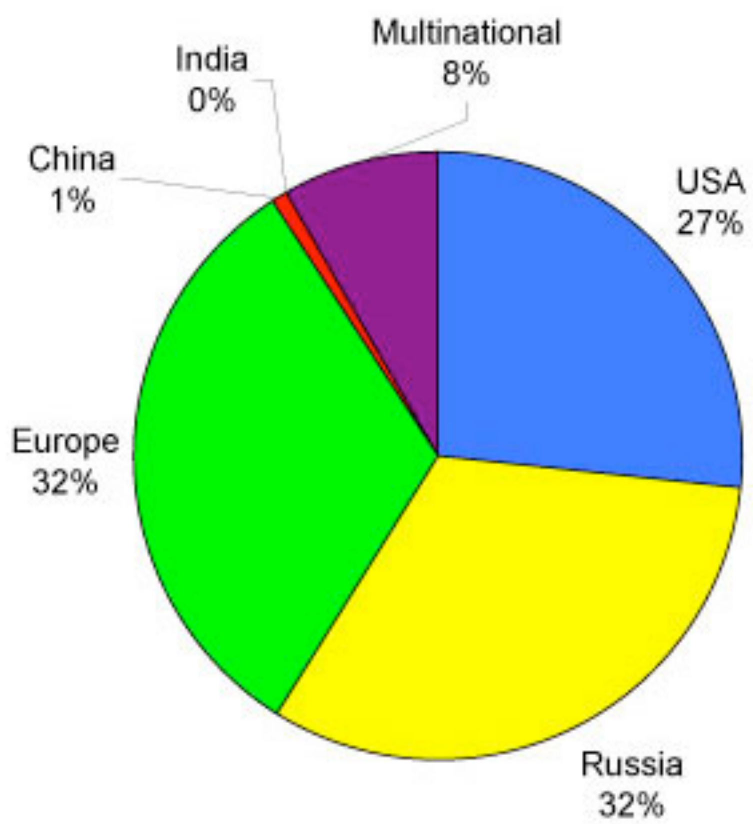
Table 6–2. Ground Equipment Market Segments

	Description	Applications	
Earth station	Stationary equipment utilized to receive, convert, and transmit data to and from satellites utilized primarily by satellite service providers.	Telephony and internet backbone, television broadcast, defense, etc.	High
Laser link & conformal arrays	Next generation technologies that allow for high bandwidth, mobile, and versatile satellite	For now, primarily aerospace and defense applications	
VSAT	Small transportable dishes that can be moved and installed quickly in widely dispersed and remote locations	News trucks, emergency response, oil and gas, rural telephony and internet, defense, etc.	Bandwidth
Consumer electronics	**Fixed:** Direct-to-home television dishes and set-top boxes, satellite phone booth, etc.	Satellite television/internet, disaster or remotely located communications, etc.	
	Mobile: Fleet management equipment, GPS receivers, hand-held satellite phones, and satellite radio equipment.	Global asset tracking, entertainment, personal voice communications, defense, etc.	Low

The large number of countries involved in producing ground equipment makes this segment of the space industry a truly global market. Hundreds of companies from many countries produce the wide variety of electronic components required to manufacture Earth stations and consumer electronics. The United States was expected to manufacture roughly 20 percent of the approximately 5,300 Earth stations that were to be produced in 2007.[6]

Revenues from the sale of ground equipment have grown for the last 8 years (see figure 6–9). Sales of ground equipment grew by over 19 percent during 2007 versus 2006. The biggest driver of this revenue growth is end-user equipment, particularly for key consumer services: satellite radio and DTH television. While prices for some ground equipment, such as VSATs, continue to decline, prices for consumer service–related hardware, such as satellite radio receivers, are increasing as new technology and capabilities are introduced.

Figure 6–9. Commercial Launch Market Share by Country, 1997-2001



Importance of Ground Equipment for National Security

Satellite ground equipment is an important component in the provision of satellite services for the military and other security personnel. Low-cost commercial-off-the-shelf satellite communications and navigation ground equipment has been effectively utilized by blue forces and enemy combatants in recent conflicts around the globe. These technologies also provide necessary support in homeland defense and crisis response situations, particularly when terrestrial technology options are hampered by the crisis situation. Users at the Federal (both military and nonmilitary agencies), state, local, corporate, and individual levels are all beneficiaries of advances in the commercial satellite ground equipment sector, though they must consider issues of communications interoperability to best use the technology. The development and deployment of advanced satellite ground equipment such as laser links and conformal array antennas could provide warfighters and crisis responders with increasingly decisive command, control, communications, and intelligence capabilities in the future.

The Next Space Age: A Commercial Space Paradigm

The world may already be witnessing the arrival of the next space age. Increased acceptance of high-risk commercial space business ventures as an element within an investment portfolio is one beginning. Space adventures such as personal spaceflight and the launch of private space habitats are another. The U.S. Government's commitment to purchase commercially produced space goods and services is yet another. Assuming success, these transformational changes will create new services and capabilities and greater interdependence among users, and thereby enhanced spacepower.

If these are indicators of a transition into the next space age, what signs might confirm the existence of a new paradigm for commercial space? How will the world know that its model of space commerce has permanently changed? Are such changes now observable? While the future is difficult to predict, certain observations might confirm a new paradigm.

One of the first signs of the new space age may be the way that space-related goods and services have become seamlessly integrated as a critical part of the human experience. Communications, navigation, weather, and satellite imagery are current applications affecting how people live on a daily basis. As barriers to entry fall and new space applications continue to increase our quality of life, the acceptance of space commerce as an investment opportunity, a business, and a career will become a naturally occurring human experience.

In the next space age, the commercial space industry will be an integral component of defense and civil space initiatives. Communications, GPS, weather, and remote sensing satellites are prominent examples of the growing interdependence identified in this chapter. Governments and private operators will seek to leverage commercially and strategically valuable space products and services. Whether private or government, space developers will consider all users in systems design and operations.

Also in the next space age, space technology will be ubiquitous and produced by many nations. The global manufacturing of satellite ground equipment is an example of what will exist more broadly in the next space age. Many of the current space-capable nations view themselves as commercial suppliers of space goods and services. New foreign space powers will utilize space in increasingly complex ways, creating competition for established space powers and for each other in a global economy. This competition will drive technology development, reduce prices, improve capabilities, decrease risk, and improve value for consumers.

Several actions must be sustained to continue to encourage and facilitate transition to a new commercial space paradigm. Government research and development, as well as funding for industry, serve as rich sources of technology and inspiration for entrepreneurs and must continue. After the first few nonclassical commercial space ventures succeed financially, transition to a new paradigm will accelerate, paving the way for new commercial opportunities.

As for assurance of success, the numbers favor a breakthrough. A large number of truly bold private business ventures currently exist. Furthermore, this is a global, not just an American, phenomenon. Commercial space is a largely unexplored and untapped frontier. However, the explorers and investors currently considering space ventures may not be the first to succeed; they have been preceded by the industry's pioneers who have already committed to advance into the next space age.

Future Projections and Implications for Spacepower

Since the beginning of this decade, the four broad sectors that together compose the commercial space industry—satellite services, satellite manufacturing, launch services, and ground equipment—have experienced market fluctuations that are related. The bursting of the 1990s telecommunications bubble proved to be a seminal event that adversely impacted all four market segments and whose effects continue to linger. The telecommunications downturn shattered expectations that demand for satellite services would grow indefinitely. This led to fewer new satellites being ordered than widely projected at the beginning of the decade, which has resulted in more competition for fewer contracts in the satellite manufacturing industry. Fewer satellite orders have meant fewer launches needed, causing a decline in the launch services sector relative to the late 1990s. And the resulting general stagnation in all of these areas has reduced future demand projections in the ground equipment segment to a certain extent. A new generation of financial owners also emerged, and their business decisions coupled with the slower market growth have also contributed to this market conservatism.

However, following an industry-wide shakeout, the worldwide commercial space industry has rebounded. Between 2002 and 2007, worldwide space industry revenues grew by 73 percent, from $71 billion to $123 billion. The explanation for this surprising growth lies in the satellite services and ground equipment segments. Although satellite services have not grown at the meteoric pace envisioned during the telecommunications heyday of the late 1990s, global Internet, DTH television, telephony, and data usage have continued to grow steadily, fueling solid demand that has boosted revenues each year. The value of the satellite services industry nearly doubled between 2002 and 2007, increasing from $35.6 billion to $73.9 billion. This steady growth has also increased the relative weight of satellite services as a component of the overall space industry. Satellite services accounted for 51 percent of industry revenue in 2002 but grew to 60 percent by 2007.[7]

Demand for satellite services, in turn, has sustained the growth of the ground equipment sector. Consumer demand for electronics to receive satellite radio and DTH video services has enabled the ground equipment sector to grow consistently each year in this decade thus far. In 2002, revenues for the ground equipment sector totaled $21 billion, increasing to $34.3 billion by 2007—an increase of 63 percent. This rapid growth in the satellite services and ground equipment markets has offset the comparative declines in the satellite manufacturing and launch services markets. As the former two markets have become linchpins for the sustained revenue growth of the space industry, the latter two have become relatively less of a factor, shrinking from 20 percent of total industry revenue in 2002 to 12 percent in 2007.[8]

The worldwide recession that began in 2008 and continues in 2009 will likely have an adverse, but delayed, impact on the commercial space industry.In the short term, backlogs from order completed prior to the recession can sustain the launch and satellite manufacturing industries.Meanwhile, satellite services and ground equipment will have become such a ubiquitous—if invisible—aspect of life that consumer demand will likely not begin to shrink significantly until the recession becomes especially prolonged. However, as unfavorable economic circumstances persist, the commercial space industry is likely to suffer the belated effects of the worldwide economic downturn.Many analysts predict that 2010 and 2011 may prove especially difficult years for the commercial space industry, with a significant flattening or contraction possible.

A downturn in the commercial space industry would have significant implications for spacepower.The existence of a commercial space industry outside of direct government spacepower efforts expands the range of spacepower options available to policymakers.If spacepower is ultimately about power projection—the ability to access and use space for strategic national needs and objectives and to deny adversaries that ability—then each of the four segments of the commercial space industry discussed in this chapter plays a key role in complementing the spacepower of the nation-state.

As the world moves into the 21st century, the possibility of asymmetric national security threats posed by terrorists or rogue states remains central to defense policymaking. In the U.S. space community, this has translated into efforts to ensure both traditional and responsive space capabilities that can deploy space assets with global effects on short notice. The U.S. Government continues to fund the development of vehicles designed for short launch turnaround times and maximum flexibility. Parallel to these efforts, the military is increasing research and development funding for smallsats, which promise to carry out many of the functions of larger satellites at a fraction of the cost.The U.S. Government is also promoting new technologies and markets through cash prizes such as the Centennial Challenges competitions, as well as initiatives such as the COTS agreements.These government-funded efforts to create an operationally responsive, comprehensive space capability will have increasing commercial implications. If the U.S. Government eventually permits nonsensitive technologies from these more agile vehicles and smaller satellites to be used commercially, payload functionality may be increased and launch costs may be lowered to the point where both the satellite manufacturing and launch services markets can be reinvigorated. Heightened focus on national security threats and growing reliance on the availability of multiple data sources have also led to an increase in the demand for satellite communications by deployed U.S. personnel, with a focus on innovations such as communications-on-the-move. This increase has a generally positive effect on the satellite services and ground equipment sectors, which provide additional communications capability to the government.

For the more immediate present and future, the commercial sector is enabling new markets largely without government assistance. The successful capture of the Ansari X Prize by Scaled Composites' SpaceShipOne vehicle in October 2004 demonstrated that private incentives could entice entrepreneurs to develop their own launch systems and other space technologies independent of government assistance. The U.S. Government, though, is also promoting these new markets through the Centennial Challenges competitions and the Commercial Orbital Transportation Services agreements. At the same time, the SpaceShipOne vehicle itself brought the prospect of suborbital space tourism one step closer to reality. Virgin Galactic and other suborbital space tourism companies are currently expected to begin service by 2010. Since the cost of a suborbital space tourism flight is projected to be several orders of magnitude cheaper than that of an orbital flight—an expected $200,000 versus $20 million—the number of suborbital space tourism flights per year may be in the low hundreds within the next decade. This emerging market, when realized, will likely have a significant impact on the structure of the space industry as a whole.

Advances in space technology will have an impact on the commercial industry as well as the space community. An example of a significant technology issue is the active lifespan of satellites. The lifespan of an average satellite ranges roughly from 5 to 15 years depending on the application. Low and medium Earth orbit satellites tend to operate for shorter life spans than GEO satellites, which have planned design lives of about 15 years. Extending the average life of all satellites could impact the industry in a variety of ways. Longer-life satellites will reduce the need for replacements to maintain the same amount of capacity, which would be financially beneficial, but there are related limitations. For example, if a satellite is designed for 20 years of service but has a defect that renders the satellite useless in 10 years, operators and insurers would face significantly increased losses. If satellites worked perfectly for 20 years but a new technology development rendered them obsolete, there would be financial losses. Long-life satellites may in general have trouble adapting to changing market conditions and innovative technologies.Conversely, making satellites with shorter lifespans may give an operator the ability to adapt to changing economic, technological, and political forces.The shorter lifespan could allow for a greater quantity of industry activity using the most up-to-date technology, but would require more launches and more satellites to meet the capability of a longer life satellite on orbit, potentially increasing total costs.

Another issue that could have effects on the commercial space industry in the future is the threat of hostile attacks against its assets, which would be detrimental to the industry.

The U.S. military has continued to increase its reliance on commercial space assets, particularly communications and remote sensing capabilities. This reliance leads to concerns about attacks on commercial assets that are being used, or are perceived to be used, for military purposes. Vulnerabilities exist in the space and ground segments as well as in the transmission and sensing of data—the entire commercial industry is vulnerable, though efforts have begun to strengthen commercial space defenses against attacks. Potential attacks could range from physical to electronic attacks that destroy, deny, or disable space capabilities. If commercial assets are targeted and rendered inoperable, their operators will incur financial losses. Satellite operators who avoid working with the military may still have their assets targeted, and the consequences of attacks on noncommercial assets—for example, orbital debris—could affect commercial assets. If commercial assets are targeted, the military may be more inclined to build their own hardened spacecraft rather than purchase services from industry, meaning there will be significant consequences for the overall commercial industry.

Space activity itself is not a major economic force, but it is a potent economic enabler and a critical component of any nation's infrastructure. For example, timing signals from the GPS constellation are utilized by banks and other financial institutions around the globe to keep financial systems synchronized. Satellite communications systems facilitate the global communications necessary for international banking and commerce. The news and entertainment industries are also dependent on satellite capabilities. Overall, the globalized economy relies heavily on satellite technology and infrastructure.

The implications of these current and future commercial space industry trends for spacepower theory are best understood as they pertain to space assets. In all four market sectors that define the industry, any U.S. advantages that exist are being reduced by competition from European and Asian organizations. In the satellite services and ground equipment segments, U.S. commercial firms have the most advanced technologies and a stable customer base. The potential customer base and content demand in the European and Asian markets, though, suggest that the services sector will continue to grow in these locations. Similarly, new Asian entrants to the satellite manufacturing and launch services markets—particularly China and India—signal that other nations will increasingly compete with the United States in space technology and hardware.

Moreover, as American export restrictions increasingly encourage other nations to collaborate in order to achieve their space goals outside the framework created by the United States, it is reasonable to assume that the United States will continue to lose market share and related technological advantage. Given these realities, the ultimate solution for the United States to achieve its spacepower objectives may lie in some combination of U.S. military investments in cutting-edge technologies coordinated with incentives that more fully align the commercial space industry with strategic spacepower goals or a return to the public-private partnerships that established the industry.

The commercial industry is a critical part of national spacepower. It provides capabilities not only commercially as a major part of the global economy but also for government use. Market forces and the business environment often drive the industrial landscape, but incentives and impediments from the government also provide significant influence. As such, when a nation is developing its spacepower, it must realize that its policies can affect the commercial industry with positive and negative results regarding national interests and the future of the space industry.

Notes

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6. InfoCom and SagaTel, Global Telecommunications Markets and Forecasts for 2003–2007 (Stuttgart: InfoCom GmbH), 38.
7. Satellite Industry Association and Futron Corporation, *State of the Satellite Industry Report*, June 2008, available at <www.futron.com/pdf/resource_center/reports/2008SSIR.pdf>.
8. *Ibid., 7–8.*

Chapter 7:

Merchant and Guardian Challenges in the Exercise of Spacepower

Scott Pace

Over 20 years ago in a speech at Moscow State University, President Ronald Reagan noted the implications of space-based information technologies: "Linked by a network of satellites and fiber-optic cables, one individual with a desktop computer and a telephone commands resources unavailable to the largest governments just a few years ago. . . . Like a chrysalis, we're emerging from the economy of the Industrial Revolution."[2]

The linkages between space, information technologies, and the global economy have accelerated and become even more profound with the widespread use of global positioning system (GPS) technologies and remote sensing imagery and the deeper integration of satellites with terrestrial communications networks. Traveling toward the Earth from deep space, one encounters whole fleets of satellites in geosynchronous and polar orbits that feed and transfer information to their commercial, military, and scientific users. Even a few educational and hobbyist payloads are in orbit or hosted on other spacecraft.

Given the scope and diversity of these space systems, it is impossible to imagine the modern global economy—not to mention modern U.S. military forces—functioning without them. This dependency in turn has led to concerns about potential attacks against space systems. While media and academic debates focus on the prospect of weapons in space—in particular, the offensive application of force from space—in actuality, existing or even prospective military capabilities are nonexistent.[3] Instead, the United States has focused on improving space situational awareness, defensive counterspace (that is, protecting friendly space capabilities from enemy attack or interference), and repairing military space programs that have encountered cost, schedule, and technical difficulties.

Spacepower has been a difficult concept to define even with a half-century of global experience with space flight and operations. Although the topic has been raised in professional military circles for decades, space-based forces lack widely accepted military doctrine, which is not the case for land, sea, and air forces. Part of the challenge is that space systems do not directly represent "hard" or traditional military capabilities. Rather, space systems enable these capabilities. Space systems tend to represent or imply other capabilities that may have great political significance (for example, the Soviet demonstration of its intercontinental ballistic missile [ICBM] capabilities with the launch of Sputnik and the U.S. demonstration of precision strike using GPS in the first Gulf War). These capabilities take time to comprehend and understand. Even purely civilian space activities, such as the Apollo missions to the Moon or the creation of the International Space Station, can be forms of spacepower. They shape and influence international perceptions of the United States, even though they have no direct relation to

U.S. military capabilities. Finally, the ability to design, develop, and deploy space systems is also a form of economic power. Not only can U.S. entities create the hardware and integrate the systems, they also have the business management skills needed to raise funding in open markets across international boundaries.

The use of space today reflects the full range of national and international interests, and its use tomorrow likely will reflect those same interests. If humanity succeeds in expanding civilization beyond Earth, what will be the values and the national and international interests that shape the expansion? Spacepower is not the same as, and need not imply, space-based weapons (which do not exist). Nor can spacepower be considered a purely symbolic concept given the criticality of space to military and economic systems. As will be argued, spacepower will be shaped and defined by national security and commercial objectives, and more generally by the competing and cooperating interests of the public and private sectors.

What is Spacepower?

In an analogy to airpower and seapower, the term *spacepower* would seem to imply the employment of military forces operating in a distinct medium (the space environment) to achieve some national goal or military objective. A decade ago, U.S. Air Force doctrine defined *spacepower* as the "capability to exploit space forces to support national security strategy and achieve national security objectives."[4] It also defined *air and space power* as "the synergistic application of air, space, and information systems to project global strategic military power." These definitions were criticized as incomplete, as they did not capture important realities of existing and potential military space activities.[5]

First, there was the implied assumption that the identification of military space forces alone provides the necessary and sufficient conditions for understanding the strategic power of the Nation with respect to space. Yet the reality of modern space activity is that civil and commercial systems also play an important role in the Nation's space capabilities and affect their ability to achieve national security objectives. Partnerships between military, civil, and commercial communities are vital to the successful execution of national and military security strategies (for example, communications, environmental monitoring, and logistics). Thus, spacepower should be understood as more than military forces. As General Hap Arnold said of airpower: "Airpower is the total aviation activity—civilian and military, commercial and private, potential as well as existing."[6] The same thought can and should be applied to a complete definition of spacepower.

Second, the definitions implied that spacepower was focused on "global" and "strategic" concerns alone. This is understandable, as national security space capabilities (including military and intelligence uses) have historically been thought of as enabling strategic functions for nuclear operations and national-level intelligence collection, for example. This is, however, an overly narrow view that became outmoded by the first Gulf War. Through the 1990s, space capabilities were becoming increasingly visible and vital to military operations. They assisted in the execution of hostile actions but also played a role in peacekeeping and humanitarian relief. Consequently, space forces were recognized as more than a tool for achieving strategic global objectives, as was the case during the Cold War. They became an integral part of how U.S. forces operated across the spectrum.

Third, the definitions gave the impression of being taken at one point in time—that is, at the instant during which power is being projected in support of a national objective. Power can be thought of as the ability to not only employ forces but also to shape the battlespace before the initiation of conflict. As with other forms of national power, both absolute and relative capabilities are important: what are my forces capable of doing, and how do they compare with those of potential adversaries? Since space-power is more than military forces alone, it should be understood as something that can evolve. The ability to shape the actions of others may be as significant as what can be accomplished unilaterally.[7]

As with any evolving military field, one can expect intense debates over doctrine. Like the emergence of airpower and seapower, spacepower is both similar to and different than other forms of military and national power. As the following examples illustrate, spacepower has many different facets depending on one's perspective and objectives. From the viewpoint of the tactical commander, spacepower represents capabilities that can help put "bombs on target." To the regional commander, spacepower represents capabilities that shape the entire battlespace, including the provision of logistical support and the use of joint and combined arms. The regional commander's view is broader than the lower level commander's view.[8] From the viewpoint of the President and Congress, the battlespace is only one of several areas of concern. Domestic political support, relations with allies and coalition partners, and economic conditions also must be considered. Spacepower, therefore, is connected to other forms of national power, including economic strength, scientific capabilities, and international leadership. National leaders may use military spacepower to achieve nonmilitary objectives or exploit nonmilitary capabilities to enhance military spacepower.

An assessment of spacepower should include all of the Nation's space capabilities, at all levels and timeframes, even in peacetime before conflict begins. In this regard, spacepower would be more properly defined as *the pursuit of national objectives through the medium of space and the use of space capabilities*.[9] Although broad and general, this definition focuses on national objectives, the use of space as a medium distinct from land, air, or sea, and the use of space-based capabilities. The effective exercise of space-power may require, but is not limited to, the use of military forces.

More recent Air Force definitions of spacepower have become more inclusive:

> Space power. a. The capability to exploit space forces to support national security strategy and achieve national security objectives (Air Force Doctrine Document [AFDD] 1). b. The capability to exploit civil, commercial, intelligence, and national security space systems and associated infrastructure to support national security strategy and national objectives from peacetime through combat operations (AFDD 1–2). c. The

> total strength of a nation's capabilities to conduct and influence activities, to, in, through, and from space to achieve its objectives.[10]

The first definition is a traditional, military-focused one, while the second includes use of nonmilitary capabilities to achieve national security objectives. The third definition refers to the total strength of the Nation. However, there are no definitions that refer to using nonmilitary capabilities to shape the environment before conflicts occur or using military capabilities to advance nonmilitary national objectives. This chapter focuses on the nature and uses of spacepower at strategic and policy levels in both military and nonmilitary applications.

Schools of Thought in Space Advocacy

Pioneering space advocates, such as Wernher von Braun, readily adopted the idea that government can and should fund space work. In a series of articles for *Collier's* magazine in the 1950s, von Braun sketched out his vision for space development. First came orbiting satellites, followed by manned reusable vehicles, then a space station, bases on the Moon, and finally an expedition to Mars. The color drawings were vivid and realistic, and the magazine was inundated with inquiries on how one could become an astronaut. The "von Braun paradigm" of space development—represented by the step-by-step creation of reusable shuttles, space stations, lunar bases, and Mars expeditions—seemed so logical and direct that it continues to hold sway years later.[11] Over the past few decades, reports recommending future space activities have repeatedly endorsed these same basic elements, building progressively more complex capabilities on the basis of government-funded research.

Disappointment with the ending of the first lunar explorations and reduction in National Aeronautics and Space Administration (NASA) spending in the 1970s led space advocates to form educational and advocacy organizations, including the National Space Institute and the L5 Society. The latter was particularly interesting in that it did not advocate a variation of the von Braun paradigm but rather envisioned creating large settlements in free space, mining the Moon and asteroids for resources, and constructing solar-power satellites to beam energy back to Earth. In reaction in part to the "Limits to Growth" arguments, which predicted a looming disaster due to overpopulation, accelerated industrialization, malnutrition, dwindling resources, and a deteriorating environment, these advocates saw space as a means to adventure and a solution to environmental and natural resource problems on Earth.[12] American space advocates typically shared the view that human expansion into space was both desirable and inevitable. This new form of manifest destiny was consistent with U.S. history. The frontier always has been viewed as a utopian wilderness, ripe for satisfying various philosophical and emotional needs, while at the same time being subject to extensive military and economic government interventions to meet those needs.[13] Examples of government interventions on the frontier include land grants, support for education and transcontinental railways, and the use of the Army to protect settlers and traders.[14] In contrast to the westward expansion across North America between 1800 and 1890, however, much more substantial technical, economic, and political constraints exist that hinder space development. These constraints quite literally create higher barriers to entry. This has prompted some advocates to support greater government spending, while others have looked to private enterprise to "open the frontier."

In the 1980s, President Ronald Reagan called for a Strategic Defense Initiative to use space weapons to defend the Nation from ballistic missile attacks. Multiple groups formed educational organizations, such as High Frontier, to support space development as part of a stronger national defense. In a variation on the von Braun paradigm, advocates supported the creation of massive launch systems and a space infrastructure to support a global defense network. With this infrastructure in place, other space activities, such as mining the Moon or sending probes farther into the solar system, would become easier and more affordable.

A common thread running through the various "post-Apollo" visions was the need for a revolutionary effort, like Apollo, to meet some overarching goal. In some cases, the motivation was to solve an energy crisis; in others, it was to defeat a military threat. The L5 Society thought that space could be colonized by a large number of people who could create whole new societies and earn their way through exports of energy back to Earth. But even they saw the need for government involvement and leadership to start the process. While the details may vary, the fundamental rationale for a national-level space effort has remained unchanged. The Nation pursues space as a way to secure scientific knowledge, security, international cooperation, and other benefits to humanity.

Meanwhile, new commercial space capabilities grew independently of the government, and now commercial investment exceeds government spending (civil and military) on space.[15] Rather than a government-driven, revolutionary development, the growth of space commerce has been largely a market-driven, evolutionary one. Given the cost of access to space, it is not surprising that the primary "cargo" now being transported between Earth and space is massless photons carrying bits of data. But these bits are part of a larger global information infrastructure that has created a new "skin" for the planet. Some of this skin is buried under the sea and underground in cables; some of it is composed of microwave relays and cellular phone networks; and some of it is in orbit, consisting of communications, GPS, and remote sensing satellites. Some of these satellites are purely commercial, while others are government-owned but used by private companies for commercial applications. The term *dual-use* in space systems, therefore, encompasses both "civil-military" and "public-private" applications.

The growth of commercial space capabilities calls attention to the interplay between public and private interests in dual-use space technologies, which include launch services, communications, navigation, and remote sensing. These technologies have great potential to shape which national capabilities actually occur and whether American interests are advanced or harmed as they are adopted in global markets. In contrast to when the von Braun paradigm was created, the size and scope of commercial space activity are immense. Events such as SpaceShipOne's 2004 suborbital flight and Bigelow Aerospace's 2006 demonstration of an inflatable structure in space, and private financing of new launch vehicles, such as SpaceX's Falcon, indicate the increasing sophistication of space entrepreneurs. The combination of well-established industries and dynamic new entrants is creating opportunities for governments as well. The Defense Department hopes to use the Falcon launch vehicle for small payloads, and NASA hopes to buy commercial launch services to support the International Space Station after the administration retires the space shuttle in 2010. Public interest in space tourism was not created by government policy; private citizens have expressed a desire to travel to space and have spent millions of dollars of their own money for the privilege. This interest could some day evolve into a viable market that will attract entrepreneurs, who in turn may create capabilities that governments can use without having to pay for their development.

Single government projects by themselves may be vital, but they are not always interesting or indicative of future challenges. Many commercial activities rely on government policies and actions, but they are independent of government command or direct control. Markets, funding, and even technologies are almost completely international. Government spending, while still dominant in many space markets, is not as important or even as attractive as it once was. As a consequence, it is insufficient to focus only on government space programs and budgets. Space analysts and policymakers need to address the more subtle relations between government actions and private markets. New schools of thought are needed that recognize a greater role for the private sector in creating and sustaining capabilities relevant to the Nation's spacepower.

Two Cultures: Merchants and Guardians

The scope and size of public-private interactions in space have implications for space doctrine, advocacy, and policy. Some of these interactions arise from debates over the choice of mechanisms, markets, or governments for accomplishing some objective.[16] For example, to what extent should the government rely on commercial space services, such as communications satellites or expendable launch vehicles? To what extent should the government provide space-based navigation and environmental monitoring services, which have commercial applications? Other interactions concern the competitiveness of commercial capabilities and how their viability affects choices by foreign governments. For example, can the proliferation of ballistic missile technologies be discouraged by the availability of low-cost launch services? What restrictions should be applied to private remote sensing activities if a country objects to having its territory imaged? Finally, some interactions affect common needs, such as international security, global trade, and even the radio spectrum. Does the widespread availability of Earth remote sensing data enhance regional stability? What restrictions, if any, should apply to sales of launch services from nonmarket economies? How should the use of the radio spectrum by public safety and national security organizations be protected from commercial interests and vice versa?

Public policy choices, whether those of the U.S. Government, foreign governments, or the international community in general, are subject to many distinct influences. Perhaps the most pervasive influences, however, are the underlying assumptions the public and private sectors bring to these choices. These assumptions constitute what has been termed as two cultures, those of the *Guardians* and those of the *Merchants*.[17] The term *Guardians* comes from Plato's *The Republic*. It includes members of the political class who are responsible for governing and teaching. In space policy, one finds many examples of Guardians, good and bad, among career civil servants, military officers, political appointees, congressional staff, journalists, academics, and even the occasional corporate officer and professional politician. The term *Merchants* refers to the group of people whose culture encourages energy and risk-taking. Although examples are mostly found in business and to a lesser extent in international science, they sometimes are represented in government, the military, and academia.

Merchant behavior is found in peaceful competition; contracts and the ability to work with strangers are accepted as normal parts of commerce. People divided by language, ethnicity, and distance will come together in a marketplace, if nowhere else, to trade. Relationships need not be permanent, outside of family, but rather flexible and transitory as necessary to make mutually beneficial deals. This flexibility creates opportunities for social movement, the absorption of immigrants, and invention. The motto "city air is free air" arose in the Middle Ages. It recognized a society free from the restrictions imposed by nobility and the church.

The role of Guardians is to protect some larger goal or system, such as society, the government, or a political philosophy. As a consequence of their public functions, Guardians are expected to be loyal, obedient, and disciplined. To avoid corruption and treason, they are enjoined from engaging in trade. To ensure that political decisions are carried out, they must respect hierarchy and the decisions made by recognized authorities. These are not necessarily modern or Western concepts. The samurai of feudal Japan were forbidden to engage in trade, just as tradesmen were forbidden to own weapons. One of the main features of a functioning government is an effective monopoly on the exercise of force. This monopoly enables Guardians to carry out other state functions. They can impose and collect taxes, establish rules and regulations, and negotiate agreements with other states.

The roles of Guardians and Merchants are in tension, but intimately linked. For the "invisible hand" of Adam Smith's market economy to function, a predictable, supportive environment must exist to create wealth. The creation and maintenance of such an environment requires the use of government power as the hidden (or sometimes overt) fist to enable the rule of law. Ideally, the need for actual force is minimized when the consent of the governed is secured via a democratic process. Whether by diplomats or soldiers, it is government power that establishes justice and provides for the common defense. Even the staunchest advocates of limited government recognize the need for preventing cases of force (by protecting against criminal violence or military aggression) and fraud (through enforcement of contracts). Thus, the key characteristics of the West—democracy, a liberal, pluralistic civil society, and capitalism—are shaped by the competition and cooperation of Merchant and Guardian cultures.

While both Guardians and Merchants may be necessary to society, they can create serious problems when they either fail to do their duty or seek to take on the role of the other. In space policy, these problems arise when the government conducts space transportation and communications or other commercial-like activities. Similarly, conflicts occur when the government does not carry out its duties and inhibits industry. Failing to uphold regulations or respond to complaints of unfair competition from foreign governments is a good example. Conversely, Merchants should not be made responsible for Guardian functions. For space activities, these can mean the enforcement of export controls, the negotiation of international spectrum allocations, or even the conduct of crucial military functions (for example, missile warnings). This is not to say Merchants cannot be patriotic or reliable, but their functions require the public service traits of a Guardian culture.

It has been said that the environments of business and government are alike in all the unimportant ways. Civil servants and businesspeople may use the same telephones and office software, occupy similar offices and parking spaces, read the same newspapers, and even attend the same churches. But their daily work and worldviews are likely alien to each other. Businesspeople in foreign countries are likely to speak a common cultural language, just as civil servants and soldiers find common touchstones with their foreign counterparts. Conversations across these separate cultures can avoid mutual incomprehension if they first recognize that they possess distinct worldviews and personalities.

"Merchants and Guardians" in the 21st Century

In the 10 years since the original presentation of the "Merchants and Guardians" paper,[18] several dramatic events have occurred, notably the 2001 attacks on New York and Washington and the global war on terrorism, the 2003 loss of the space shuttle *Columbia*, and President Bush's 2004 speech on the "Vision for Space Exploration." Over the same period, conditions in the commercial space industry have evolved greatly. Space-based information systems have continued to grow, with direct TV, direct audio broadcasting, and ancillary terrestrial components to mobile satellite services (MSS) filling in for the collapse of overly optimistic MSS expectations. After emerging from bankruptcy, Iridium and Globalstar are today serving customers worldwide. A new generation of better financed entrepreneurs is developing suborbital and orbital launch vehicles and Soyuz-based tourist flights to the International Space Station. The provision of these services has become a familiar, if not routine, occurrence. The prospects of space tourism are being taken more seriously, and as a result, commercial space ventures are starting to progress beyond the movement of photons (information) and into the movement of actual mass, including people.

The most significant event for the civil space sector was the loss on reentry of *Columbia* on February 1, 2003. As in the case of the *Challenger* accident, the tragic loss of the crew and one-fourth of the Nation's shuttle fleet led to a deep reexamination of why the United States was risking human lives in space. In the aftermath of *Challenger*, President Reagan directed NASA to use the space shuttle only to launch those satellites that could not use commercial launch services. Human lives would not be risked to perform tasks that could be done just as effectively by unmanned rockets. This action also eliminated the shuttle as a source of government competition to commercial suppliers and helped to jump-start a viable commercial launch industry.

In the aftermath of the tragedy, the *Columbia* Accident Investigation Board (CAIB) criticized NASA not only for the technical failures leading to the accident, but also for a lack of national focus and rationale for risking human life. In its report, the CAIB observed that there had been a "lack, over the past three decades, of any national mandate providing NASA a compelling mission requiring human presence in space."[19] So while the *Challenger* accident resulted in a decision forbidding the risking of human life for certain purposes, the *Columbia* accident raised the question: for what purposes was human life worth risking? These questions sparked internal White House discussions during the fall of 2003, which were expanded to include NASA and other agencies.[20] The answer was provided in President Bush's January 14, 2004, announcement at NASA headquarters of a new "Vision for Space Exploration." With the completion of the International Space Station, the shuttle program would end in 2010, and a new generation of spacecraft would conduct a "sustained and affordable human and robotic program to explore the solar system and beyond."[21] If human lives were to be placed at risk, the potential gain would be commensurate and require explorations beyond low Earth orbit.

Congress later endorsed the objectives of the President's speech in the passage of the 2005 NASA Authorization. After a prolonged start-up phase in 2004, as NASA considered a range of technologies and options to fulfill the direction of the President and Congress, work accelerated with the arrival of Michael Griffin as the new NASA administrator in April 2005. He summarized the proposition of the "Vision for Space Exploration" in a speech before the National Space Club on February 9, 2006:

> We assume risk in human spaceflight because leadership in this endeavor is a strategic imperative for the United States. . . . Our Nation needed to decide whether the goals and benefits of human spaceflight were commensurate with the costs and risks of this enterprise, and that for this to be true, those goals must lie beyond the simple goals achievable in low-Earth orbit. . . . The Agency is directed to "establish a program to develop a sustained human presence on the Moon, including a robust precursor program, to promote exploration, science, commerce, and United States preeminence in space, and as a stepping stone to future exploration of Mars and other destinations". . . . We will do these things in concert with other nations having similar interests and values. And, as we look forward to the events that will define this century and beyond, I have no doubt that the expansion of human presence into the solar system will be among the greatest of our achievements.[22]

During 2005, NASA defined its architecture for returning humans to the Moon. The agency designed a new generation of launch vehicles for taking humans and cargo to space, including a heavy-lift cargo launcher that would play a vital role in sending humans to Mars. In contrast to the von Braun paradigm, NASA's exploration plans build new capabilities gradually and incrementally to adapt to changing budget priorities. In essence, it is a "go-as-you-pay" philosophy. These plans also make more intentional use of commercial capabilities. The largest single example is the $500-million Commercial Orbital Transportation Services (COTS) program to help develop commercial sources of crew and cargo services for the International Space Station. In August 2006, NASA selected SpaceX and Rocketplane Kistler to develop and demonstrate their vehicles with partial NASA support. Under the Space Act Agreements, the work will be performed before a competitive award of service contracts. If successful, commercial suppliers could help support the International Space Station after NASA completes the shuttle assembly missions. They also could provide alternatives to the use of foreign launch systems. This would in turn free up the shuttle's planned follow-on systems, including the Crew Launch Vehicle (Aries) and Crew Exploration Vehicles (Orion), to support lunar operations.

The "Vision for Space Exploration" is an example of the use of space-power to achieve national objectives. While the NASA effort is exclusively civil, the capabilities created have the potential to advance U.S. economic, foreign policy, and national security objectives. The process of creating new technologies and systems to operate routinely on the Moon will enable the Nation to venture farther into the solar system—exploring, using local resources, learning new skills, and making new discoveries. In the broadest sense, the "Vision for Space Exploration" is not about repeating Apollo. In the words of the President's science advisor, John Marburger, it seeks to "incorporate the Solar System in our economic sphere."[23] Thus, the civil space strategy chosen by the United States can be seen as an effort to advance national interests of a Guardian culture, while using the narrower interests of a Merchant culture. Commercial capabilities strengthen the Nation's space abilities; they also deepen the Nation's interest in securing and protecting any resulting economic benefits.

U.S. national space policy has routinely recognized three distinct sectors of space activity: national security (military, intelligence), commercial, and civil (including both scientific research and services, such as weather forecasting).[24] The functions performed by each can be organized along a spectrum, depending on whether they are driven by governments or markets. Satellite communications occupy one end of the spectrum and are largely driven by commercial interests, such as numbers of customers, revenue, and the deployment of new technologies. At the other end are force applications that include space-based weapons and ballistic missile defense systems. Although they may use commercially derived technologies, they are driven by political-military requirements. In the middle are civil government functions that involve public safety. These include weather monitoring and navigation. These positions are not static; they can change over time. For example, GPS was developed to meet military requirements, but civil and commercial entities developed many useful applications of the technology. Space launch capabilities are considered to underlie all space activities and are thus a primary concern for all sectors.

Government and commercial interests in space technologies, systems, and services can intersect. They can be categorized in three segments. First, there are those that only the government would require due to their associated high costs or specialized nature.

Examples include space-qualified fission-power reactors and space-based observatories. Interactions are at government direction, mainly through contracts and grants. Second, there are segments dominated by the private sector due to the size of global markets and diffusion of underlying technologies. Examples of this segment include information technologies and biotechnologies. Governments are important for a variety of purposes but do not exercise control. Interactions can be more commercial-like, particularly where the government is another customer or partner. Third, there are gray areas, namely launch services, navigation, and remote sensing. The government is crucial, but not dominant. In these cases, the government may play the role of the research and development patron, anchor customer, service provider, and regulator. It is in these gray areas where the Merchant and Guardian cultures are more likely to clash because of evolving and changing roles. Such clashes can be expected to continue as human activity expands beyond low Earth orbit.

In its major outlines, U.S. space policy has remained remarkably stable since the end of the Cold War. The 2006 National Space Policy of the Bush administration can be seen as a continuation of the 1996 National Space Policy of the Bill Clinton administration, which in turn continued many of the themes of the 1989 National Space Policy of the George H.W. Bush administration. Much of the media commentary after the release of the 2006 policy focused not so much on substance as on presentation and tonal differences, particularly with respect to U.S. national security interests. Foreign governments expressed concern with the new policy, which prompted State Department Under Secretary Robert Joseph to state:

> At its most basic level, U.S. space policy has not changed significantly from the beginning of our ventures into space. Consistent with past policies, the United States does not monopolize space; we do not deny access to space for peaceful purposes by other nations. Rather, we explore and use space for the benefit of the entire world. This remains a central principle of our policy. What the new policy reflects, however, are increased actions to ensure the long-term security of our space assets in light of new threats and as a result of our increased use of space.[25]

In addition to stressing increased U.S. reliance on space assets and clarifying what the new policy did not mean, Joseph tried to bring attention to items that were novel: "The new policy also gives prominence to several goals only touched upon in previous policy documents, including: strengthening the space science and technology base, developing space professionals, and strengthening U.S. industrial competitiveness, especially through use of U.S. commercial space capabilities."

Not surprisingly, these are areas of great common interest for the public and private sectors and areas of friction between the Merchant and Guardian cultures. In addition, the 2006 policy included the need to assure "reliable access to and use of radio frequency spectrum and orbital assignments," which is a logical corollary to ensuring access to the space assets themselves. One cannot run wires to satellites; therefore, spectrum access and protection are of crucial importance, perhaps second only to the launch itself.

A comparison of the 1999 discussion of "Merchant and Guardian" policy conflicts with those seen today reveals many recurring issues. Spectrum management and the burden of export controls remain important, while concerns about competition from nonmarket economies seem to have abated—perhaps as a side effect of continuing export control limitations. However, there is increased interest in space tourism and related regulations, particularly with the 2004 flight of SpaceShipOne and the 2006 coverage of space tourist Anousheh Ansari. The prospect of commercial involvement in lunar operations, in addition to commercial supply of the International Space Station, has led to renewed discussions of private property rights on the Moon and other celestial bodies (to be discussed below).

In recent years, the national security space sector has not experienced developments as outwardly dramatic as those occurring in the commercial and civil space sectors, which have included everything from major accidents and Presidential initiatives to mass media interest. However, the implications of these developments to national security space are just as important, if not more so, for the Nation's spacepower. The past decade has seen a growing concern with the ability of the Defense Department to develop and deploy space systems on time and on budget. Difficulties with major missile warning, communications, and imagery programs, just to name a few, have been widely reported in the press, although specific details are usually highly classified. Even relatively mature programs, such as GPS, have faced difficulties keeping to modernization schedules due to changing requirements, contractor difficulties, and gaps in system engineering expertise. So severe are these difficulties that the U.S. Air Force is reportedly considering "hiring outside engineers or consultants to oversee systems integration of its next-generation navigational satellites."[26]

In fact, most of the new initiatives in the 2006 National Space Policy address four areas now considered to be serious problems for the U.S. Government: developing a high-quality cadre of space professionals, improving development and procurement systems for space systems, enhancing interagency cooperation, and strengthening the space science, technology, and industrial base.[27] Thus, while international media coverage painted the United States as taking a more aggressive military posture in space, the substance of the policy reflected problems in military acquisition programs that in turn stem from deficiencies in government management and contractor capabilities. It is not so much a question of which military capabilities the United States *wants* to deploy in space, but rather which capabilities it *can* employ, and whether they are commensurate with the threats and critical dependencies faced by the United States. Rather than the deployment of space-based weapons, as was contemplated during the Cold War, the immediate concerns of the military space sector are more basic. Can the military deliver space-derived services to deployed forces? Can it improve space situational awareness? And can the military get acquisition programs under control?

The organizational challenges for U.S. military spacepower are formidable and too extensive to be treated in this chapter. However, as with all other parts of the national security community, the attacks of September 11 and the conflicts in Afghanistan and

Iraq have affected U.S. spacepower in three important areas: capabilities, objectives, and relations with allies and partners.

First, space capabilities have been and will continue to be crucial to almost all types of military operations, in all regions, and at all levels of conflict. That said, fiscal and technological limitations make it impossible to create space capabilities ideally suited to all conflicts in all regions, and choices must be made in what to buy and field. This in turn requires choosing among different U.S. military strategy objectives and the consequent force infrastructure to implement that strategy. Prosecuting a conventional conflict against one or more states, up to and including a peer competitor,[28] is very different than fighting nonstate actors, rebuilding failed states, and carrying out operations other than war. Uncertainties over strategy objectives create tensions between funding development and operations, between competing technologies, and between which armed services, contractors, and parts of the industrial base should receive resources and attention. It would be easier if the United States could afford two different but interoperable force structures. However, it cannot, and space systems are caught in the debate over objectives.

Second, unrelated to the September 11 attacks, the U.S. defense industrial base has experienced a dramatic consolidation since the end of the Cold War. On one hand, U.S. defense spending is very large—by some estimates almost half of global total spending.[29] On the other, like all U.S. industries, defense and space firms have been affected by globalization. New international competitors, increased competition for talent, and concern over market access have become issues. The size and sophistication of U.S. military capabilities, in particular the use of space systems, has made it difficult for all but a few countries (such as the United Kingdom, Australia, and North Atlantic Treaty Organization members) to operate easily with U.S. forces. The problems of the U.S. space industrial base cannot be solved by going outside the United States, even if the country wanted to. Comparable sources for the capabilities that the United States needs simply do not exist.

Third, given the divergent but overlapping interests of Merchant and Guardian cultures engaged in space activity, uncertainty over national security objectives, and challenges to the creation of military space capabilities, it is increasingly important that the United States find partners to help shape the global environment before conflict occurs. Potential partners include public and private actors, international civil agencies, and foreign militaries. Shaping the environment means creating mutually beneficial relationships to reduce unintentional as well as intentional threats to crucial space dependencies. Examples include international protection of the space spectrum from interference, effective international enforcement of missile proliferation controls, promotion of common protocols to enhance interoperability of space-based communications, remote sensing and navigation services, and rules for international trade in space-related goods and services. While these steps may benefit foreign countries and companies, they would be even more beneficial to the United States given the country's reliance on space for economic stability and security.

One of the newer and perhaps more difficult areas of conflict between Merchants and Guardians will be that of protecting commercial space infrastructure. As the U.S. military and economy rely more heavily on space, it is natural to worry about potential threats to the infrastructure, just as one might worry about critical ground-based infrastructure. Yet what can or should be done to protect those assets? Should they be hardened or made redundant? Should they carry sensors to warn of attack? Should the protected entity pay for the protection, or should the U.S. Government provide the enhanced security as a public good and cover the costs with tax money? What about internationally financed space infrastructure, which is practically everything commercial in orbit? It is easy to imagine the commercial sector resisting what it would perceive as new regulatory burdens or an "unfunded mandate." Likewise, it is easy to imagine the Defense Department's reluctance to absorb new costs when existing programs face difficulties. Yet the result for failing to protect these assets may be increased vulnerability of the United States and a threat to its ability to exercise spacepower.

To summarize, events over the past several years have accelerated and intensified trends observed in the 1990s. They have shaped public and private sector interactions in space. As a result, leading challenges to the Merchant and Guardian relationship now include:

- globalization and the characteristics of a "Flat World." This means that technology, capital, and talent move ever more freely and can create competitors to government programs.[30] This is true even in the space world, with American tourists flying on Russian rockets, with small satellites being built from Surrey to Bangalore, and with European-Chinese collaborations to build constellations of navigation-satellite systems.
- increased government dependence on commercial space capabilities. This has created new concerns, in addition to traditional government resistance to the loss of control over independent commercial space markets.
- a recognizable loss of government "intellectual property" necessary to develop, oversee, and manage complex space systems. NASA is somewhat better positioned than the Air Force due to the talent of its field-center personnel. But NASA's workforce is getting older, and the agency has limited ability to hire. For Apollo, NASA was able to import skilled systems engineers from the Air Force's ICBM programs. That, however, is not an option today. NASA is trying to rebuild its internal systems engineering skills, and the Defense Department is proposing to create a new cadre of technical "space professionals."
- a competitive environment and limited resources. Today, execution is the paramount policy issue. So to whom does spacepower flow? More than likely, it will be to those who can deliver capabilities necessary to meet threats or exploit opportunities— whether they are military, economic, scientific, or political.

The Guardians within the U.S. space community are facing great difficulties, but the Merchants also are vulnerable. Weakness in security can be destabilizing because it invites opportunistic attacks and changes the deterrence calculations of adversaries. Weakness in commerce can cause commercial losses as well as longer term damage, especially if weak Guardians allow market distortions to persist because they fail to enforce international trade rules, spectrum regulations, intellectual property protections, and even export controls. In short, globalization is creating greater interdependency between the public and private sectors, not less.

Space Exploration and Spacepower

In spite of uncertainties and challenges in the national security sector, the Nation's interest in pursuing military spacepower is unquestioned. Similarly, the demands of a competitive global economy underscore the national interest in maintaining space-based information systems—most of which are dual use in nature (such as GPS, remote sensing, and communications). Separate from the military and commercial needs are the scientific ones. Although science and exploration are not required to ensure spacepower, the pursuit of knowledge can be seen as a discretionary activity that great nations undertake to help define their society, enhance their international prestige, and create new technologies to benefit people worldwide. What, then, is the enduring role of science and exploration in the spacepower of the Nation?

The Cold War and competition with the Soviet Union for technological preeminence drove the Apollo, Gemini, and Mercury programs. Despite the desires of space advocates for the robust industrialization and settlement of space, the United States had not made their aspirations a compelling national interest. Even though the military and commercial sectors benefit enormously from space, it is not impossible to imagine a nation retreating from human spaceflight once it achieved the capability. That was not the case for the former Soviet Union. Even during the most extreme economic turmoil following the fall of communism, Russia did not abandon human spaceflight. In fact, it strived to maintain its program through every possible means. The U.S. "Vision for Space Exploration" is neither Apollo redux nor a commercial venture, and debates among space advocates continue over its purpose and meaning. It is therefore instructive to understand differing perceptions of the rationale for U.S. space exploration plans.

Only tiny minorities of those engaged in space-related policy debates oppose government-funded space activities. Those who do are more concerned with particular uses and technologies, namely nuclear power, space-based weapons, and ballistic missile defenses. In fact, apathy and taking space capabilities for granted are arguably greater problems than direct opposition. At the risk of oversimplification, if not caricature, at least five different schools of thought have evolved from discussions about the priorities of human exploration of the Moon, Mars, and beyond, and how the Nation should carry out the program.

Baseline

The first school is that NASA itself is simply responding to the 2004 direction of President Bush and the 2005 NASA Authorization Act. The United States is fulfilling its commitments to its partners under the International Space Station agreements, ending the space shuttle program in 2010 once NASA completes assembling the space station, building a new generation of launch vehicles to ferry crew and cargo to space after the shuttle retires, establishing an outpost on the Moon, and laying the foundations for human expeditions to Mars—all while maintaining a diverse program of scientific research. Given limited budgets, the program is a "go-as-you-pay" effort, and programmatic priorities follow the policy priorities defined by the President and Congress. Given those same limited resources, NASA is open to international cooperation and commercial partnerships in all areas—with the exception of core launch and communications/navigation capabilities that are so strategic as to require avoiding foreign dependency.

Technology First

The second school argues that the United States does not have the technology to return to the Moon and travel to Mars, at least in a way that will be sustainable and affordable. Thus, the Nation should make the funding and development of new technologies the first priority and not commit to a specific architecture until several years from now. Arguably, NASA tried this approach for about a year after President Bush's speech, generating many interesting ideas and concepts. But the lack of tangible momentum was unsatisfactory to the White House and Congress. Upon confirmation in 2005, the new NASA administrator initiated a 90-day Exploration Systems Architecture Study precisely to help define a specific architecture for implementing human missions to the Moon. Funds were shifted from technology development to pay for new launch vehicles that were based on shuttle components and workforce skills.

Science First

This school argues that supporting peer-reviewed science should be the highest priority of NASA and that by implication, exploration efforts are little more than government-funded "tourism." Peer review is seen as providing the most objective assurance of quality; consequently, civil space activities not subject to peer review are seen, almost by definition, as less worthy. More practically, supporters of this school will say they are not intrinsically opposed to exploration because it may generate new opportunities for scientific research. However, they do not believe that funds should be shifted from science missions to pay for exploration. To fund the development of a new launch vehicle while maintaining the shuttle and space station programs, however, NASA chose to slow the rate of growth of science spending to 1 percent over the next several years. In previous budgets, the science community had planned for increases of up to 5 percent for a few years and then 2.4 percent per year as NASA's top line grew with inflation. This slower rate of growth required deferring several planned missions to keep international partner commitments on the space station. The resulting unhappiness with this decision was understandable, but it also reflected a fundamental difference in policy priorities for government funding.

Commercial First

This school is an example of Merchant culture. It argues that the government is so incapable of or grossly inefficient in the creation of space capabilities, especially compared with the private sector, that it should take an entirely different approach to human spaceflight. Instead of development contracts with government oversight, NASA should offer contracts for services, prizes, and other "pay-on-delivery" mechanisms to excite entrepreneurs. The rationale is that this will attract more private capital, create more diverse solutions, and offer a better chance of success than a government "all-eggs-in-one-basket" approach. NASA is seeking to test this argument in part through the COTS program but is hedging its bets (post-shuttle) by having multiple backups for space station supply (use of the Crew Launch Vehicle, Russian launchers). Advocates of this school have argued that the very act of having backups shows NASA is insufficiently committed to commercial sources and therefore is deterring investments that would otherwise occur. Given the policy priorities of the President and Congress, however, it is hard to see how NASA could do otherwise than to hedge its bets. Again, this school reflects a fundamental difference in policy objectives for exploration—in this case, the highest good is growing commercial capabilities rather than doing science.

Regional Interests

The fifth school is a form of the old adage, "All politics is local." The primary concern lies with where the government spends its money. States with NASA field centers and major contracts can be expected to support programs that build on existing capabilities. This is not necessarily a bad thing, as minimizing new developments can help control costs. On the other hand, it can cause political resistance, especially if NASA tries to move work from one center to take advantage of workforce skills and efficiencies at another. Therefore, debates over program priorities will be less about policy or products and more about process and the impact on the workforce. As with the "science first" and "commercial first" schools, giving priority to regional interests can result in misdirecting resources. It places parochial interests above national interests and national spacepower.

These differing forms of advocacy for space exploration can obviously affect how NASA pursues international and commercial partnerships. While technological, regional, and scientific advocates can be expected to be lukewarm to government-to-government international cooperation in exploration, the reality of limited budgets and need for such cooperation would suggest that these types of advocates would not be opposed. Even so, the Merchant culture of commercial advocates can be expected to be skeptical of contributions from other governments on a nonmarket basis. For them, it is the process by which space capabilities are acquired, not the product, that matters. In other words, government competition should be opposed. This is another area of Merchant and Guardian conflict. It would be worthwhile for NASA to explain, multiple times if need be, what it sees as a proper role of government in space exploration. Examples could include being a patron of science and other activities, being a reliable customer of commercially available goods and services, and being a fair and transparent regulator to ensure national security and public safety.

Given the competing views, even among space exploration advocates, what does this say about the sustainability of an exploration enterprise that requires several decades? Again at the risk of caricature, advocates of long-term, civil space exploration tend to fall into different camps based on their underlying values. The traditional von Braun paradigm represents a Guardian approach. It sees space exploration as a government activity that adds indirectly to the spacepower of the Nation via new technologies, dual-use capabilities, and increased international influence. There are established government and private-sector interest groups that promote funding for technologies, systems, and partnerships with near-term benefits, especially scientific ones.

Astronomer and author Carl Sagan was an advocate of robotic exploration of the solar system and the search for extraterrestrial intelligence. He also was an advocate of human spaceflight for one fundamental reason:

> every surviving civilization is obliged to become spacefaring—not because of exploratory or romantic zeal, but for the most practical reason imaginable: staying alive. . . . The more of us beyond the Earth, the greater the diversity of worlds we inhabit . . . then the safer the human species will be.[31]

While initially skeptical of the scientific value of human spaceflight, Sagan became an advocate for noncommercial and nonmilitary reasons. The use of robots to obtain scientific knowledge was well and good, but humanity itself had a transcendent value, and human spaceflight could contribute to its survival. This Sagan paradigm is very much a Guardian approach, but one that does not yet have an established base in or outside of government, as the potential benefits are beyond the planning horizons of governments, not to mention industry.

Gerard O'Neill was a physicist and author who became an advocate of space colonies, not necessarily on the Moon or Mars, but in free space. He proposed using space resources, via mining the Moon and asteroids, to construct large space habitats and solar-powered satellites to beam energy back to Earth.[32] Space development, rather than space exploration, was the focus. It was to be carried out by private companies and quasi-government corporations. In addition to the practical benefits of tapping space resources and energy, the O'Neill paradigm envisioned opportunities in the image of the American frontier. The images of self-sustaining human space settlements appeal to both Merchant and Guardian cultures and with plausible, nearer term steps. Beyond just survival, the O'Neill image offered a way to advance American (or Western, to be more general) values beyond Earth. Unfortunately, the economics of the O'Neill scenario are not realizable with current space capabilities. Even so, the attraction of this encompassing paradigm is as powerful today among space advocates as the one advocated by von Braun.

The point of reviewing the varying visions of space exploration and development is to observe that each represents decades-long efforts. They are adaptable and could persist even in the face of temporary political or fiscal setbacks. Like the "Vision for Space Exploration," they represent directions and purposes to which many different types of space activity could make contributions.

The space capabilities implied by successful space settlements, particularly those in which the United States is a leader, also represent a gigantic increase in the Nation's spacepower. Unfortunately, it is not clear that such capabilities are realizable, although many advocates believe they are. Two important questions are: can humans "live off the land" in space and function independently of Earth for long periods, and are there economically useful activities in space that can sustain human communities there?

If the answer to both questions is *yes*, then the long-term future in space includes human space settlements. If the answer to both is *no*, then space remains a place that one might visit briefly for science or tourism, much like going to Mount Everest or other remote locations. If the answer is that one can, in part, live off the land or at least be reliably supplied, then one can imagine space as akin to Antarctica—a place for science, tourism, and habitation by government employees and contractors. Finally, if one cannot live off the land, but the tasks to be performed are economically attractive, then one can imagine habitats like the North Sea oil platforms. These locations may be privately owned and operated, but they cannot really be called settlements (see table 7–1).

Table 7–1. Viability of Space Settlement

	Can live off land/be supplied	**Cannot live off land**
Nothing commerically useful	Antarctica	Mount Everest
Commercially sustainable	Settlements	North Sea oil platform

These outcomes do not preclude other motivations, such as protection of Earth from hazardous asteroids or the protection of U.S. and allied space infrastructure from hostile attacks. The point is, we do not know which of these outcomes represents our long-term future. Advocates and skeptics may believe one outcome or another is most likely, but no one actually knows. Determining the future of humans in space would be a watershed event not only for spacepower, but also for the United States and humanity. Just as space science can be organized around great questions (How did the solar system form? Is there life elsewhere in the universe?), so might human spaceflight be organized to answer similarly great questions. One of the purposes of human spaceflight is to explore the unknown and see what humans are capable of doing, where they are capable of going, and what communities they can sustain. Taking risks to get that knowledge would seem to be a worthwhile activity for nations that are technically sophisticated and wealthy enough to do so.

Policy Challenges for the Second Space Age

The period from the launch of Sputnik to the last Apollo mission can be considered the first space age—driven by Cold War competition across civil and military sectors. It is unclear when the second space age might begin; some say it started with the launch of the space shuttle, and others say it will start with the end of shuttle flights in 2010. More commercial and international involvement, as well as deep cooperation and conflict across public and private sectors, will characterize the second space age and the role of Merchant and Guardian cultures.

With stable national space policies, many old debates have long remained settled. Save for historians, it is difficult to recall the intense debates over military versus civilian leadership in human spaceflight in the 1960s or the U.S. Government's resistance to commercial space innovations in the 1980s. New debates over spacepower in the second space age will reflect both the growing strength of the Merchants and the worrying weaknesses of the Guardians. As discussed earlier, government space programs are increasingly facing difficulties in delivering capabilities on time and on budget. Limited fiscal resources and concerns over lack of management skills have stoked interest in outsourcing and privatizing government space functions (for example, launch communications, remote sensing, and navigation). Whether it makes sense to change responsibilities for some or any of these functions will make for much debate.

The civil space sector, notably NASA, also sees potential advantages in relying more on the private sector for launch services and other operational capabilities. At the same time, the private sector is looking to open new markets, particularly in the area of space tourism. These markets are not directly of interest to the government, but the dual-use capabilities they could support are. The ongoing issue for the civil space sector likely will be what kinds of mutual interest there might be in human space exploration for the commercial, scientific, international, and perhaps the national security communities. Exploration can be hard to justify on commercial, military, or even purely scientific grounds (one will not find "exploration" among the top priorities of the decadal surveys done by the National Academy of Sciences), but the conduct of exploration can create opportunities for commercial, scientific, and even military interests. Identifying and acting on those mutual interests will be an ongoing part of the second space age as the United States establishes a lunar outpost and prepares for Mars.

The priority for NASA when it returns to the Moon for the first time in decades will be to do so successfully, safely, and affordably. In moving beyond the space shuttle and low Earth orbit operations, NASA is effectively learning to fly again. Just as Gemini was a necessary forerunner to Apollo, so too is the Moon a necessary precursor to Mars. Not only technologies but also organizational and management skills need to be demonstrated. The International Space Station was, and is, a massive educational experience in the assembly and operation of a multinational space facility, and the establishment of a lunar outpost will be as well. This effort will be different from the space station, however. Both international and commercial partners will be involved.

Commercial involvement in a return to the Moon has been the subject of much speculation, but little is definitive.[33] Proposals have been made for extracting platinum metals to use in commercial fuel cells as part of a global hydrogen economy, mining of helium-3 for fusion reactors, and the construction of solar-power beaming stations on the lunar surface or in free space using lunar materials. Other proposals see commercial firms separating oxygen from lunar rocks and providing support services to government facilities on the Moon, or even offering tourism and entertainment activities. Some of these endeavors may make commercial sense, but it is possible that none will.

In the near term, expectations are that the U.S. Government will want to ensure that necessary research and technology development occurs to support a lunar outpost, that a robust space transportation network is created (which may or may not be government-owned in the long term), that accurate maps and surveys of the Moon exist (we have better maps of Mars today than we do of the Moon), and that reliable communications and navigation services are available at the Moon. In short, the government should ensure that basic services are present to enable scientific and commercial opportunities, but it will not be a governmental responsibility to do everything possible on the Moon. It simply will not have the resources. As a policy matter, the most difficult area for Merchant and Guardian cultures likely will not be how to provide any particular good or service, but what legal rights private parties have on and, most crucially, on the way to the Moon. This is not an area in which the United States can or should act unilaterally. It affects what values are recognized beyond the Earth, and therefore the type and character of spacepower available to the United States.

Space Property Rights

Current international law recognizes the continued ownership of objects placed in space by governments or private entities. Similarly, resources removed from outer space (such as lunar samples from the Apollo missions) can be and are subject to ownership. Other sorts of rights in space, such as to intellectual property and spectrum, are also recognized. Article II of the 1967 Outer Space Treaty, however, specifically bars national appropriation of the Moon or other celestial bodies by claims of sovereignty or other means. It also says that states shall be responsible for the activities of persons under their jurisdiction or control. Thus, the central issue is the ability to confer and recognize real property rights on land, including in situ resources found on the Moon and other celestial bodies.

In common law, a sovereign is generally required to recognize private property claims. Thus, the Outer Space Treaty, by barring claims of sovereignty, is usually thought to bar private property claims. Many legal scholars in the International Institute of Space Law and other organizations support that view. Other scholars, however, make a distinction between sovereignty and property and point to civil law that recognizes property rights independent of sovereignty.[34] It has also been argued that while article II of the treaty prohibits territorial sovereignty, it does not prohibit private appropriation. The provision of the Outer Space Treaty requiring state parties to be responsible for the activities of persons under their jurisdiction or control leaves the door open to agreements or processes that allow them to recognize and confer property rights, even under common law.

Current international space treaties are built on the assumption that all matters can and should trace back to states. This is in contrast to admiralty law and the growing field of commercial arbitration in which the interests and responsibilities of owners, not necessarily the state, were the legal foundation. It can be argued that the Outer Space Treaty was not the final word on real property rights in space even within the international space law community, as drafters of the 1979 Moon Treaty felt it necessary to be more explicit on this point. The treaty states:

> *Article 11. (1) The moon and its natural resources are the common heritage of mankind. (2) The moon is not subject to national appropriation by any claim of sovereignty, by means of use or occupation, or by any other means. (3) Neither the surface nor the subsurface of the moon . . . shall become property of any State, international intergovernmental or nongovernmental organization, national organization or nongovernmental entity or of any natural person [emphasis added]. The placement of personnel, space vehicles, equipment, facilities, stations . . . shall not create a right of ownership over the surface or subsurface of the moon or any areas thereof. The foregoing provisions are without prejudice to the international regime referred to in Paragraph 5 of this Article . . . (5) State parties to this Agreement hereby undertake to establish an international regime . . . to govern the* exploitation of the natural resources of the moon as such exploitation is about to become feasible . . . (7) The main purposes of the international regime to be established shall include: a) The orderly and safe development of the natural resources of the moon, b) the rational management of those resources, c) the expansion of opportunities in the use of those resources, d) an equitable sharing by all State parties in the benefits derived from those resources, whereby the interests and needs of the developing countries, as well as the efforts of those countries, which have contributed either directly or indirectly to the exploration of the moon shall be given special consideration.[35]

Article 11 was the most controversial aspect of the Moon Treaty when it was introduced. The Outer Space Treaty had already excluded claims of national appropriation, and this provision is repeated in article 11, part 2. Article 11 goes further, however, in part 3 to exclude property claims of any sort, and if any benefits are derived, they are presumably to be shared in accordance with the "common heritage" provision of article 11, part 1. Even the exercise of effective control of a region, as in placing a permanent base, would not support a claim of ownership by any entity. There is no mention of any limitations that would be placed on a regime controlling nonterrestrial resources or what mechanisms would be considered to resolve disputes. One might argue that article 11 prejudges the design of an international regime for the orderly and safe development of the Moon in that a system of internationally recognized property rights could, in fact, be the more rational way to manage those resources, expand opportunities for their use, and equitably share the benefits therein derived.

Furthermore, privacy and the right of persons to be secure in their dwellings are not rights supported by the Moon Treaty. Article 15 reads:

> Article 15(1). All space vehicles, equipment, facilities, stations and installations on the moon shall be open to other State parties. Such State parties shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited.[36]

No limits are placed on the reach of article 15, and the right to inspect space-based facilities would presumably extend to individual quarters and personal effects and papers. If state parties owned all facilities on the Moon and all persons on the Moon were state employees, an inspection regime, based on reciprocity, would seem to be a simple requirement. If some facilities are privately owned and their occupants are private citizens (which the Moon Treaty does not forbid), then a broad inspection requirement like article 15 would necessarily supersede those privacy rights enjoyed in the United States and other democracies. Thus, the Moon and other celestial bodies would be regions where inhabitants enjoyed fewer liberties than in the United States or other nations on Earth.

The 1979 Moon Treaty may not appear very relevant since the United States and almost all other spacefaring nations did not sign it and none has ratified it.[37] However, the view that real property rights are forbidden by international law is widely prevalent. This in turn creates uncertainty in the minds of potential private sector partners and is inconsistent with the goals enunciated by the President and Congress in supporting the "Vision for Space Exploration." At minimum, real property rights in space are legally ambiguous and the United States need not accept flat statements that the Outer Space Treaty per se forbids such rights.

There is a wide variety of options for the establishment of a system of real property rights in space. These could include negotiation of a new international treaty to replace the Moon Treaty, extend existing international structures (such as the World Trade Organization), and use international arbitration mechanisms (for example, the London Court of International Arbitration). Alternatively, other regimes, such as the International Seabed Authority, could be modified to enable more predictable exploitation without recognizing private property rights. Or they could create a claims registry that would leave definition of a recognition regime to future specific cases. These options intentionally exclude more extreme positions, such as rejection of the Outer Space Treaty, or the unilateral assertion that the United States recognizes private property claims. Such actions would not engender international acceptance and the predictability required for such claims to be effective.

Conclusion

Spacepower encompasses all aspects of national power: military, economic, political, and even cultural as represented by the values that shape the Nation's space activities. The differing outlooks of Merchant and Guardian cultures are central aspects of today's space policy debates and can be expected to continue no matter what the human future in space turns out to be. The commercial space sector is continuing to grow and diversify. While it is easy to overestimate the potential of space commerce, weaknesses in the management and technical skills of the national security and civil space sectors are arguably a greater concern for the Nation's spacepower than the rate of growth of private space enterprise. In short, Guardian weaknesses are a more serious problem than Merchant strengths, as there is no substitute for Guardian responsibilities assuring national security and public safety.

In the national security sector, the key challenges will be to strengthen the ability to implement and execute major space acquisition programs and partner with commercial interests to shape the international environment to the advantage of the United States and its allies. In the civil space sector, the key challenges will be to implement the "Vision for Space Exploration" in an affordable manner and create partnerships with commercial and international interests to ensure the long-term sustainability of human exploration beyond low Earth orbit. The capabilities created by the successful establishment of a lunar outpost and human missions to Mars will add greatly to the Nation's spacepower.

There are many uncertainties with meeting these challenges because they require government agencies to work across traditional lines, partner with organizations having very different worldviews, and integrate policy, acquisition, and operational functions more thoroughly. Highly complex systems tend to create internal stovepipes that control the amount of information with which decisionmakers have to deal. For space systems, this can lead to disconnects between the acquisition and operational communities, and national policy objectives. Keeping these communities in sync with evolving world conditions is a major and daunting challenge for U.S. agencies and the entire executive branch.

Human and robotic exploration of space is a decades-long effort that has no clear end, but there are vastly different potential outcomes for humans' long-term future in space. Humans could live permanently in thriving communities beyond Earth or embark on limited to relatively brief expeditions and not establish a permanent presence. If it is assumed that humans are not permanently limited to the Earth and that the future exercise of spacepower includes humans living and working in space, then the questions become: who will make these expeditions, and what values will they hold? If they are Americans, then it is to be hoped that there will be room for Merchant as well as Guardian cultures on the Moon, Mars, and beyond.

Legal issues will become increasingly more important as the "Vision for Space Exploration" proceeds and humans attempt to expand farther and more permanently into space. In exercising spacepower, the United States should seek to ensure that its citizens have at least as many rights and protections in space, including the right to own property, as they do on Earth. Whether such rights would be as complete as those in the United States would be the subject of negotiation and debate. Simply put, however, the Moon and other celestial bodies should not be a place of fewer liberties than those enjoyed on Earth.

Recognizing conflicts between Merchants and Guardians is only a first step. The pursuit of spacepower should serve to increase national power, whether measured in economic, military, or political terms, as a way to advance American values and interests. This does not mean the pursuit of an isolationist or unilateral approach by the U.S. Government or the United States as a whole. The reality is that the United States must be engaged in shaping the international environment, and the Nation needs partners and friends to succeed. The task is to craft partnerships and strategies with Merchants and Guardians worldwide as human activities of all kinds expand into space.

Notes

1. I am grateful for the comments I received and the lively discussions I participated in at workshops and seminars hosted by the National Defense University. I am also grateful for comments I received from colleagues who could not attend these sessions in person. The chapter also draws on prior works, in particular: Scott Pace, "Merchants and Guardians," in *Merchants and Guardians: Balancing U.S. Interests in Global Space Commerce*, ed. John M. Logsdon and Russell J. Acker (Washington, DC: Space Policy Institute, George Washington University, May 1999) Scott Pace, "Merchants and Guardians in the New Millennium," in *Space Policy in the Twenty-first Century*, ed. W. Henry Lambright (Baltimore: The Johns Hopkins University Press, 2003) Dana J. Johnson, Scott Pace, and C. Bryan Gabbard, *Space: Emerging Options for National Power*, MR–517 (Santa Monica, CA: RAND, 1998). NASA identification is for biographical purposes only.
2. Ronald Reagan, "Speech at Moscow State University—May 31, 1988," in *The American Reader*, ed. Diane Ravitch (New York: HarperCollins, 1990), 364–365.
3. Simon Worden, "Forget about space dominance: U.S. interests should start focusing on space competence," *Bulletin of the Atomic Scientists* (March–April 2006), 21–23.
4. *Air Force Basic Doctrine*, Air Force Doctrine Document 1 (Washington, DC: U.S. Air Force Headquarters, September 1997).
5. Much of this discussion is drawn from Dana J. Johnson, Scott Pace, and C. Bryan Gabbard, *Space: Emerging Options for National Power*, MR–517 (Santa Monica, CA: RAND, 1998), chapter 2.
6. General Henry H. Arnold, USAF, *Global Mission* (New York: Harper and Brothers, 1949), 290–291.
7. Having low-cost access to space is useful in its own right and can be an additional deterrent to the entry of potential competitors. Similarly, the provision of free, high-quality navigation signals from global positioning systems makes it more difficult to raise commercial funds for competing systems. States may, of course, choose to build such capabilities for their own reasons, but they will bear the costs more directly.
8. Unfortunately, the exercise of spacepower by field commanders would require a more technical and detailed analysis of specific space capabilities than we have room for in this chapter.
9. Johnson, Pace, and Gabbard.
10. Air Force Doctrine Document 2–2, *Space Operations* (Maxwell AFB, AL: Air Force Doctrine Center, November 27, 2001), 54.
11. I am indebted to Dwayne Day for the term *von Braun paradigm*.
12. Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens III, *Limits to Growth* (New York: Universe Books, 1972). See <www.nss.org/settlement/L5news/index.html> for a brief history of the L5 Society.
13. Interestingly, this view of space did not find much support outside Anglophone cultures. Most international advocates of space development saw large-scale human activities in space as useful in building cooperation among existing societies, not in building new ones.

14. During the Civil War, President Lincoln signed several key legislative initiatives for the American frontier such as the 1862 Homestead Act, the Morrill Land-Grant Colleges Act, and the Pacific Railway Acts of 1862 and 1864.
15. The Space Foundation, *The Space Report: The Guide to Global Space Activity* (Colorado Springs: The Space Foundation, 2006).
16. For a deeper treatment of choice, see Charles Wolf, Jr., *Markets or Governments: Choosing between Imperfect Alternatives* (Cambridge: MIT Press, 1988).
17. I am indebted to Jim Bennett for first using these terms together. This discussion is drawn from my 1999 paper of the same title.
18. Scott Pace, "Merchants and Guardians," in *Merchants and Guardians: Balancing U.S. Interests in Global Space Commerce*, ed. John M. Logsdon and Russell J. Acker (Washington, DC: Space Policy Institute, George Washington University, May 1999).
19. *Columbia Accident Investigation Board Report*, vol. 1 (Washington, DC: NASA and U.S. Government Printing Office, August 2003), 209, available at <http://caib.nasa.gov/>.
20. John M. Logsdon, "A Failure of National Leadership," in *Critical Issues in the History of Spaceflight* (Washington, DC: NASA, 2006), 270.
21. See <www.whitehouse.gov/infocus/space/vision.html>.
22. Michael Griffin, remarks to the National Space Club, Washington, DC, February 9, 2005.
23. John Marburger, keynote address, 44th Robert H. Goddard Memorial Symposium, Greenbelt, MD, March 15, 2006.
24. Office of Science and Technology Policy, Executive Office of the President, *U.S. National Space Policy* (Washington, DC: The White House, August 31, 2006).
25. Robert G. Joseph, remarks on the President's National Space Policy at The George C. Marshall Institute, Washington, DC, December 13, 2006.
26. Andy Pasztor, "Air Force May Hire Outsiders to Oversee Projects," *The Wall Street Journa*l, December 28, 2006, 3.
27. John Logsdon, "Missing the Point?" *Space News*, November 6, 2006.
28. A peer competitor is a state capable of fielding multiple types and robust numbers of both emerging and current weapons, then developing a concept of operations to realize the full potential of this mix. Its goal is to capture a vital interest of the United States and then defeat the military response.
29. Petter Stålenheim, Damien Fruchart, Wuyi Omitoogun, and Catalina Perdomo, "Military Expenditure," in *SIPRI Yearbook 2006: Armaments, Disarmament and International Security* (New York: Oxford University Press on behalf of Stockholm International Peace Research Institute, June 2006).
30. Thomas Friedman, *The World is Flat* (New York: Farrar, Straus and Giroux, 2005).
31. Carl Sagan, *Pale Blue Dot: A Vision of the Human Future in Space* (New York: Random House, 1994), 371.
32. Gerard K. O'Neill, *The High Frontier* (Princeton: Space Studies Institute Press, 1989).
33. Rick Tumlinson and Erin Medlicott, eds., *Return to the Moon* (Ontario, Canada: Collectors Guide Publishing Inc., Apogee Books, November 2005).
34. Wayne N. White, "Real Property Rights in Outer Space," in *Proceedings of the 40th Colloquium on the Law of Outer Space*, American Institute of Aeronautics and Astronautics on behalf of the International Institute of Space Law (1998), 370.
35. *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, United Nations Office for Outer Space Affairs (1979), available at <www.unoosa.org/oosa/SpaceLaw/moon. html>.
36. Ibid.
37. Ibid.

Chapter 8:

Economic Development of the Solar System: The Heart of a 21st-century Spacepower Theory

Dennis Wingo

The current definition of spacepower in use by the United States is incomplete, and a "geocentric" mindset has become an embedded assumption in the development of national spacepower theory. This mindset must be expanded in order to provide options to our nation's current and future leaders in navigating through the difficulties that define the 21st century. The change has begun within the top echelon of our elected leadership but has yet to be integrated into the thought processes of the majority of spacepower theorists and government agencies responsible for science, exploration, and national security.[1] It is this author's position that the time has come to extend the economic reach of mankind into the solar system to create a multiplanet civilization with a resource and energy base that dwarfs our present single planet system. Integrating this worldview into American spacepower theory and practice will bring tremendous economic and national security benefits. This chapter will explore why this shift is needed and how it might unfold.

Current World Status and the Linkage to Spacepower Theory

As we enter the first decades of the 21st century, profound challenges confront the United States and the family of nations in transcending the limitations of hydrocarbon energy and other resources. The U.S. Census Bureau estimates that the population of our planet will continue to grow from today's 6.5 billion to an estimated 9.4 billion in the year 2050.[2] Beyond this, the expanding major powers of Asia, principally China and India, with the majority of the Earth's population, aspire to the same level of affluence that Americans, Europeans, and the Japanese enjoy. This will further strain the resources of our single planet, and the current nontechnical geocentric solutions envisioned by many well-meaning leaders point toward an extended period of economic contraction and war over a shrinking resource base. Worse yet, the diversion of resources to preserve the status quo of a single planet civilization will likely result in a period of population and industrial collapse as resources are exhausted due to the lack of investment in technical innovation.

Therefore, we must develop a new spacepower theory in the context of our times reflecting the challenges that face our people, our nation, and our world in order to protect our liberty, improve our lives, and continue our collective and individual pursuit of happiness. This spacepower theory must provide hope and illuminate a path toward a positive, peaceful, and affluent future for all the citizens of the world. In order to catalyze this, the American free enterprise system must be enabled toward the goal of the economic development of the solar system. These perceptual shifts have fundamental implications for the shape of spacepower theory.

Definitions and Context

Considering that various definitions of spacepower theory exist, this chapter adopts the one that best supports the construction of its premise. The following definition is from James Hyatt: "Spacepower is defined as the ability of a state or nonstate actor to achieve its goals and objectives in the presence of other actors on the world stage through . . . exploitation of the space environment."[3] This definition carries broad connotations to include commercial activities, scientific researchers, and other actors. However, this definition embraces, as do all current spacepower definitions, an underlying assumption or mindset defined as geocentric. The definition of *geocentric* within the context of a discussion of spacepower theory is as "a mindset and public policy that sees spacepower and its application as focused primarily on actions, actors, and influences on earthly powers, the earth itself, and its nearby orbital environs."

The geocentric mindset is a key assumption undergirding the last 40 years of spacepower theory. This assumption became a foundational principle during the administration of President John F. Kennedy and Secretary of Defense Robert McNamara. This was not always the case. In the 1950s, the Dwight Eisenhower administration supported a military presence on the Moon in the form of an outpost as the ultimate high ground, beyond the reach of ballistic missiles, as a deterrent to a Soviet first strike nuclear capability. This was laid out in the Project Horizon Report, a classified (at the time) document that was basically the first serious U.S. military study of the uses of space beyond low Earth orbit (LEO).[4] The U.S. Armed Forces' interest in a lunar military base was curtailed by the creation of the National Aeronautics and Space Administration (NASA), a civilian agency given the lead role in the race to place humans on the Moon as defined by President Kennedy. With the creation of NASA, military space assets (principally Army) were transferred to the new agency, along with the budgets for space systems development.

With that divorce, space beyond geosynchronous Earth orbit (GEO) was excised from military planning, activities, and spacepower theory development. This was further reinforced by Secretary McNamara's decision to embrace mutual assured destruction as the cornerstone of U.S. strategic policy along with ballistic missile submarines as the survivable leg of the triad of nuclear deterrence. The functional result of that decision meant that anything beyond passive military satellites was "bad" and "destabilizing."[5] This effectively removed the military from any space mission beyond communications satellites in GEO, reconnaissance in LEO, and the global positioning system in medium Earth orbit. This remains the status quo today, with the singular exception of the Ballistic Missile Defense Organization's (now the Missile Defense Agency) Clementine mission to the Moon in early 1994.[6] However, the intervening years have brought new concerns to light that signal a shift in defense policy interests beyond LEO.

There has been recent acknowledgment in military circles that near Earth objects (NEOs) are a potential threat to our nation, and a joint NASA/U.S. Air Force project called the Lincoln Near-Earth Asteroid Research (LINEAR) program has dramatically improved the search for NEOs using existing terrestrial telescopes.[7] However, this is still a geocentric interest as the emphasis is on their danger to the Earth; there is no attempt to characterize these objects for their resource potential, which is easily accomplished with the same assets.

With the death of the Apollo program in the early 1970s, NASA's role in shaping an expansive national spacepower theory was curtailed as well. NASA became geocentric in outlook, in manned spaceflight, and in the human development of space. This shift is especially important to note today, given that the same forces (the perceived threat to the terrestrial environment by human activity) are at work, incorporating the same geocentric mindset that dismisses space as a part of the solution set for our problems here on Earth. The exception to this has been the very successful robotic spacecraft missions that have probed the planets and traveled beyond the confines of the solar system. However, this exception proves the rule as NASA's planetary robotic exploration program has been the sole province of scientific inquiry with no consideration of the economic potential of any solar system bodies visited. In terms of shaping a broad national spacepower theory, the White House and the Office of Science and Technology Policy (OSTP) assumed this role mostly by default while the Department of Defense continued to be limited in scope to geocentric applications of passive military strategic and tactical systems.

The Ronald Reagan administration strongly supported a role for the armed services in the development of strategic defense. While it went beyond the confines of McNamara era policy, it still exhibited a geocentric posture focused on ballistic missiles launched by terrestrial adversaries. The White House and other entities showed a trace of support for the development of a new spacepower theory and implementation that incorporated economic activity. The National Academy of Sciences hosted a public symposium in Washington, DC, in October 1984 that addressed the issue of the exploration of the Moon, Mars, and beyond. This symposium resulted in a book, *Lunar Bases and Space Activities in the 21st Century*. In the keynote address, Presidential science advisor and OSTP director George Keyworth had this to say:

> I think we have to ask, right at the outset, where we go from the lunar base? What steps should we be taking in parallel with the lunar base, and what comes after it? Do we go to Mars, and if so, why? Do we try to visit an asteroid? Remember that much of the momentum of our space program was lost after Apollo because we treated the Moon landing as an end in itself. This time we should know enough to define and update our goals in space in broad terms related to our future, not in terms of individual projects. And we should cast as wide a net as possible in creating this vision of our future, involving the American public and being driven by their enthusiasm as well as our own.[8]

This speech, and those that followed, still showed commitment to the bifurcation of space efforts: space exploration and development (primarily science and exploration driven) was the sole province of NASA, while military efforts focused on geocentric strategic defense. There was no sense of a national spacepower theory that melded the larger interests of the Nation and its people into a coherent foundation for policy. Keyworth asked the right questions in his speech&#mdash;questions we still seek answers to today.

While the George H.W. Bush administration strongly supported manned exploration of the Moon and Mars for scientific purposes, economic development remained the province of poorly funded and organized civilian space advocacy movements. It is only with the George W. Bush administration's "Vision for Space Exploration" (VSE) that economic development of the solar system has been embraced as an underlying rationale by the government. This new rationale, as mentioned by President Bush in his January 2004 speech announcing the VSE and amplified by OSTP since, is a startling departure from previous policies regarding space exploration and development and is the first true break from the geocentric outlook by policymakers.

John Marburger, director of OSTP, elaborated on the new policy in a speech at the Robert H. Goddard Memorial Symposium in March 2006:

> As I see it, questions about the vision boil down to whether we want to *incorporate the Solar System in our economic sphere, or not*. Our national policy, declared by President Bush and endorsed by Congress last December in the NASA authorization act, affirms that "The fundamental goal of this vision is to advance U.S. *scientific, security, and economic* interests through a robust space exploration program" [emphasis added].[9]

In order to clearly contrast the departure that this new policy represents, the equivalent statement by the National Academies of Science in 1961 was that "scientific exploration of the moon and planets should be clearly stated as the ultimate objective of the U.S. space program for the foreseeable future."[10]

The above statement had been the guiding principle during the Apollo era all the way until the Bush speech of 2004 and Marburger's Goddard talk of 2006. Marburger became even more explicit in his speech in describing what the new space policy means in terms of breaking with past programs:

> I want to stress how very different this kind of thinking is from the arguments that motivated America's first great space vision, the Apollo program. . . . The ultimate goal is not to impress others, or merely to explore our planetary system, but to use accessible space for the benefit of humankind. It is a goal that is not confined to a decade or a century. Nor is it confined to a single nearby destination, or to a fleeting dash to plant a flag. The idea is to begin preparing now for a future in which *the material trapped in the Sun's vicinity is available for incorporation into our way of life* [emphasis added].

As Marburger stated, this new policy, endorsed by the President and the Congress, shifts our nation's space exploration goal to embrace the economic development of the solar system as a core principle. In this departure, Marburger conclusively answered the questions proposed by his predecessor, Keyworth, 22 years before. The Marburger speech is the culmination of 50 years of space policy development, which must now be incorporated into a 21st-century spacepower theory.

We now have 22 years of further history that help to clarify the problems that confront the United States and the world in maintaining our civilization. We have 22 years of further scientific exploration by NASA and other space agencies that give us a much clearer picture of the potential resources obtainable in the solar system. We have as a fundamental construct the principle of private enterprise, the engine that has powered our entire national development. Therefore, by national temperament, this moves free enterprise and commercial activities to the forefront of national spacepower theory development. However, NASA, the Department of Defense, and other executive agencies have yet to integrate the new executive policy or economic development into a comprehensive spacepower theory.

The questions for our generation then become:

- What form of economic development and activity will be the focus of these efforts?
- What is the form of the "material trapped in the Sun's vicinity," and how will we access these resources?
- Will this be command-driven, like the Apollo era and the current military industrial complex, or do we as a nation fully embrace the free enterprise system and unleash it into the solar system?

There are legal ramifications related to this development as well. While there has been considerable debate about the ability to use the economic resources of solar system bodies, article 1 of the Outer Space Treaty of 1967 clearly states that "outer space, including the moon and other celestial bodies, shall be free for exploration and *use* [emphasis added] by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies."[11]

Conflicts over interpretation aside, for the sake of argument we will assume that resource rights can be obtained. In the context of a spacepower theory, the economic development of the solar system provides new options that allow us to positively address and indeed transcend many of the most pressing problems that our planetary civilization must confront in the 21st century, therefore improving our economic prospects while reducing some of the pressure toward warfare over the limited resources of the Earth.

The development of a spacepower theory must also assimilate the perspective that we are a planetary civilization. Even though the United States is one nation, it also is the core member of a planetary civilization that has been evolving for several centuries. This places a unique responsibility for us as a nation, in developing our spacepower theory, to provide a path for other nations to achieve our level of civilization without the inevitable conflicts that limit our vision to a single planet's resource guarantees. The resources of the solar system will provide the wealth to make this happen, and a new spacepower theory should incorporate that as a fundamental principle. In making bold statements regarding the ability of free enterprise to contribute to solving problems, it is necessary to state the nature of the problems that we face, construct a desirable endpoint that illustrates the potential benefits, and then elaborate on steps to be taken to reach the desired results.

The Problem Statement, Energy, and Resources

This chapter posits that free enterprise has the capacity to play the key role in the expansion of human civilization into the solar system. This expansion is a natural result and consequence of a planetary civilization such as we have today whose population is growing beyond the carrying capacity of our single planet. The World Wildlife Fund (WWF), in its 2006 Living Planet Report, suggests that "by 2050 humanity will demand resources at double the rate at which the Earth can generate them."[12]

The organization's perspective has been shared by various writers dating back to the late 18th century such as Thomas Malthus, who wrote the first treatise on exponential population growth.[13] Indeed, the Malthusian perspective can be considered the quintessential exposition of the geocentric mindset, as he originally postulated: "That, in time, because of an ever increasing population rate, man will come up against a ceiling, one created by the fact that the *world's* [emphasis added] resources needed for life, are, limited. Once these resources are exhausted, or spoiled, life as we know it will come to an end."

So far, mankind and Western civilization have been able to transcend successive limits to growth through the advance of technology and the increasing use of more compact forms of inexpensive and portable energy. The advance of technology continues to confound those who predict our doom, and yet at some point the sheer number of people and their desires for the same level of prosperity that the Western world enjoys threaten to overwhelm the currently favored solutions that rest upon a geocentric viewpoint. The WWF/Malthusian perspective illustrates one end of the political spectrum, but there are others who are reading from the same pages.

In a December 2006 interview in the *Wall Street Journal*, General Charles F. Wald, USAF (Ret.), called for a complete redefinition of energy security and asserted that the U.S. military could no longer fully protect our energy interests around the world.[14] Since his retirement in 2006, General Wald, along with General P.X. Kelly, USMC (Ret.), 28th Commandant of the Marine Corps, and Fredrick Smith, chief executive officer of the Fedex Corporation, have helped to found the Securing America's Future Energy (SAFE) out of their joint concern for our energy future. Legendary oil tycoon T. Boone Pickens echoed this concern on his personal Web site: "The Achilles heel of the United States is that we're using 20 percent of the oil in the world a day and we have less than 5 percent of the supply."[15]

Another concurring voice is that of Matthew Simmons, chairman and chief executive officer of Simmons and Company International, a Houston-based bank that is an investment leader in the oil industry. Mr. Simmons wrote in 2005 that world demand for oil is going to grow to over 130 million barrels of oil per day by 2030 and that the capacity to meet that demand with the existing resources of oil is not possible.[16] The point is that inexpensive petroleum energy, which has enabled the growth of global population from 1 billion in the 19th century to 6.5 billion today, is a resource that will effectively cease to exist no later than the latter part of this century in even the most optimistic scenario. Without the portable energy for transportation fuel that oil represents, it is highly unlikely that the current standard of global prosperity can be maintained, much less extended to several billion more of our fellow global citizens. This is not a problem only if the discomfort that a population reduction down to a billion souls would entail is discounted.

Furthermore, the shift in wealth to the oil-producing countries, most of which are not particularly friendly to the United States, represents a near-term strategic threat to our long-term economic health. Until the early 1970s, the United States was virtually self-sufficient in petroleum resources. During World War II, the United States was an oil exporter. This was a source of foreign exchange and wealth to the Nation that has been dramatically reversed in the past 35 years. Other threats related to the availability of oil in the 21st century continue to shift the balance of wealth and industrial power away from the United States. In the era before the new century, most of the oil produced by foreign entities had very little local demand. This is changing as Middle Eastern nations and others use the local availability of oil to fuel a dramatic growth in their own industrial base. This accelerates the accumulation of wealth in these nations as their industrial potential increases along with sales of products derived from these new industries.

Additionally, General Wald estimates that between 75 and 90 percent of the world's petroleum reserves are in the hands of state-owned companies that are quite willing to use oil as a weapon in political disputes.[17] In late 2006, Russia wrested control of the billions of dollars' worth of investments that Shell Oil made in Siberia and turned it over to the state-owned Gazprom.[18] A similar effort has consummated with British Petroleum. Venezuela and Ecuador have both nationalized foreign oil industry holdings as well. With ownership comes profits, and these profits are increasingly used in ways not beneficial to the United States. Venezuela, as just one example, uses its newfound oil wealth to purchase arms rather than to reinvest in the local economy.[19] In February 2007, the *Washington Times* and other news sources published articles concerning the creation of a natural gas cartel, similar to the Organization of Petroleum Exporting Countries, between Russia, Qatar, and Iran.[20] As this trend accelerates with the depletion of oil and gas resources in the Western world, the options of the United States will become increasingly limited.

How does the economic development of space solve the energy problem? In what way do the material resources of the solar system help to overcome the finite resources of our world? The following sections will address these questions.

Wealth, Resources, and National Security and Spacepower Theory

In 482 BCE, a rich vein of silver was discovered in the Athenian mines at Laurium. It was proposed at the time to use the profits derived from this discovery as a boon to the people of Athens. Themistocles, a leader of Athens who rose from the merchant class to power, argued for the money to be used to build a fleet to protect the city. This proposal was accepted, and in a development even Themistocles never foresaw, this fleet formed the backbone of the Greek city-state's navy that defeated the Persians at the battle of Salamis.[21] This battle, one of the crucial East/West battles of ancient times, guaranteed the freedom of Greece and halted the ambition of Persia to dominate the West.

In later centuries, it was the pattern for Rome to extract as much of the wealth as possible from their conquests. This wealth fueled the growth of the empire and provided the economic basis for its further expansion. As wealth obtained in conquest dissipated, Rome began its long decline. In the modern era, the Spanish emulated Rome in the expropriation of wealth from the New World. The Spanish wasted their wealth in wars, and their power waned after the destruction of their fleet in 1588 by the English. England, on the other hand, used the path of commerce tied to conquest leading to the empire "where the sun never sets." However, the exhaustion of British wealth in the two World Wars led to the breakup of the empire and the greatly reduced position of influence that England holds in the world today.

The United States used its plentiful internal natural resources, commerce, and a commitment to industrialization to give our nation its first burst of power. This is turning to a disadvantage as those resources are depleted. If the pattern of past centuries holds, the power centers of the 21st century will shift to those areas where the remaining planetary natural resources are located, and industrial infrastructure supports the underpinning of military power. If we are not able to overcome the factors leading to this shift in wealth and industrial power, our national power is apt to become far more limited than it is today.

So the fundamental question is: can the resources of the solar system enable the United States and the world to transcend the intrinsic limitations associated with relying only on what is available on the Earth? The follow-on question is: what is the implementation strategy that follows from an adoption of an expansionist policy based upon this redefinition of spacepower theory and its intimate linkage to national power theory?

The Resources of the Solar System

In conducting a necessarily circumscribed survey of the resources of the solar system, it is important to understand that the level of our knowledge of these bodies is still limited, though far greater in quality and quantity than 40 years ago. We have landed humans on the Moon and returned enough material to provide ground truth tests of previous and future lunar remote sensing missions. However, there has been no detailed examination of the Moon from the standpoint of a true economic resource survey. This is also decidedly true for the NEO population, Mars, and the vast quantity of asteroids in the belt between the inner rocky planets and Jupiter. However, since the first robotic asteroid flyby by the Galileo probe in 1990, a tremendous amount of data has been obtained about the asteroids, and NASA's Mars missions continue to make daily discoveries, each one opening new vistas for potential resource exploitation. European, Chinese, Indian, and American missions have recently or will soon return to our Moon to continue scientifically examining our nearest celestial neighbor. In 2000, the Near Earth Asteroid Rendezvous mission was the first robotic spacecraft to orbit and later land on an asteroid (433 Eros). This mission provided a great deal of operational experience in the uneven gravity field of these small objects. Therefore, with the availability of these new datasets, we can make informed speculations regarding the resource potential of our solar system and from that construct plausible scenarios regarding how those resources can supplement and eventually supplant those thought only available on the Earth.

A differentiation must also be made between materials obtained from various locations and returned to the Earth from those obtained and used in situ. As the interplanetary economy develops, there are materials that tend to be plentiful on the Earth, such as iron, that are also plentiful in space. It is doubtful whether iron will ever be an economical import material to the Earth but will be extremely valuable in space and on planetary bodies for structures, radiation shielding, and other uses. This is also true of other metals such as aluminum. Due to the depth of the Earth's gravity well (11.2 kilometers [km]/second [sec]$^{-1}$ escape velocity versus lunar 2.4 km/sec^{-1}, as little as 100 millisecond^{-1} from an asteroid), it will be cost-effective to utilize local resources as much as possible in building up an industrial infrastructure around the solar system. However, the primary purpose of these resources is to enable the ability to obtain valuable commodities for export to the Earth.

The Moon and Cislunar Space

Material resources. Some advocates of space development have called the Moon the "great slag heap" of the solar system.[22] This is partially due to the rocks returned by the Apollo astronauts that sampled an extremely small part of the lunar surface. Figure 8–1 shows the ranges of chemical composition for the major lunar minerals in various rock types.[23] All major minerals on the Moon are oxides of metals. Iron, magnesium, aluminum, silicon, and titanium make up most of the metal oxides by weight. While far from being a slag heap, the Moon's resources are tightly bound to oxygen, and it takes a significant amount of energy to separate the metals. Unlike on the Earth, oxygen itself is a resource on the Moon, and most lunar resource extraction concepts envision oxygen as the first resource product. While the majority of these metals are valuable, it is unlikely that they will be exported to the Earth due to the cost of fuel for their transport. The valuable metals on the Moon are those that have been implanted by the constant bombardment of asteroids over its 4.4-billion-year history.

Figure 8–1. Ranges of Chemical Compositions for Major Lunar Minerals

Ranges of Chemical Compositions for the Major Lunar Minerals in Various Rock Types
[Modified from Waldron, Erstfeld, and Criswell 1979]

Components (wt. %)	Pyroxene	Olivine	Plagioclase	Opaques (mostly ilmenite)
a. High-titanium mare basalts				
SiO_2	44.1 - 53.8	29.2 - 38.6	46.9 - 53.3	<1.0
Al_2O_3	0.6 - 6.0		28.9 - 34.5	<2.0
TiO_2	0.7 - 6.0			52.1 - 74.0
Cr_2O_3	<0.7	0.1 - 0.2		0.4 - 2.2
FeO	8.1 - 45.8	25.4 - 28.8	0.3 - 1.4	14.9 - 45.7
MnO	<0.7	0.2 - 0.3		<1.0
MgO	1.7 - 22.8	33.5 - 36.5	<0.3	0.7 - 8.6
CaO	3.7 - 20.7	0.2 - 0.3	14.3 - 18.6	<1.0
Na_2O	<0.2		0.7 - 2.7	
K_2O			<0.4	
b. Low-titanium mare basalts				
SiO_2	41.2 - 54.0	33.5 - 38.1	44.4 - 48.2	<1.0
Al_2O_3	0.6 - 11.9		32.0 - 35.2	0.1 - 1.2
TiO_2	0.2 - 3.0			50.7 - 53.9
Cr_2O_3	<1.5	0.3 - 0.7		0.2 - 0.8
FeO	13.1 - 45.5	21.1 - 47.2	0.4 - 2.6	44.1 - 46.8
MnO	<0.6	0.1 - 0.4		0.3 - 0.5
MgO	0.3 - 26.3	18.5 - 39.2	0.1 - 1.2	0.1 - 2.3
CaO	2.0 - 16.9	<0.3	16.9 - 19.2	<1.0
Na_2O	<0.1		0.1 - 1.3	
K_2O			<0.3	
c. Highland rocks				
SiO_2	51.10 - 55.4	37.70 - 39.9	44.00 - 48.0	<0.1
Al_2O_3	1.00 - 2.5	<0.1	32.00 - 36.0	0.80 - 65.0
TiO_2	0.45 - 1.3	<0.1	0.02 - 0.03	0.40 - 53.0
Cr_2O_3	0.30 - 0.7	<0.1	<0.02	0.40 - 4.0
FeO	8.20 - 24.0	13.40 - 27.3	0.18 - 0.34	11.60 - 36.0
MgO	16.70 - 30.9	33.40 - 45.5	<0.18	7.70 - 20.0
CaO	1.90 - 16.7	0.20 - 0.3	19.00 - 20.0	<0.6
Na_2O			0.20 - 0.6	
K_2O			0.03 - 0.15	

The author has taken the knowledge of the composition and distribution of metallic asteroids to construct a theory that states that some fragments of these bodies survive impact and are available as a resource. The basis of the hypothesis is related to the strength of materials of a solid nickel/iron meteorite as found on the Earth, and the known energy of an impacting object hitting the Moon's surface. In essence, the average impact velocity of these bodies is insufficient to either completely destroy them or to eject the fragments from the Moon's gravitational field. Therefore, based on the known statistics of the distribution of NEOs of the nickel/iron type, we can estimate a resource base in the billions of tons distributed on the lunar surface. This has been at least partially verified by the Apollo missions.[24]

Figure 8–2 shows the distribution of platinum group metals (PGMs) obtained from meteorites that have survived Earth impact.[25] Metallic fines (powdered metals) in quantities of 0.1–1 percent are common in Apollo-era regolith samples, indicating a lower bound for this resource. A possible upper bound is known on the Earth as the Sudbury Complex in Canada. The Sudbury mining district in Ontario province has produced nickel for 100 years. Over $100 billion in nickel has been produced so far at Sudbury, with another $100 billion still in the ground.[26] PGM mines are also producing quantities of metals for the market. It is estimated that the total value of all metals from the Sudbury district is in excess of $300 billion.[27] In recent years, the geophysical community has come to the conclusion that the Sudbury mining district is an "astrobleme," or a remnant of an asteroid impact approximately 1.9 billion years old.[28] In South Africa, the famous Merensky Reef mining district is near another asteroid impact known as the Verdefort structure. In truth, we have always used asteroid-derived metals.

Figure 8–2. Platinum Group Metals Concentrations in Parts per Million in Select Terrestrial Meteorites

Meteorite	Pt	Ru	Ir	Au
Arispe	22.85	3.008	11.06	0.771
Bennett County	38.89	26.93	43.87	0.419
Cape York	11.85	7.47	3.13	0.848
Henbury	18.31	14.04	13.78	0.422
Grant	2.84	1.85	0.01	1.910

PGMs are crucial to our industrial civilization as the catalysts for oil refining, the critical element in the coatings for liquid crystal displays for our computers, as well as a vital component in achieving the fantastic data densities of hard drives. PGMs are also the key chemical element that makes proton electron membrane fuel cells work. These fuel cells are the "engines" for automobiles and the hydrogen economy. Without PGMs, there is no hydrogen economy.

It is estimated that it will take the production of over 25 million ounces per year of PGMs to support just the production of fuel cells for transportation uses. Today, that production is only 5 million ounces.[29] There are only five major regions in the world where PGMs are produced. South Africa has most of the reserves of PGMs, and other producers are in Russia, Zimbabwe, the United States, and Canada. The global reserves of PGMs may not be adequate to support this level of production. The United States Geological Survey estimates that there are approximately 48 million kilograms of PGMs in the global resource base, with 72 percent of that total in South Africa.[30] However, the South African government's own estimates are less than 50 percent of that total, and they have recently indicated that the PGMs in the Merensky Reef are virtually exhausted.[31] The limit on the availability of PGMs will pace the hydrogen economy just as much as the limit on the availability of oil restricts our options in the hydrocarbon economy today.

An article in *Resource Investor* from October 2006 illustrates the vulnerability of the United States and its allies in this area:

> The platinum group metals (PGMs) are an excellent example of one such resource controlled today by a virtual cartel made up of private western companies that will never, on their own, allow the price of these metals to grow to the point where they cannot be used, so that demand collapses. The virtual platinum cartel, however, is nervous of the Russians and the Chinese in Africa, because supplies of new platinum group metals are being developed almost exclusively in Russia and Chinese-dominated Africa. Worse for the virtual cartel is the fact that most of the demand for new platinum group metals for autocatalyst, petroleum reforming catalyst and jewelry is coming from Russia and mainland China.[32]

The article also indicated that the strategy of nations such as Russia and China is not to challenge the United States on the battlefield, but to attack the economic foundations of the United States in a way that weakens our ability to field a superpower class military. Russian sources recently have indicated their desire for a PGM cartel similar to the one that existed in the interwar years of the 1920s when African production was nil and they controlled the market.[33] This is why lunar-derived PGMs are increasingly important to access. This is our flanking maneuver. If we have unfettered access to off-planet PGM resources and can deliver them to the market at a reasonable price, then we eliminate the threat to the emerging hydrogen economy that such a cartel would have.

This type of warfare on the economy is outside of the traditional military-oriented purview. However, this is the value of the reexamination of our spacepower theory: to incorporate it into a comprehensive national power theory in order to sidestep the economic warfare that is directed at us today and that will become an increasing threat should we continue to rely only on the resources available on the Earth. With this flanking maneuver, we disarm our adversaries without having to fire a shot, while increasing the wealth of our nation in such a way as to continue to afford our strategic and tactical deterrence.

It is a fair probability that there are vast quantities of asteroid-derived material impacted on the Moon. These resources are several orders of magnitude more accessible and immediately valuable than the proposed Helium 3 resources advocated by others. If there is one nickel/iron body on the Moon whose size is the equivalent of an asteroid a few hundred meters in diameter, then its value is easily several trillion dollars.[34] Today, PGM prices are generally four times what they were in 2003, with platinum costing over $1,300 per ounce. Lunar-derived platinum, refined on the Moon, also would not contribute to pollution or the production of carbon dioxide, both considerations for the future. It is imperative for the United States to not become hostage to unfriendly states for our resources, and the Moon is the gateway to making that happen.

Recent computer modeling simulations support the contention of large quantities of PGMs on the Moon. In a paper presented at the Lunar Planetary Science Conference in 2008, support for the resources associated with metallic impactors was studied by a group of the foremost researchers in planetary impacts. Their conclusions were that:

> 1) Numerous low velocity impacts events will be recorded on the Moon; 2) Projectile material will be relatively unshocked, and largely contained within the crater; and 3) The total mass of the asteroidal material associated with these events is significant.[35]

With the above conclusions based upon solid computer modeling, experimental evidence should be obtainable from remote sensing that will indicate "significant asteroidal material." If even one such multi-billion-ton object of this type was discovered on the lunar surface, it would significantly change the economics of lunar development, to the tune of trillions of dollars worth of concentrated metals.With the number of spacecraft in lunar orbit at this time, such a discovery could happen any day. The question is, what would happen to change the strategic position of the Moon, and how would this work to explode the geocentric mindset?

Another metal of strategic importance to military hardware is titanium. Some areas of the Moon contain upward of 20 percent titanium dioxide (TiO_2) in the regolith. This is a valuable resource in terms of the metal and oxygen for chemical propulsion systems. The Defense Advanced Research Projects Agency (DARPA) has recently invested large sums of money in the DARPA Titanium Initiative (DTi) to develop a process to more efficiently reduce TiO_2 to metallic titanium.[36] This process is aiming to reduce the cost of titanium from $13–$16 per pound to $2–$6 per pound. While this actually makes lunar titanium less attractive as a transportable resource, it does indicate the value that the Defense Department places on this metal.

Anthony Tether, DARPA director, indicated in a 2006 interview that the reduction in price for titanium would result in its being used for steam piping in naval ships, which would reduce wear from corrosion as well as offer weight savings over stainless steel used today.[37] It is interesting to note that 90 percent of the world's resources in titanium are located in Russia. The United States minimized the use of titanium in militarily important systems during the Cold War due to this fact. It is also worth noting that the process of improvement on the Earth for titanium production will also lower that cost on the Moon and result in more cost-effective production of oxygen, one of the key ingredients for liquid-fueled launch vehicles. There is tremendous value both here on the Earth and in space for lower cost oxygen as propellant.

Many studies have shown that lunar production of oxygen has a payback ratio as high as 60 to 1 in improving the ability to lift mass from LEO to higher orbits. Lunar oxygen, derived in 1,000-ton quantities per year, could lead to dramatically lower costs for large spacecraft moving from LEO to GEO or any other orbits in near Earth space. Lunar oxygen could lead to a complete revolution in the way that military communications, remote sensing, and positioning systems are developed and operated. Today, most military LEO assets and GEO assets are limited in life due to the exhaustion of fuel. This places limitations on the operational use of these multibillion-dollar assets as an increased operational tempo results in shorter fuel life (LEO satellites primarily). What if an inexpensive means of refueling these assets existed? This would considerably increase lifetimes, reduce lifecycle costs, and provide an operationally responsive flexibility far beyond today's capabilities. Lunar oxygen would enable this capability with titanium and other metals as the side benefit.

In developing lunar metals and oxygen, the probability of a positive feedback mechanism for terrestrial mining exists. It is inevitable that as we begin large-scale efforts to derive oxygen and metals from what is nominally base rock, we will discover ways to improve the processes and reduce costs. These methodologies could feed back into terrestrial processes to improve them as well. The problem on the Earth is the lack of concentrated resources rather than lack of supply, at least for the base metals. Since the dawn of civilization, mining on Earth has relied on the localized enhancement of valuable resources based on volcanism (veins of gold in quartz intrusions, for example), weathering (placer deposits), and other processes that do not exist on the Moon. If we can, through the exploitation of lunar resources, improve the processes here on Earth, we can continue to increase the supply of industrially important metals. This does not work for rare and valuable metals such as PGMs, titanium, and other strategic metals that are not common in the Earth's crust. This positive innovation feedback loop has been discussed by Robert Zubrin (author of chapter 12 in this volume) in his works on Mars as well.

Industrial production on the Moon and in cislunar space. Very little has been written in recent years concerning lunar industrial-scale production, but a lunar materials extraction economy inevitably leads in this direction. For example, for every metric ton of oxygen produced using titanium as a feedstock, 1,375 kilograms (3,025 pounds) of titanium result. For every metric ton of oxygen produced from an iron oxide, 2.4 tons of iron are produced. For every metric ton of oxygen produced from aluminum oxide (Al_2O_3), 923 kilos of aluminum (2,030 pounds) result. It is likely that oxygen in multi-ton lots will be made to support the reduction in costs associated with NASA's "Vision for Space Exploration." Preliminary estimates are that 269 tons of liquid oxygen could be stored per year if the spent descent stages from NASA's Lunar Surface Access Module are used for storage, increasing by this amount per year as the spent stages build up on the lunar surface.[38] This means that there are potentially going to be hundreds of tons of base metal available very quickly after NASA begins its outpost operations on the lunar surface. This does not include any possible resources from NEO metallic impactors.

With all of this metal, what can be done? Many advanced manufacturing processes today use a vacuum to improve the quality of processed alloys. These alloys, when poured into sheets, beams, or other structural support material, can be made into living or manufacturing space on the Moon. With abundant oxygen for propellant (hydrogen brought from the Earth or locally derived), spacecraft could be built with physical parameters unlike anything made today. In 2004, one of the author's companies did a study for DARPA Special Projects Office for an optical system with a primary optical mirror diameter as large as 50 to 100 meters.[39] This optical system would form the core of a persistent surveillance system with a ground resolution of <1 meter over an area the size of Iraq or Iran. This system could be built almost entirely of lunar-derived materials for the structure and even the mirrors using a silicon foam process developed under contract to the National Reconnaissance Office by Shaefer Corporation. The velocity change to go from the lunar surface to GEO orbit is only slightly more than departing from LEO (3.8 km/sec^{-1} versus 3.0 km/sec^{-1}) and less than a third of the energy required to lift the same payload from Earth.

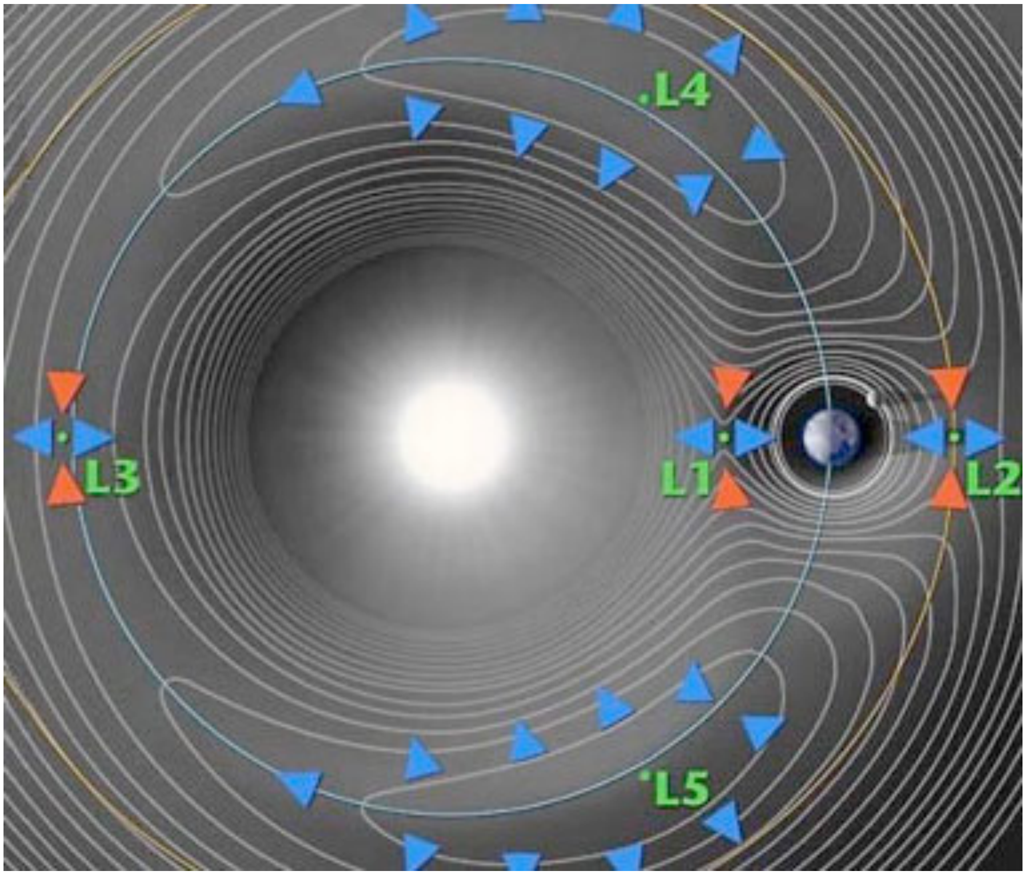
The U.S. Armed Forces today have far more requirements for space systems than they have money to fulfill them; time and time again, programs have been cancelled due to excessive costs. At some point, the Services will have to consider alternate means to satisfy the growing need for space operations capability. Many smaller missions such as the TacSats and the XSS–10 and 11 spacecraft have proven the rudiments of space operations capability. However, when DARPA took the next step with Orbital Express, the costs quickly spiraled out of control.[40] Orbital Express proved out many of the technologies needed to extend the life and expand the operational capabilities of U.S. strategic and tactical space assets. The Department of Defense must move from high-cost developmental missions to a routine military/commercial model in order to achieve the operational cost reductions necessary for future space systems. A robust American space operations capability demands that we meet future threats to our assets in space and deny potential adversaries the use of their own systems. With the dramatic brain drain at work in the American aerospace industry today, we simply must look at new ways of doing business.

Responsive space has also become a buzzword of note in the space community. However, the vast majority of efforts in this area have focused on launch vehicles. We live at the bottom of a deep gravity well. The day is fast approaching where we will either aggressively adopt alternate means of obtaining responsive space access or continue to pour billions into a process that at its very best provides only incremental improvements in capability. An expansive capability to access material resources derived from the Moon will provide a true transformational capability to the warfighter. The top leadership in the Nation understands the transformational nature of the economic development of the solar system, and this is codified into law by Congress. The Moon and its development are the first jumping-off point for this effort.

Spacepower theory and the economic development of cislunar space. In the expansion of spacepower theory from a purely geocentric mode to a more expansive one, near Earth space—including the Moon and libration points (the gravitationally stable regions of the Earth/Moon and Earth/Sun system—is the first near-term logical extension of our economic sphere. In energy terms, this includes all space within the gravitational influence of Earth, which stretches for a radius of approximately 1 million miles from the center of Earth.[41] A gravitational potential plot of the Lagrange points is shown in figure 8–3. These gravitational potentials indicate stable points where spacecraft can maintain their position with little or no fuel expenditure relative to their position in Earth orbit. Today, we have several scientific spacecraft in these orbits, providing important information about the Sun and giving warning of dangerous solar storms that can damage spacecraft in Earth orbit. There are also similar Earth/Moon Lagrange points that are 20,000 miles inside and outside of the Moon's orbit (L_1 and L_2).

Figure 8–3. Lagrange Points in Earth/Sun System

(Image Courtesy of Wikipedia)



Proximity is the first principal reason for an initial generation expansion of spacepower theory to encompass the near Earth environment. The Moon is only 3 days away for humans and unmanned vehicles using chemical propulsion. The lunar Lagrange points are at a similar distance. The Earth/Sun Lagrange points are a few months away in terms of time to get there, but energetically they are easier to get to than the surface of the Moon. As spacepower theory develops for near Earth space, we must begin to think in terms of time and energy as important considerations in military/civilian logistics. The second principal reason is related to the resources available from the surface of the Moon. Even if NEO resources are limited to the dispersed fines already known from the Apollo missions and the amount of water at the lunar poles is considerably less than forecast, the Moon's vast quantity of materials and the potential for permanently lit locations at the poles represent the new economic high ground of space. The lunar poles have the two critical ingredients needed for an off-planet industrial system: inexpensive energy and material resources in abundance.

Even though competition for these locations has not yet begun, it is inevitable. The nations and industries that establish themselves at the poles will gain a dramatic strategic advantage. In space, energy is everything, and it is only at the lunar poles (more in the north than the south) that the Sun shines through most if not all of its monthly rotation. This allows inexpensive solar power to be used rather than relying on expensive nuclear power. A solar power system can be implemented on an incremental basis, and some researchers have devised ways to actually make solar cells on the Moon, providing a bootstrap approach to power levels all the way to the gigawatt level.[42] Having abundant energy available from the Sun aids in developing the lunar industrial infrastructure, considering that the biggest users of energy will certainly be the oxygen and metals production industries.[43]

As the emplaced power grows, so does production capacity in direct proportion. Large enclosed structures can be built for living space, food production, and advanced manufacturing, both in the extreme lunar vacuum and within an atmosphere. With even a modest production rate of tons per month, new systems, both manned and unmanned, can be constructed that are as far beyond the Apollo or current NASA plans as the 747 is beyond the Wright Flyer. Building a system that launches from a surface in vacuum eliminates the current constraints of the pencil-shaped launch vehicles and their fairings. The low energy for transit enables the construction of large GEO structures for many purposes, which will help to preserve the ability to use that orbit and lessen the need for formation flying systems in today's crowded equatorial orbit.

The advantages of the Moon only begin with the examples given in the previous sections. With lunar manufacturing and propellant production enabled by plentiful energy, we can build spacecraft that can travel to NEOs such as 2004 GU9, a small body that is actually gravitationally bound to Earth at this time. With advanced spacecraft and with operational experience gained in near Earth space, it becomes relatively easy to reach resources far in excess of what is available on the Moon.

The skeptic at this point would insist that the cost/benefit ratio for going to the Moon and extracting resources will never have a positive payback. That is because most previous efforts described the resources in geocentric terms, whereby only raw materials and possibly energy were beamed back to Earth. This limited perspective was developed by previous generations of space advocates who envisioned beaming power back to Earth or bringing the raw materials back to Earth or LEO for processing. By expanding our perspective to building a bootstrapping industrial infrastructure, it becomes possible to build up the robust operational capabilities that would be needed to lower the cost of transportation within all near Earth space. With reusable space-based systems, the cost of transportation can decline to the marginal cost of fuel plus profits. This leads to an actual cislunar economy where advanced high-tech materials flow from Earth to the Moon, and industrial production and high-value resources such as PGMs flow back to Earth, which benefits with new GEO platforms for telecommunications, remote sensing, and other applications not possible with individual spacecraft launched from Earth. The sky is no longer the limit, and this is just the beginning.

It is the GEO applications that will drive private enterprise in the development of cislunar space. Private enterprise in space today is a conservative enterprise with well-defined parameters related to risk mitigation, profitability, and technology implementation. Commercial GEO assets have advanced technologically in a very incremental way, and this is not likely to change in the near term. However, some proponents (including this author) advocate that by using existing space assets such as the International Space Station as a base to construct commercial GEO platforms, the first steps can be taken toward shifting the technological implementation rate in a profitable manner. Unfortunately, at least in the near term the Moon will not be a bastion of private enterprise without a parallel government effort that goes beyond the minimalist efforts that characterize the current NASA plans. This is where a wider spacepower theory development can play a critical role in informing leaders across the government of the economic development potential of cislunar space. Today, the United States has the technological and financial wherewithal to execute on the ideas set forth herein. It is a matter of will if we do so. The risk is low, and the results will continue to benefit the Nation for possibly hundreds of years.

The Resources of the Near Earth Asteroids

There are no technological showstoppers preventing the United States from aggressively moving into the solar system to exploit its economic potential. The great thing about this move is that there is enough for everyone. With the Moon as the first link in a chain of economic development, we next step out to the NEOs.

In his book *Mining the Sky*, John Lewis of the University of Arizona developed some amazing statistics concerning NEOs. The sizes and numbers of asteroids whose orbit either crosses the Earth's orbit or comes between the Earth and Mars are as follows: 1 kilometer or larger, 1,000 to 2,000 objects;100 meters or larger, 500,000 objects; 10 meters or larger, 100,000,000 objects.[44] A 10-meter asteroid, weighing about 100,000 tons, hitting the Earth at an average speed of 20 kilometers per second, has an equivalent nuclear yield of 100 kilotons, or 5 times larger than the devices used at Hiroshima and Nagasaki. It is known by the study of meteorites that approximately 3 to 4 percent of the NEO bodies are nickel, iron, cobalt, and small quantities of PGMs. On top of this, about 5 percent of these bodies are known to be carbonaceous chondrites (CC), with up to 20 percent water in hydrated minerals, carbon, nitrogen, oxygen, and even greater fractional quantities of PGMs than the metallic asteroids. This means that there are significant economically valuable resources available on bodies that energetically are as easy, if not easier, to land on than the Moon. Additionally, it is strongly suspected that the inner moon of Mars—Phobos—and possibly the outer moon, Deimos, are CC bodies. The water in these bodies can be obtained by placing the hydrated minerals in an enclosed vessel and simply heating to 400° C.

Here is a scenario related to a metallic and CC body. First of all, it is entirely possible that a kilometer class metallic asteroid has impacted the Moon and remained at least somewhat intact. The smallest positively identified metal asteroid is the 2-kilometer sized 3554 Amun asteroid, estimated by Lewis to be worth between $20 trillion and $30 trillion in metals.[45] The largest metal asteroid known is 216 Kleopatra. This body is a dumbbell-shaped object approximately 217 by 94 by 81 kilometers.[46] This is a main belt asteroid, more difficult to get to than 3554 Amun, but a very cursory estimate of the value of this asteroid is 1 billion times the $30 trillion value of 3554 Amun. There are tens of thousands of these metallic asteroids that are easier to get to energetically than the orbit of Mars. There is little danger of asteroidal metals cartels controlling the distribution of these resources. If there is an intact body of this size class on the Moon, then there is instantly a resource of PGMs greater than the aggregate global reserves of these metals.

The second scenario is the discovery of water on Phobos and Deimos, the moons of Mars. Phobos is ~22 kilometers in diameter, and Deimos is ~12 kilometers in diameter. If one or both of these bodies are CC type asteroids, a mission could be sent there for less energy than it takes to land on the Moon. These bodies literally could become gas stations as the estimated potential amount of water on Phobos could be in excess of 100 billion tons.Couple this with the possibility of water on the Moon (estimated at between 100 million to 1 billion tons), and the fuel becomes available to move around in the inner solar system. Add to this the hundreds of billions of tons of water available as hydrated minerals on NEOs, and there is virtually an unlimited supply of fuel for operations in the inner and mid solar system.

Mars

Although this presentation does not discuss the promise of Mars, the author does see it as an intrinsic part of the overall plan for the solar system and agrees with Zubrin that Mars has all the necessary resources to become a second permanent outpost for humanity. Coupled with the rich resources of the asteroids, the Moon, and energy available in free space, the author feels confident in the future of a prosperous humanity. One counterpoint to Zubrin is that we must begin with a less onerous target than Mars. While Mars has material resources far in excess of the Moon, the distance and the problem of a lack of plentiful energy without nuclear power indicate that gaining operational experience in the backyard of cislunar space brings enough benefits to the development of Mars that it is worth the time it takes to do so.

Energy

Far more than resources, energy is the Achilles' heel of modern society. The exploitation of the resources of the solar system addresses this issue through indirect methods.

Lunar Power

A chapter in this volume advocates the emplacement on the Moon of 1 gigawatt of electrical power by the year 2030. This is difficult but achievable if the will of the government is coupled with appropriate economic incentives to private enterprise. This power would be used locally on the Moon to drive economic development to produce propellants and metals for lunar industrialization. Plentiful energy is the key on the Moon as on Earth. With this level of power, the United States would have an incredible operational capability to support the development by private enterprise of manufacturing infrastructure that could be used to support any level of space activity desired by the U.S. national security enterprise.

Fusion

Harrison Schmidt makes a convincing argument concerning the energy content of helium-3 (He_3), which is known to be available in diffuse quantities on the Moon.[47] Many obstacles must be overcome to be able to utilize He_3, but the investment in fusion power is the world's ultimate liberator from enslavement to hydrocarbon energy. Practical fusion systems are under development today with the 2006 signing of the ITER Agreement, an international fusion energy agreement. The United States should dramatically increase its commitment to include building its own research reactors on the Moon. Its vacuum removes a major impediment in the operation of a fusion reactor.

The hydrogen economy stands or falls not only on the availability of PGMs but also on the production of vast quantities of electrical energy to split water into hydrogen and oxygen. Fusion does this in a carbon neutral way, and a He_3 reactor will ultimately be the radiation byproduct–free way of generating this power. Eventually, this He_3 could be obtained from the atmospheres of the outer planets, where it is billions of times more plentiful than on the Moon. But again, this treads a path well into our future. Both He_3 and its acquisition at the outer planets are entirely possible by the latter decades of the 21st century.

Conclusion

This chapter has sought to stimulate a change in mindset in the development of a coherent 21st-century spacepower theory. Beginning with the dramatic restatement of American goals by OSTP director Marburger to economically develop the solar system, this chapter proposes that this become a core value of a future American spacepower theory. The struggle for global control of energy and planetary resources is actively under way today. At this time, the U.S. Armed Forces are ill prepared, both psychologically and materially, to actively influence these events within the context of current power theory, which are in the realms normally reserved for civilian leadership. It is proposed that spacepower theory build upon the theme of economic development of the solar system and a wide ranging operational capability to operate in inner solar system space. The resources available from the Moon are a beginning step in this process. Near Earth objects represent an incredible boost to our nation's wealth, helping us sidestep issues of direct conflict with potential adversaries.

The cost of this economic expansion into space is not cheap. However, it is not more expensive than the current operational tempo in the Middle East or the recent economic stimulus spending. The United States is entering an era more dangerous than any it has ever faced, and it is incumbent upon the engineers and scientists who build space hardware to provide decisionmakers proper advice on what can and cannot be done in this arena. NASA in the 1960s went to the Moon when it was virtually impossible to do so except for with the mobilized resources of an entire nation. Today, this can be done with a mixture of policy decisions, limited financial support, and the enablement of private enterprise. With the Moon as a beginning, the economic development of the entire solar system becomes possible and mankind will be freed from the cradle of our birth. All that is necessary to begin this process today is the realization by decisionmakers that this can be done.

Recommendations

This change can begin with the resources already in place today or expenditures that are already within the planning of the Armed Forces and NASA. Following are some recommendations on things that can be done now, with no more risk than the current operating environment for space.

Tax policy. A bill to remove the levying of Federal taxes for profits made in off-planet activities (not including existing communications and remote sensing satellites) with a holiday of not less than 20 years would help provide incentive for private investment in space. This bill, called the Zero G Zero Tax Bill, passed the House and was defeated by a few votes in the Senate in the year 2000. This bill should be passed.

Transponder bandwidth long-term purchase. The Armed Forces and Congress have resisted this approach as it reduces flexibility in expenditures and scheduling. However, the Leased Satellite program of the 1980s provided significant capabilities to the Armed Forces without having to pay for development costs. The profit motive allowed the contractors to utilize maximally efficient development techniques for spacecraft in order to obtain a profit for the deal. This model or something similar should be implemented in order to offer incentive to commercial U.S. providers only. If the issue is concern over survivability under attack, simply levy appropriate requirements on the commercial provider and provide cash incentives in the transponder lease to cover the costs.

Asteroid search. The Armed Forces through the LINEAR program already have a NEO detection network in place. Follow this up with instruments capable of spectrophotometry of these bodies in order to increase the confidence of mission planners in the potential resources of these bodies. This program has been highly successful in locating these objects, and spectrographic follow-up will be similarly useful to the astronomical community.

Operationally responsive space. Much is written about this area of military operations, albeit with a geocentric approach. Expand the parameters of the definition of operationally responsive systems to include on-orbit servicing of existing assets. Also, expand the definition to include propellant depots, the on-orbit assembly of spacecraft, and the ability to navigate ubiquitously in cislunar space.

Advanced studies. As a beginning, provide funding through DARPA for advanced (above seedling level) studies on the uses of lunar derived materials to construct persistent surveillance systems in GEO and other orbits. Also, provide funding similar to the titanium initiative for the reduction in cost to provide lunar oxygen, metals, and manufacturing infrastructure to support large GEO platforms for communications and other operational needs.

Practical Effects of a Solar System–encompassing Spacepower Theory

Conflict will not end with expansion into the solar system. There will always be reasons for conflicts, but one of the major ones throughout history, the acquisition of resources, will change focus. The strategic focus will change to acquiring the most easily accessible resources off planet rather than a scramble for the remaining resources here on Earth. It is speculated that a psychological shift in the populace of the world will take place that will lessen the causes for conflict here. If it is seen that there are resources beyond those of just our one planet, then much of the strategic posturing that is in active process today by China, India, countries in the Middle East, and Russia will be rendered moot, as it is based on securing a dwindling terrestrial resource base.[48]

The biggest problem that confronts the United States today is that many who would read this simply refuse to believe that what is laid out in this chapter is feasible. From those of us who have given our lives to the development of space, we assure you that all of this is possible and indeed necessary if we are to transcend the physical resource limitations that confront our civilization today. Problems such as climate change cannot be solved simply by conservation and alternative energy. We need to create a planetary civilization that provides opportunity for all of our world's citizens to have a better life than our ancestors and provide our children with the same beneficial society that we enjoy today. With the resources of space, this becomes possible. Without them, we are on a course toward conflict far worse than the skirmishes that have defined the last 30 years of history. We have a choice before us, and the results of the choice made by our generation will last for a very long time. Ideas are the currency of hope, and the idea of an expansive economic development of the solar system is a necessary step in educating our political leaders and our people of the hope that is out there for us to grasp.

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Chapter 9:
The Long-term Outlook for Commercial Space

Ivan Bekey

The Nation's space programs are in a horrible mess and appear to be locked in a downward spiral. Almost all defense and civil government space programs suffer from similar symptoms:

- no toleration of or planning for failures
- avoidance of risk
- lack of funding for new technologies
- inability of industry to afford research or to develop technologies alone
- suppression of disruptive technologies
- disappearance of the concept of experimental systems in space.

As a result of these symptoms, the following conditions are now the norm:

- absence of innovation
- long timelines for even modestly new developments
- billion-dollar price tags for major systems
- major overruns and schedule slips
- need for long on-orbit life to amortize the investment
- obsolescence of systems upon launch or soon thereafter.

Although these symptoms and conditions have been deliberately overstated for emphasis, they are more true than not. The question is then: Is there any way out of this morass? After all, countless committees have grappled with this situation and proposed courses of action, but apparently to not very much effect. In fact, the problem really has no solution as long as the U.S. Government remains the principal customer for space systems for several reasons: the government suffers from chronic risk aversion, it avoids new technologies and concepts, it has deep pockets of tax money and protests otherwise, there are few real incentives to save major amounts of money, new space systems are overloaded with requirements that guarantee that they overrun budgets and timelines and underperform, and the requirements process is broken so that even if requirements initially are contained, they inexorably will rise during a program and lead to major cost and schedule growth.

The only escape from this situation is to use market forces to bring costs down and spur innovation. This typically is how commercial systems live. However, a large market requires that products and services be relevant to large numbers of people. It requires risk-taking and a willingness to fail often. It requires many actors in competition, which means commercial approaches to space products and services.

The government's role must be to take most of the risk out of new technologies, which the private sector cannot now afford to do. Furthermore, the government must avoid competing with the private sector (we should imitate Japan, where the government and industry are partners in fostering national growth, whereas in the United States they are more adversaries than partners). In short, the Nation's space programs must mimic how commercial systems in general have always worked and how commercial space systems in particular must work.

New Technologies as Drivers

In the next few decades, an explosion of new technologies will transform space systems, including commercial ones, in every way. While it is impossible to forecast what technologies and systems will appear, there are a number of currently identified, though not yet fully developed, technologies that will enable a great number of advances to be made in the space field. Some purveyors of current techniques and systems view many of these technologies with suspicion because they have seen past technology development efforts take longer and be much more difficult than anticipated, and they then project these real-life experiences, rightly or wrongly, onto all future technology proposals. Others are heavily invested in current technologies and are threatened by the promises of newer ones, consciously or unconsciously. And other purveyors are skeptical of the new technologies because they lack the proper science grounding or fail to understand the technologies' principles of operation.

Many people will label the technologies discussed in this chapter, and therefore the space capabilities that they will enable, as somewhere between too optimistic and bordering on science fiction. I would like to offer two perspectives as defense against these criticisms. The first is from Arthur C. Clarke: "Any sufficiently advanced technology is indistinguishable from magic." The second perspective is from Niccolo Machiavelli's *The Prince*: "Those who advocate a new order of things have a very difficult journey, for they have as enemies those who would lose by the introduction of the new, and yet only lukewarm supporters in those who would gain thereby."

The only credible way to make the case that the technologies that will be presented are not too risky or optimistic is to examine the capabilities and technologies that existed 50 years ago and compare them with today's technologies that are accepted as commonplace (see figure 9–1).

Figure 9–1. 50-year Technological Perspective

A projection 50 or even 25 years into the future will fall short because we may underestimate the pace of exponentiating technological development and we cannot forecast new inventions. As a result, it is proposed that the technologies about to be discussed are a reasonable set to expect to see developed in the future, possibly much sooner than 50 years because of the accelerating pace of technology. Rather than offering too optimistic a vision of the future, these technologies probably present, if anything, too conservative and myopic a view. Some thoughts on the likely steps, time, and effort that will be required to bring these technologies to maturity, with the understanding that such an effort is fraught with uncertainty, are offered later in the chapter.

Some of the technologies with maximum leverage, presented in random order, include:

- carbon nanotube composites and pure grown structures and devices
- nano-engineered carbon nanotube electronics, detectors, solar arrays, components, heat pipes and radiators, and multifunctional devices
- high specific impulse (Isp), high thrust micromachined field emission electric propulsion thrusters
- space tethers and tether arrays
- large adaptive membrane optics and antennas (to replace precision structures with information)
- ultra-efficient and lightweight quantum dot/nanostructured solar power arrays

- formation-flown autonomously cooperating swarms of silicon satellites
- adaptive, semi-autonomous, modular, self-assembling systems.

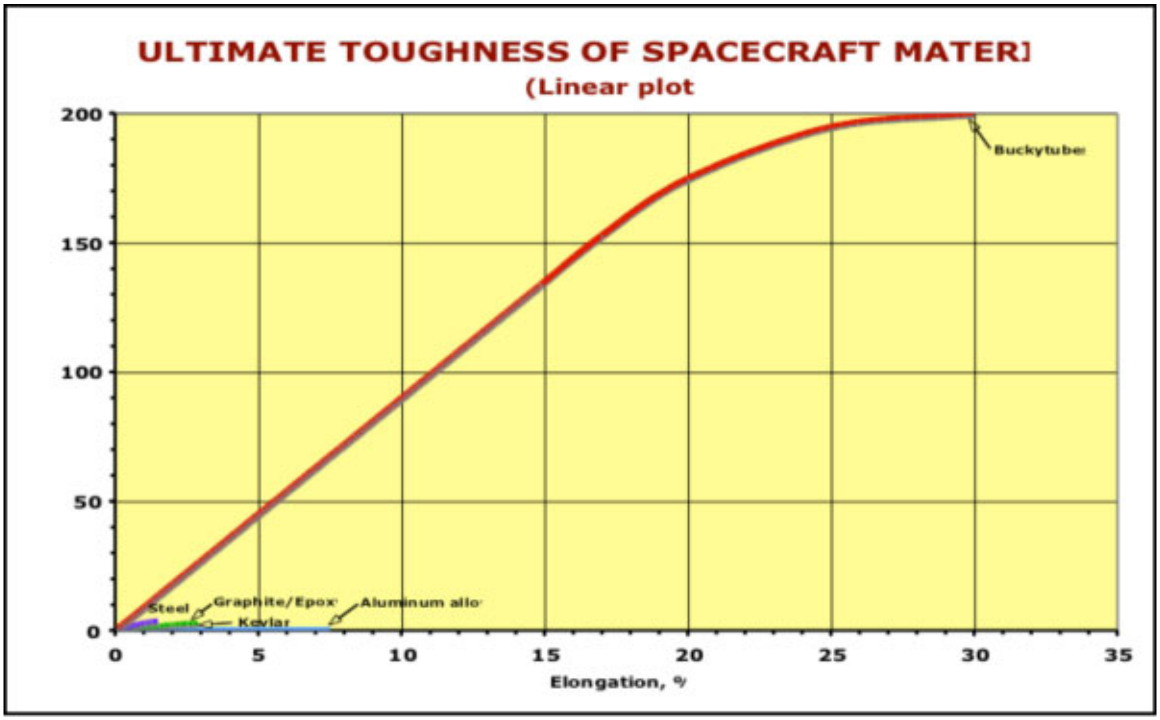
These and other new technologies will revolutionize space system applications. These applications will transform defense and civil space programs but will also enable commercial programs in the process. The result will be a space future that is very different from today's practices and will include:

- huge apertures for sensing anything from geostationary orbit (GEO)
- enormous and inexpensive power available anywhere in space or on ground
- lightweight yet large spacecraft that have little or no structure
- inflatable and membrane-based habitation and utility space modules
- semi-autonomous, adaptive, reconfigurable space systems
- routine in-orbit servicing and upgrading on schedule or on demand
- true mass production of picosats with radically lowered spacecraft costs
- acceptance of failures of experimental and new technology space systems
- dramatically reduced costs of all spacecraft
- access to space that is commonplace and comparatively "free."

While each of the above and other technologies will have a major effect, the carbon nanotubes or buckytubes will have the greatest effect and will result in access to space at costs so low as to seem free relative to today's launch costs of about $20,000 per kilogram.

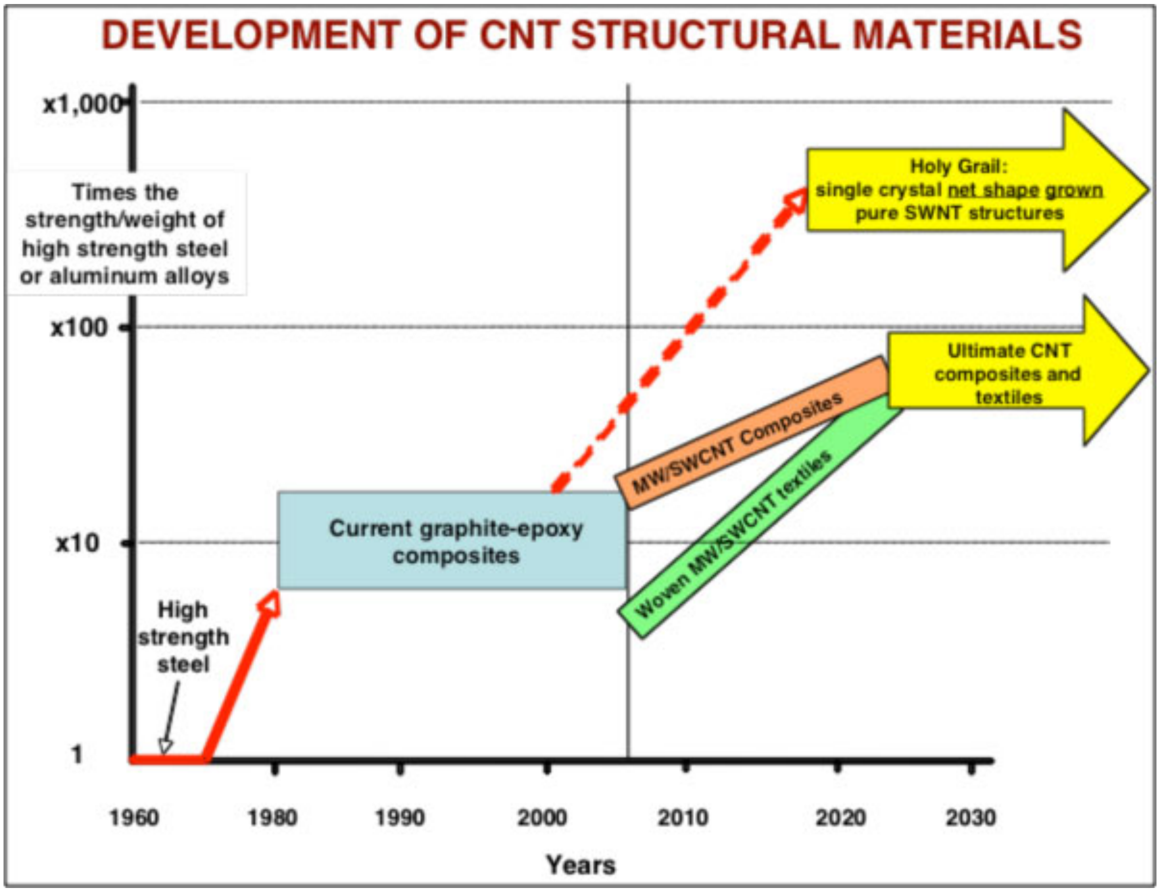
Carbon nanotubes are a new form of matter discovered just over a decade ago. They are perfect molecular structures of carbon atoms, forming carbon-carbon atomic bonds into hollow cylinders; they are true carbon polymers. This material is the strongest and stiffest one possible in this universe, as the carbon-carbon double valent bond is the strongest known. Carbon nanotubes have a strength-to-weight ratio 600 times greater than high-strength steel or aluminum alloys. The material is very flexible and tough; it can elongate 20 to 30 percent and yet rebound with no damage. Likewise, it is tolerant of buckling on compression and can recover with no damage. It conducts heat three times better than pure diamond, has an electrical conductivity like copper, and can be grown to be a metal or a semiconductor. It is the most thermally stable of all polymers, has the highest possible accessible surface area of any material, and will not rust or corrode to over 900° F. The phenomenal strength-to-weight ratio and toughness of carbon nanotubes is illustrated in figure 9–2.

Figure 9–2. Ultimate Toughness of Spacecraft Materials



These materials will revolutionize spacecraft (as well as practically all ground and air uses), but as in most things, change will come incrementally—with initial forms being composites whose matrix is laced with carbon nanotubes, spun textiles of carbon nanotubes in randomized orientations—and only eventually reaching the holy grail: the growing of net-shaped, pure, single-wall carbon nanotubes with wall-wall tube contact and with all tubes in a parallel or desired orientation (see figure 9–3).

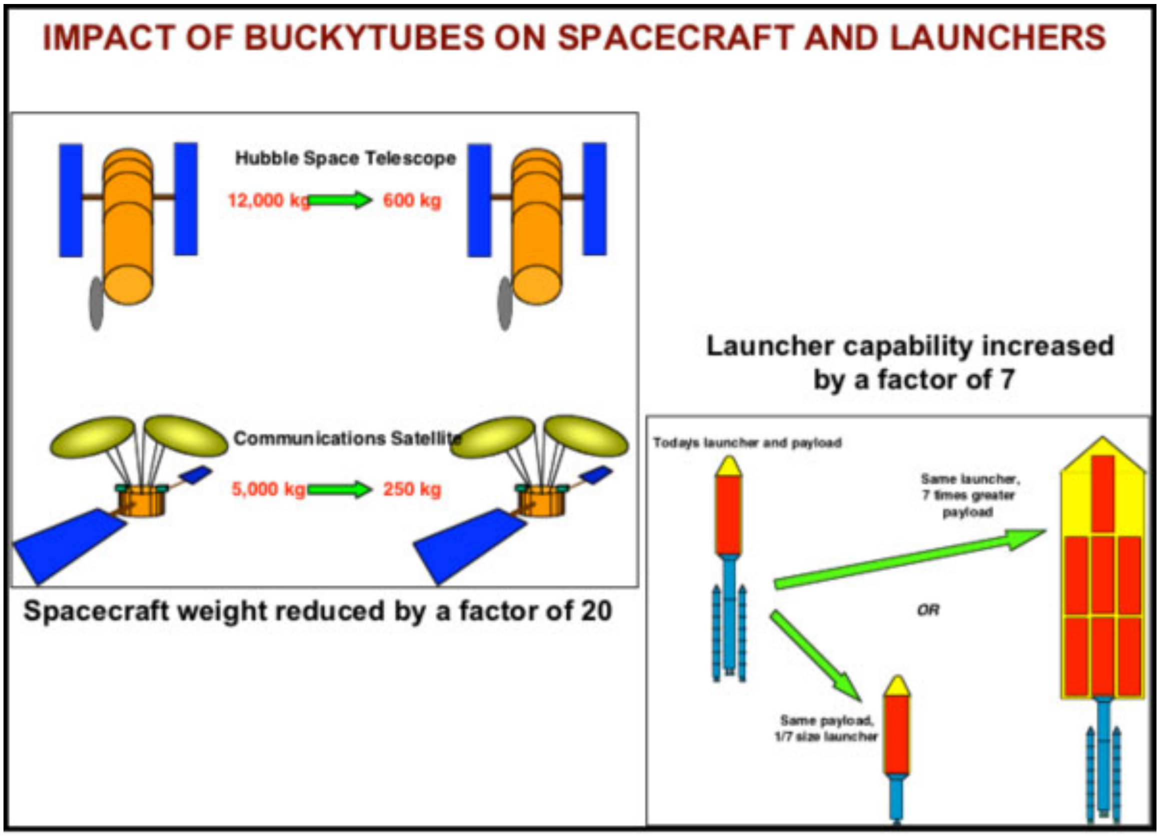
Figure 9–3. Likely Development of Carbon Nanotube Material



While recognizing that progress will be incremental, we will focus on the ultimate impact of the pure grown single-wall carbon nanotubes. Typically, people focus on spacecraft structures and conclude that carbon nanotubes will at most reduce the weight of a spacecraft by 15 percent, the fraction of an average spacecraft that the structure represents. But this is in error, since in the timeframe of interest, practically all components and devices of spacecraft will be able to be grown with carbon nanotubes. This includes tankage, plumbing, engines, electronics, solar arrays, actuators, batteries, momentum wheels, antennas, sensors and their apertures, and on and on. It is therefore likely that practically all of the components of a spacecraft can be made of carbon nanotubes. The actual weight reduction of a component upon substituting carbon nanotubes for today's materials depends on how the component is loaded. Materials experiencing mostly tension will see a weight reduction of a factor of 600 compared to steel or aluminum alloys, while those in bending or compression will see the square root of 600, or 25. However, if we consider the actual fraction of a typical spacecraft that is employed by each subsystem and the weight reduction potential in that use, the typical entire spacecraft will see about a factor of 20 weight reduction.

Similarly, if all the components as well as all structure elements of a typical launch vehicle were made from carbon nanotubes, its dry weight would be reduced by a factor of over 50, but its effect on the lift capability of the launch vehicle would be a factor of 7 (see figure 9–4).

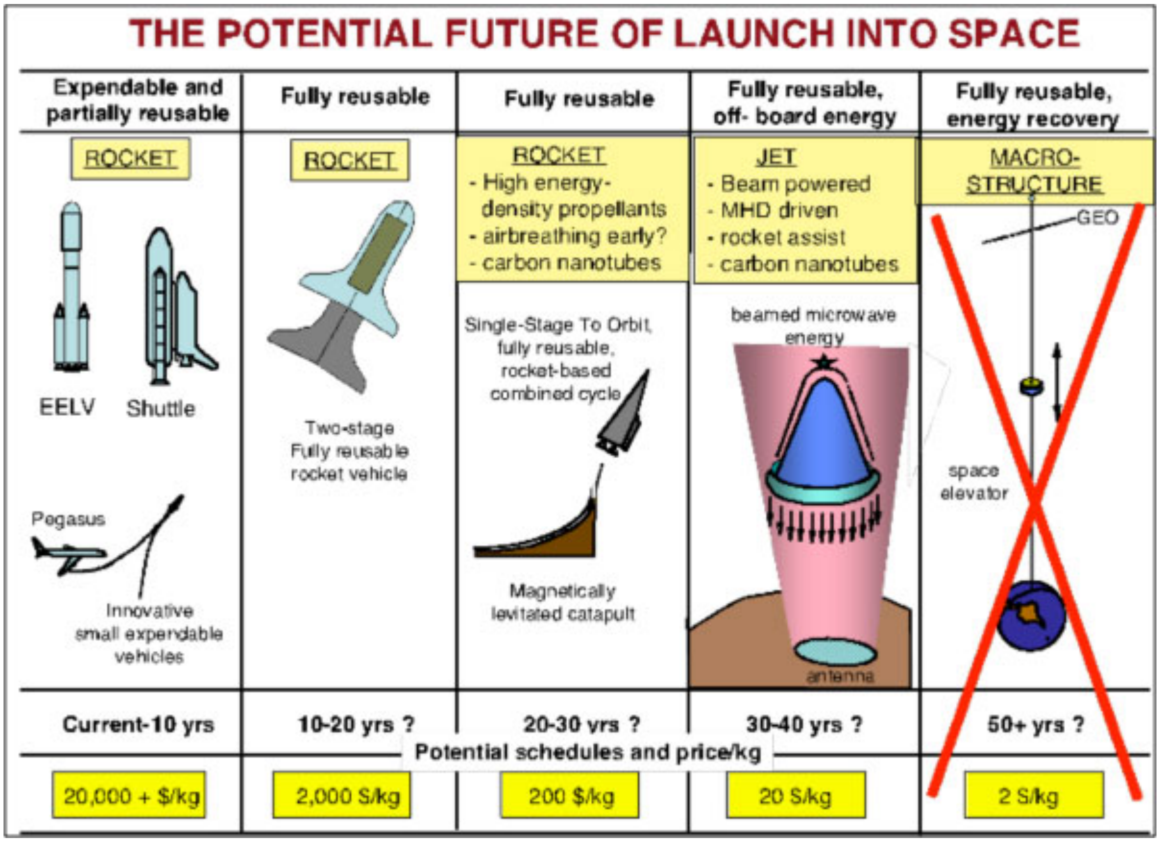
Figure 9–4. Impact of Carbon Nanotubes on Spacecraft and Launch Vehicles



The implications are clear from the figure: the net effect of reducing spacecraft weight by a factor of 20 without sacrifice of function, and the increase of launch vehicle capability by a factor of 7 for the same size, together result in a factor of up to 140 in reduction of the costs of fielding a space system, solely due to the introduction of pure oriented carbon nanotubes. While it remains to be proven in practice, this weight reduction for the same capability—or, conversely, the capability increase for the same weight—should translate directly into a factor of up to 140 in cost for the same capability.

Amazingly, it does not stop there. The technology of launch vehicles will result in roughly one order of magnitude decrease of launch costs every decade or so independent of the introduction of carbon nanotubes (see figure 9–5). This is not a pipe dream but rather is based on many studies performed over the years by the National Aeronautics and Space Administration (NASA) that have shown such price reductions; however, the time period in which these steps are likely to be attained is based only on what could be done if the will and budgets existed. The early steps are likely to occur later; however, when carbon nanotubes are introduced, it is likely that the later steps will occur sooner and prompt even more dramatic cost reductions than shown in the figure. The last step shown in figure 9–5 is the widely publicized space elevator, a concept long postulated that could be made feasible by carbon nanotube materials but that would be totally impractical because every satellite currently in orbit or that will ever be launched into orbit would eventually collide with it and destroy it. No reasonable, effective countermeasures have yet been identified, so the space elevator is unlikely to materialize.

Figure 9–5. Potential Future of Launch into Space



The net result of the foregoing is that the costs of access to space a few decades from now will be comparable to those of airborne systems and will be so low that, compared to the costs of current vehicles, launch into space will be relatively inexpensive. This will bring the costs of space programs into an attainable range for a large number of commercial entities, which will begin to develop and field their own space systems to offer products and services in the marketplace. The entry of commercial enterprises will be the key to breaking the downward spiral of the Nation's space program. In fact, it will enable a second industrial revolution, but this time in space.

The Space Industrial Revolution

The revolution that will be enabled by finally bringing space fielding and operations costs in line with all other operations costs in the air or on the ground will unleash a plethora of services that have been studied and discussed over the years but that have not been taken seriously due to high costs of doing business in space.

Some of the commercial space programs that could take off include evolution of conventional services, including communications, navigation, tracking and location, and remote sensing. However, a host of new products and services will emerge, some robotic and others manned. The robotic services will include:

- global Federal Express–like delivery services
- provision of commodities from extraterrestrial sources
- provision of light from space for night illumination and crop growth
- power distribution via space relays
- power delivery from space
- power distribution utilities in space
- contracted provision and support of some "defense" functions.

The manned services will include:

- public travel to suborbital space
- rapid public travel through space from point to point
- public travel to space hotels and resorts
- space business parks
- space sports pavilions
- space movie studios
- support for NASA human exploration
- commercial lunar and asteroid mining
- operation of space infrastructure.

Potential Commercial Space Programs

A few of the most likely commercial space programs that could emerge in the 2010 to 2040 time period will be described here.

Public space travel (space tourism). Public space travel has been on the forefront of the commercial drive into space for decades, only awaiting reliable and less expensive space transportation to materialize.

Suborbital space travel—that is, climbing to an altitude of at least 100 kilometers—officially qualifies the traveler as an astronaut by international agreement. The drive into suborbital space was greatly aided by the X-prize competition, won in 2004 by Burt Rutan's SpaceShipOne and his pilot. Other candidates are still trying to get off their flights, including other air-launched first stage configurations. There is a healthy but relatively small market forecast for suborbital flights, since they entail at most a few minutes of weightlessness, even though they are much less risky than orbital flights. Nonetheless, Virgin Galactic, the company formed to commercialize the SpaceShipOne concept, has several hundred reservations.

Surveys done in the last decade suggest that orbital flights are needed for a large market to develop. The surveys predict that 100,000 people annually would like to go into space at a $100,000 ticket price, and 1,000,000 would go annually at a $10,000–$20,000 ticket price. Public space travel (space tourism) has already started with a few wealthy tourists going to the International Space Station (ISS). While suborbital travel has yet to occur, commercial suborbital flights are planned (Rutan/Virgin Galactic). Initially, tourists will stay in the transportation vehicles, as they must for suborbital travel, but they will also do so in the initial orbital trips. If public space travel is to develop as hoped for, orbital hotels will be needed. This would represent a new business for the travel industry with a forecast market well over $30 billion annually. Hilton, Sheraton, and others are beginning to consider such ventures; however, entrepreneur Robert Bigelow has funded and flown, at his own expense, a test inflatable habitat (Genesis) and fully intends to develop and orbit space hotels.

Once demonstrated to be safe, the necessary inexpensive orbital vehicles will inevitably follow, starting with initially expendable vehicles adapted from evolved expendable launch vehicles (EELVs), and eventually transforming into fully reusable vehicles (Kistler two-stage-to-orbit, single-stage-to-orbit [SSTO]), which will offer greatly reduced launch costs and increased reliabilities.

These small steps are very encouraging and promise to make real the large business potential in public space travel. By the end of the 2030s, there could well be dozens of space hotels serviced by routine flights to them for tourist stays of a week or more. While the hoped-for cruise-ship–like space resorts will eventually become real, they will probably take longer to materialize. However, excursions around the Moon are also planned by Bigelow, and extravehicular activities are already being planned.

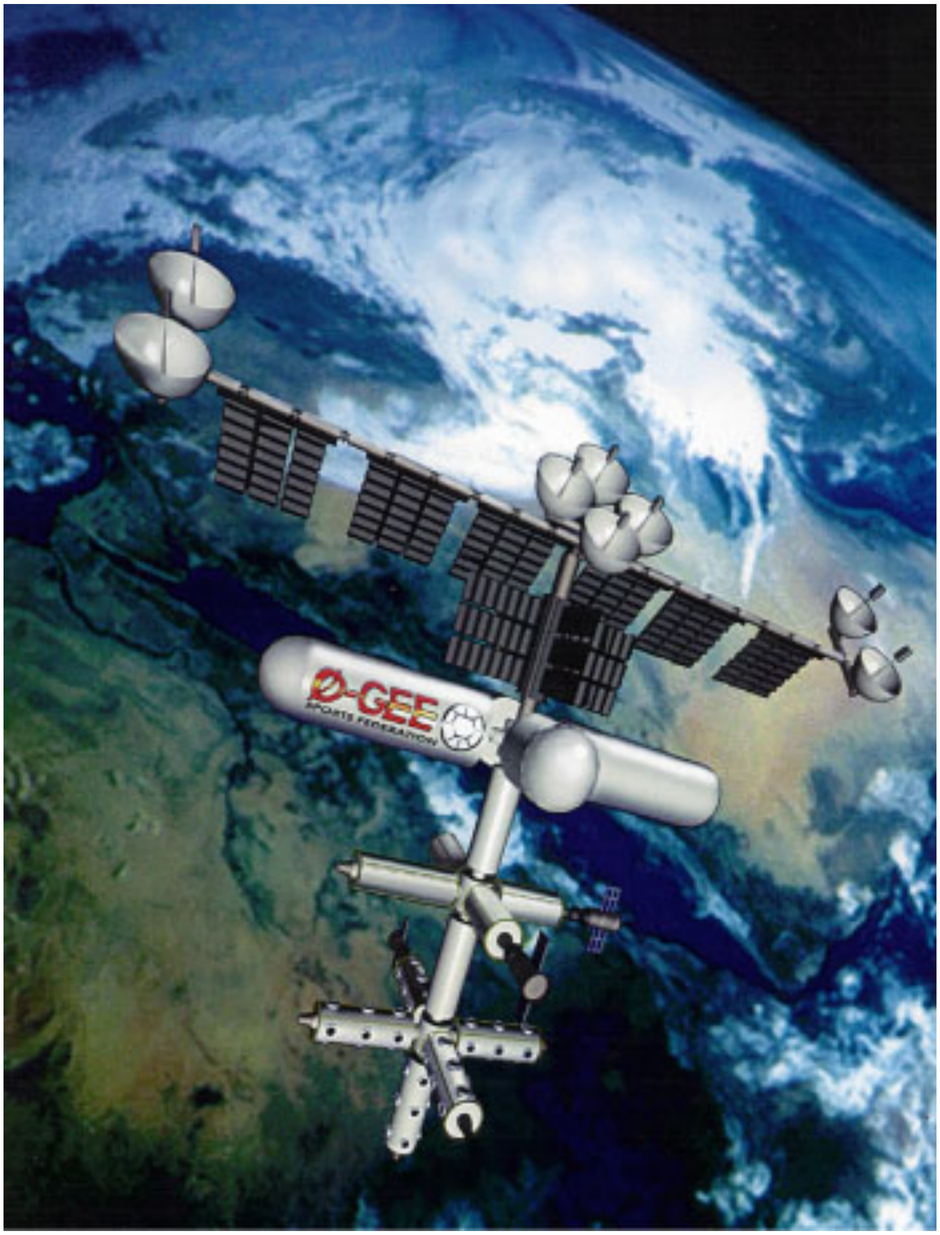
Space business parks. The advent of cheap and reliable space transportation, in addition to heralding ubiquitous public space travel, will also enable privately developed and operated space business parks—mixed-use facilities in orbit dedicated to supporting a number of different businesses with common infrastructure.

These business parks will be privately developed, owned, and operated. They will comprise leasable facilities for long- or short-term occupancy by a variety of business tenants, which could include laboratories for pharmaceutical research or production and real estate for sports, movies, and other business activities. These tenants will be supplied by common supporting infrastructure by the park operator, including:

- staterooms with private bath
- common viewing and relaxation areas
- power and thermal facilities
- kitchen and commissary
- air locks and docking ports
- service and logistics support
- instrumentation, experiments support
- communications to/from ground
- frequent or on-demand transportation
- emergency equipment and vehicles.

An artist's concept of such a facility is illustrated in figure 9–6.

Figure 9–6. Space Business Park Concept



Power delivery to International Space Station. Support to the ISS could well be an early commercial service. Indeed, current NASA programs are competing commercial provision of logistics to the ISS from the ground, though no commitment has been made yet for their use.

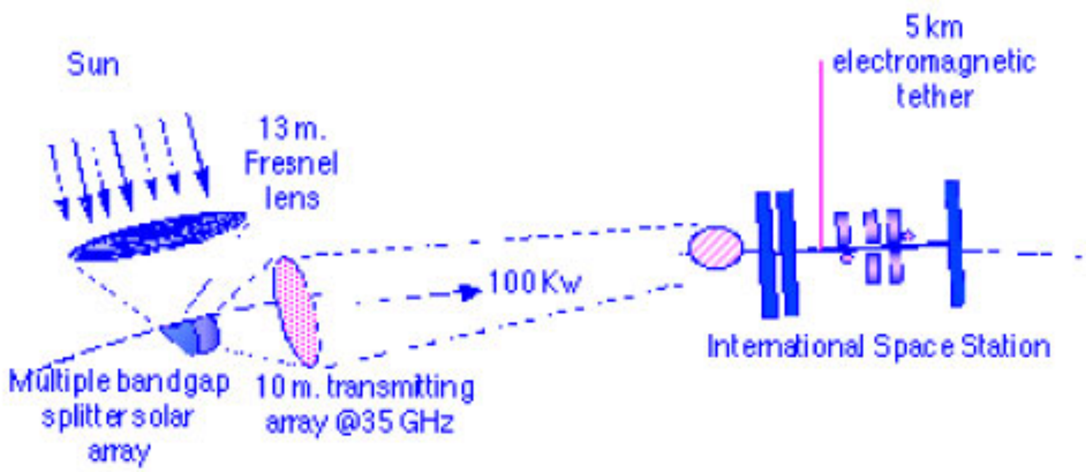
The ISS has a number of characteristics that may make it a good candidate for commercial support. One such is the provision of power to the science and other users aboard the ISS, which is very limited. The ISS itself has little dedicated experimentation space, is very expensive to operate (costing about $1 million per person per day), is very sensitive to vibration (to support microgravity processing), and has no spare habitation space.

One potential commercial service could be beaming of power from a commercial co-orbiting free flyer to the ISS, which studies indicate could supply hundreds of kilowatts at a fraction of the costs were the ISS to grow its on-board power. A simple commitment by the government to buy a certain number of kilowatt hours per year from a commercial entity delivered to the ISS would suffice to obtain private funding. This service is typical of a number of services that could be provided by commercial ventures:

- local transportation to/from resupply vehicles
- resupply of commodities for ISS operations
- experimentation space and facilities for some experiments
- provision of variable gravity for life sciences experiments if tethered to ISS
- provision of propellantless reboost of ISS using electromagnetic tether.

This would be a good way to begin commercial infrastructure in space, with the government being the anchor tenant. The power delivery concept is illustrated in figure 9–7.

Figure 9–7. Power Delivery to International Space Station



Fast global package delivery. A global reach rocket vehicle, whether just suborbital or orbital with deboost, could fly anywhere in the world, spaceport-to-spaceport, in under 2 hours. This could readily give rise to Global Federal Express–like mail and package markets, which studies have shown is a large unmet demand and market. The service would be provided by small but fully reusable unmanned vehicles, which a combination of SSTO technologies will make feasible, probably in the 2015 to 2020 time period.

This service could be one of the first commercial robotic transportation space applications. Studies have shown ready financial feasibility of such a fast global delivery service, which would cut the time to deliver a package or document by an order of magnitude from today's aircraft-based systems. It would be technically feasible once the government reduces the risk of the needed technologies.

Support to lunar base. Many studies have shown that a lunar base has high potential for science, exploration, and industrial research. Indeed, a lunar base is the centerpiece of NASA's human space exploration plans, which it is planning in the 2020 time frame. While it would be a government undertaking to establish the base itself, any such facility will need ongoing support in the form of oxygen, propellants, water, surface digging, processing plants, and transportation infrastructure.

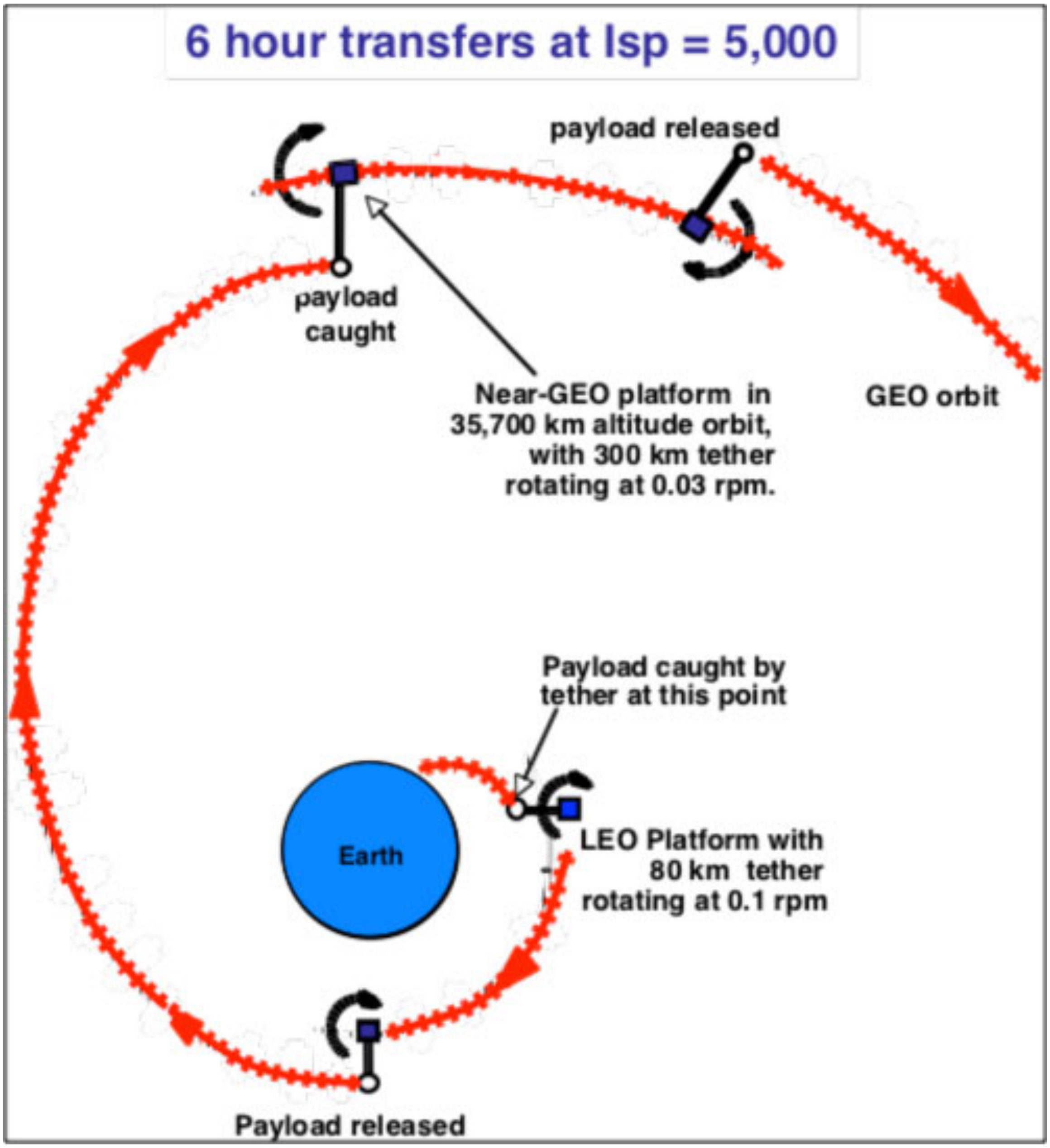
Water may well exist as ice in a lunar South Pole crater. The base thus could supply its own needs plus those for exploration of other lunar areas. It could export liquid oxygen to Earth orbits for propulsion applications. It would begin as a simple outpost, with the crews living in the landers, but would soon be followed by a complete and permanent base, which would be used as a learning and staging base for forays to Mars and elsewhere in the solar system. A more complete facility would follow in the 2020–2030 time period. It would initially be a government-emplaced and -run facility but would transition to being commercially operated, building on the government's investment. This operation would be a commercial enterprise of unprecedented magnitude.

Movie studios in orbit. Creating the illusion of free fall (zero gravity) in space movies and adventure television series is difficult, expensive, and very limited. Studies have shown that habitation modules or converted shuttle external tanks can provide needed volume and be outfitted with studio equipment. Such orbital "sound stages" could be owned and operated by a film studio, or they could be owned by a consortium and leased to individual studios as needed. Studies have shown financial viability of space movie studios under the right circumstances. Such studios would be attached to space stations or business parks for housekeeping support.

LEO-GEO transfer infrastructure. A permanent low Earth orbit (LEO)-GEO transportation infrastructure that is made available to both government and commercial users on a fee basis is a distinct possibility in the time period of interest and is enabled by the technologies described earlier. While initial infrastructures would use chemical or electric propulsion, a particularly intriguing concept is one that uses momentum exchange tethers to sling payloads between heavy permanent platforms. The heavy platforms transfer energy and momentum to the payload, which is transferred from LEO to GEO without consuming any propellants. Each platform adds up to 2,000 meters per second to the payload's velocity since the tangential velocity of the spinning tethers adds to the orbital velocity when releasing the payload and subtracts from the orbital velocity at the catching end to make a zero relative velocity catch.

The payloads are thus placed into a 6-hour Hohmann transfer trajectory to near-GEO, and no propellants are expended in the transfer. Of course, the energy to do so must come from somewhere, and indeed it comes from slightly lowering the orbits of the heavy platforms, which they then make up with ion propulsion over a longer time at an Isp of 5,000. Thus, in effect, the payloads are transferred with an effective Isp of 5,000 per second, yet the transfer is completed in 6 hours. This is impossible to attain with any known propulsion technology. In fact, this tether "ladder" in space works equally well in reverse, lowering GEO payloads to LEO for servicing, upgrading, or disposal. Eventually, as such systems are emplaced, the GEO traffic will increase greatly, and if the "upmass" equals the "downmass" over time, the energy gained by lowering payloads from GEO to LEO can be used to boost the next payloads from LEO to GEO, and, except for some unavoidable losses, the system requires no energy to operate. Thus, a propellantless permanent transportation infrastructure would have been created. This infrastructure would be operated by the commercial sector for the Nation (see figure 9–8).

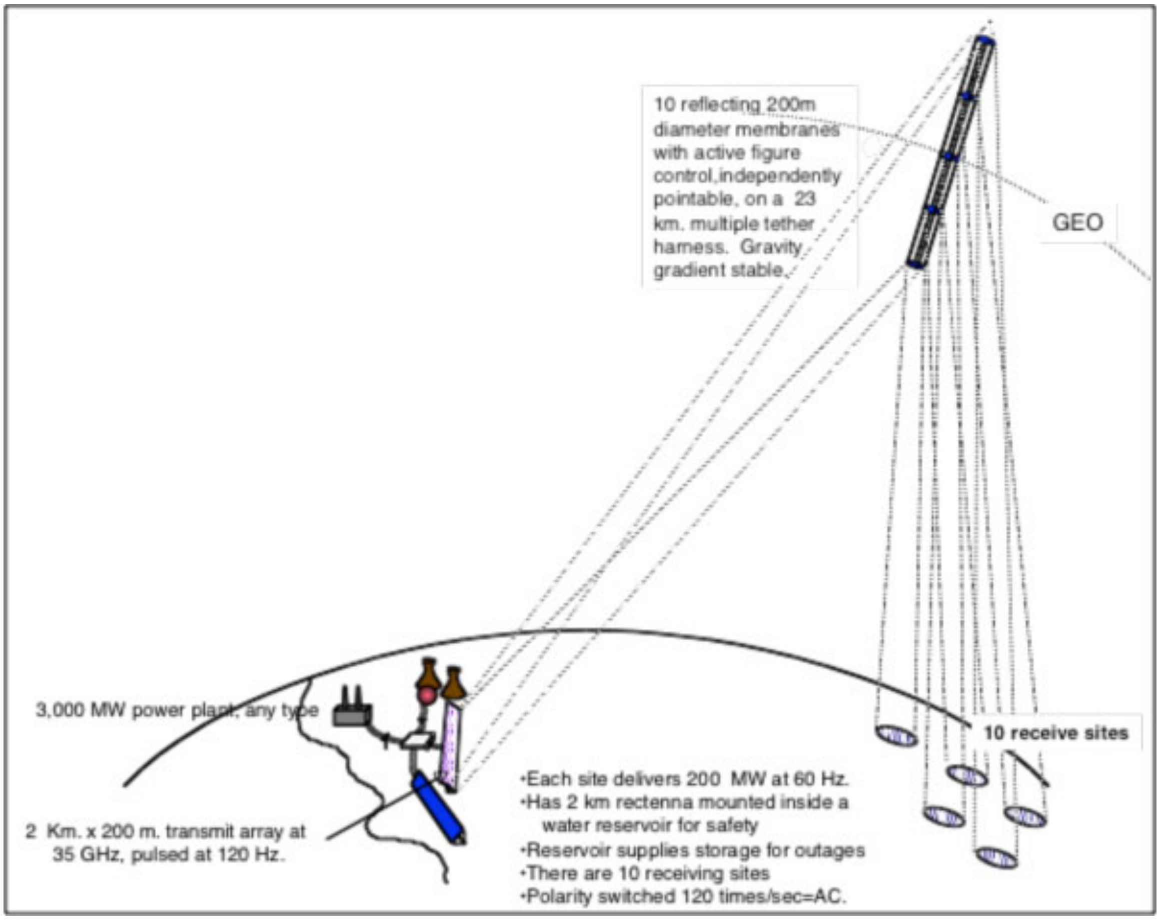
Figure 9–8. Propellantless, Reversible LEO–GEO Transportation



Passive power distribution via GEO relay. Large passive radio frequency (RF) reflectors in orbit can be used to relay RF energy generated by powerplants in an energy-rich part of the globe to other areas that may be energy-poor, where it would be received and converted to electricity used to augment the local powergrid. This system would also be suitable for rugged or underdeveloped areas where population centers are far apart and for countries with no oil, such as Japan. Studies have shown that this means of distributing electrical energy is cheaper than wire transmission lines for distances greater than about 2,000 kilometers.

The system uses simple meshes or membranes to reflect the RF power, and the spacecraft is much lighter and less expensive than those that generate the power in space. A single spacecraft would contain several independently steered reflectors so that energy could be supplied to a number of destinations. Studies show that a $6-billion investment could result in a 35 percent internal rate of return and would be a financially rewarding project that could readily find commercial financing (see figure 9–9).

Figure 9–9. Power Relay Using Space Reflectors

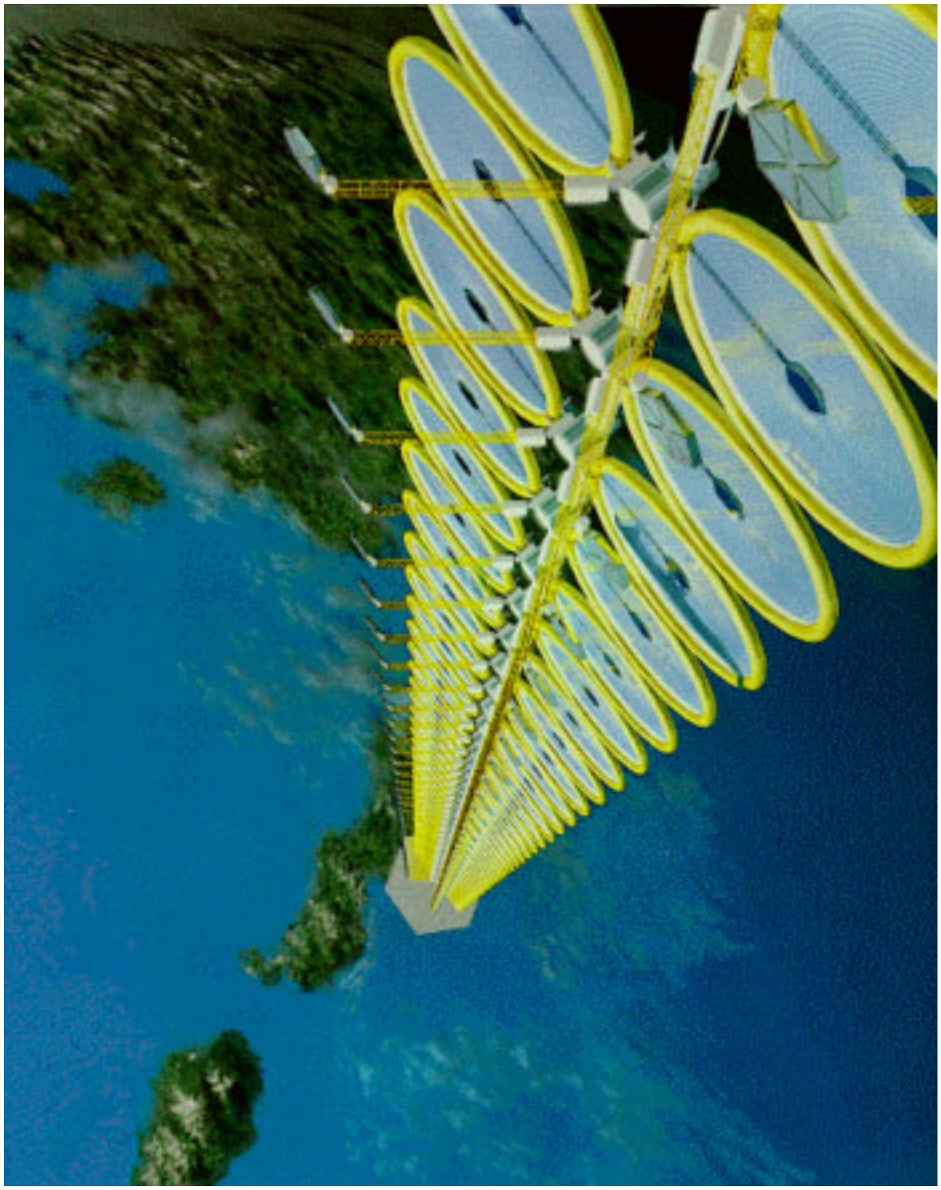


Solar power from space. Solar power satellites were conceived by Peter Glaser in 1958. The concept of converting abundant, clean, and inexhaustible solar energy into microwaves and beaming them to rectennas at receiving facilities connected to the powergrid is simple. However, the concept initially used huge structures assembled by hundreds of astronauts and was an enormous space program whose technology did not exist and whose sizeable investment could not be recouped by the large, noncompetitive energy prices that could be charged to customers.

More recent studies were made with modern technology including adaptive membrane reflectors, modular robotic assembly, highly efficient solar arrays, medium/low Earth orbit constellations, formation flown elements, gravity gradient stabilized configurations, efficient solar arrays, microwave or laser beam power delivery, and a whole host of modern electronic approaches to the antennas and transmitters. These studies have shown that power could be delivered at a price competitive with fossil or nuclear power and that a totally renewable and clean energy source could be implemented with little if any significant environmental impact, which could solve the world's power and pollution problems at the same time.

Such space solar power systems could be available in the 2030 time period if governments lower the technology risk, which is beyond the capability of privately financed technological institutions. Such programs represent a huge commercial market for entrepreneurial private industry. Power utilities and commercial providers would likely team to develop, field, and operate these systems. The very large mass to be orbited would be a huge market for development of low-cost launchers, which would be needed if the delivered cost of electricity is to be competitive with other options. Thus, although this is a long-term proposition and a very large undertaking, it is no larger than many other commercial energy plant activities. One LEO concept is illustrated in figure 9–10.

Figure 9–10. Solar Power Delivery from Space



Potential Roadmaps

The several concepts described in the last section could each represent a major commercial space program. In the aggregate, they represent a potentially enormous collection of space programs that represents the future of the commercial space sector. This potential was assessed by constructing a reasonable but not definitive development and operation roadmap plan for each of the programs described above and the annual number of launches and the mass launched into space derived for each. Figures 9–11 and 9–12 illustrate, respectively, the mass in orbit and the number of launches per year resulting from these commercial space programs as a function of time through 2080.

Figure 9–11. Potential Annual Launched Mass

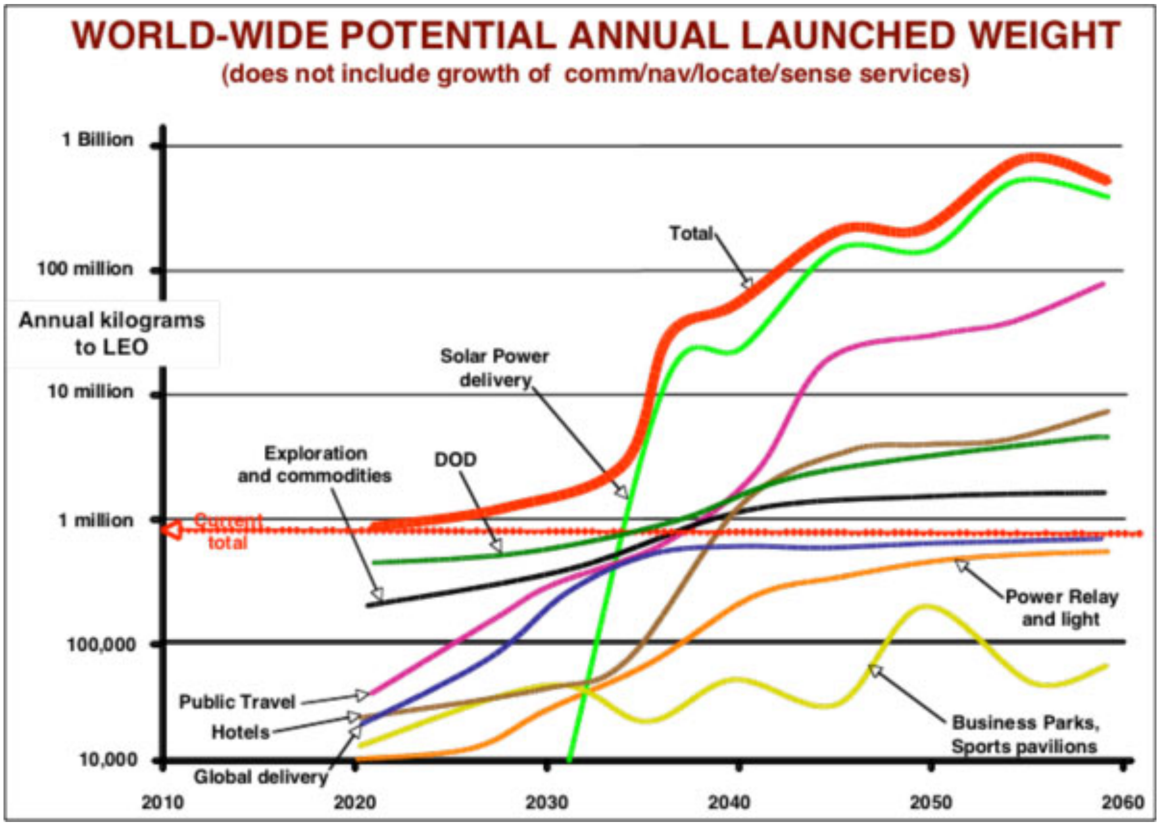
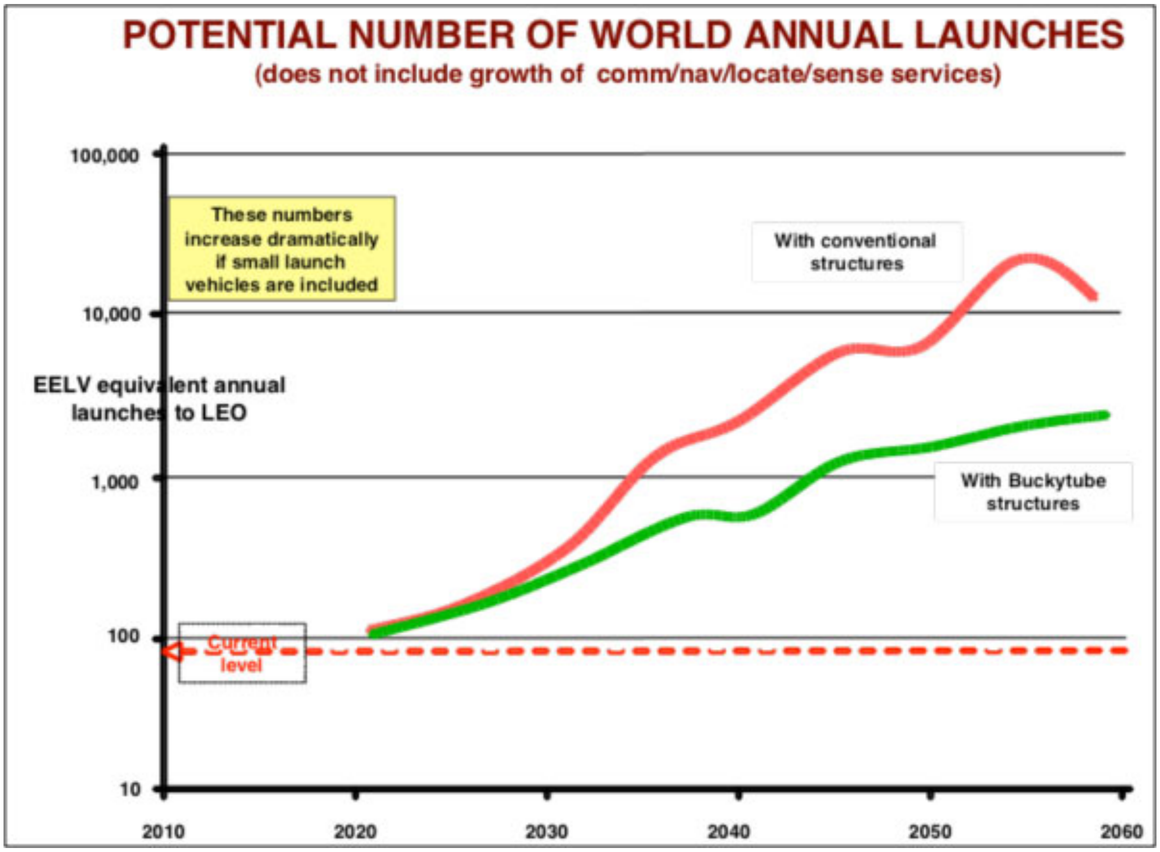


Figure 9–12. Potential Number of Annual World Launches



Inspection of these figures indicates that if these programs develop as postulated, the total mass into orbit of these commercial programs will grow rapidly within a decade of their introduction and by 2030 will equal the total mass launched into space by all current and projected defense and civil space programs. The mass will then grow even more rapidly, driven by the space solar power delivery systems and public space travel, becoming two orders of magnitude larger than the government programs by 2040 and three orders of magnitude larger by 2050 and beyond.

Likewise, an examination of the second figure shows that the annual number of launches of large, EELV-class launch vehicles will increase by an order of magnitude by 2035–2040 and by two orders of magnitude by 2050 and beyond. While it is true that these figures were developed for assumed scenarios of development of the individual component programs, and it is impossible to predict whether the particular programs will be developed, the trends in the figures are inevitable and inescapable.

Perspectives

The prior sections have laid out a series of potential commercial programs that could materialize in about the next 30 years and a potential roadmap for their appearance. It must be realized that both the programs themselves and especially their development and employment schedules and activity levels are based on the author's educated estimates, as there are no hard and fast commitments or schedules for any such applications by any entities save for the first public space travel venture by Virgin Galactic and Scaled Composites, Inc. Thus, while the programs described are believed to be reasonable estimates, their actual appearance is dependent on many commercial, business, and technology activities and decisions whose undertaking, let alone outcome, is not possible to predict.

These activities will be undertaken principally by the private sector. However, as in many advanced technology commercial activities, they could well be preceded by some government activities to reduce the risk of those technologies that could have beneficial dual use for government activities as well. This could run the range of simple technology investment to cooperative government-industry partnerships resulting in demonstrations useful to both parties. Indeed, such government investment could be substantial and may be key in the start of some commercial activities that would otherwise be unable to raise private financing. In addition, inducements could be offered by the government in the form of tax incentives, grants of licenses, and other benefits to spur some activities perceived to be either dual use or of substantial benefit to the Nation's economy.

Indeed, the government is already investing in fundamental technology developments such as research in carbon nanotubes and other advanced technologies that will be necessary to fully realize the potential of some of these applications. This investment is sponsored by the Defense Advanced Research Projects Agency, the Air Force, the National Science Foundation, and others. Practically every technologically advanced nation is doing likewise due to the extreme promise of carbon nanotubes in a host of commercial and military application areas. In addition, many electronics, power, and thermal applications of carbon nanotubes are being researched and will probably be the first to make it into the commercial electronics marketplace.

The potential for a delay in when some commercial applications might materialize exists if the government's financial support of research in this and other science and technology areas is reduced substantially—an eventuality that, while not anticipated, cannot be ruled out and could have considerable negative effect. However, since there is intense international activity in carbon nanotube science and technology, major reductions would place the United States behind other nations and therefore are not very likely to occur. This is particularly true considering that so many commercial products will benefit from inclusion or adoption of carbon nanotube technologies. These include consumer electronics of every description; structures for cars, trains, airplanes, boats, and ships; medical equipment and diagnostic techniques; sporting goods; and many other products whose use underpins the economic well being of our country.

This raises the question of what happens to the commercial space applications identified should carbon nanotube development fall short of the described progress. In a very real sense, none of the commercial programs described in this chapter depend on carbon nanotubes. They could just as well be developed and operated with conventional materials, though they would be heavier and costlier than if they used carbon nanotubes and other advanced technologies. Nonetheless, even if that came to pass, the business model and financial feasibility of these programs would still be positive for the most part, though their introduction might be delayed to allow demand to compensate for the increased price these services would thus feature.

Being able to develop some thoughts on a technology investment strategy to facilitate commercial undertakings such as those described herein would seem attractive. Unfortunately, even if it would be possible to develop such a strategy, it would have questionable utility because it would have to assume myriad critical activities and factors that underpin all commercial entrepreneurial ventures and that can only be considered by the parties themselves. In addition, the undertaking of any such strategy, even if its limitations were to be accepted, would be completely beyond the scope of this chapter. Thus, the development of a more specific technology investment strategy and development roadmap than the one discussed in the previous section is not possible.

Based on commercial activity already beginning in public space travel (both suborbital and later orbital), it seems evident that these programs, if economically successful, will spur technology investment to create the next application. This effect will begin to create the momentum for the realization of the second industrial revolution in space that is central to this vision for the future of commercial space.

Conclusion

This chapter has shown that technological advances in the 2010–2020 time period, spurred by private capital and some government seed technology investment, will enable new commercial products and services, in addition to new government programs. These technologies will result in orders-of-magnitude reduction in the costs to develop, orbit, and operate space systems for both government and commercial space programs. The principal driver will be orders-of-magnitude reduction of launch costs, which will unleash explosive growth in new, nontraditional commercial space programs in addition to growth in more traditional communications, navigation, location, and sensing commercial programs.

By 2030 or beyond, the magnitude of these commercial programs will, in the aggregate, exceed all government space programs in the total investment in space systems, in the number of annual launches, in the total mass in orbit, and in the infrastructure in orbit. The future commercial space program as a whole will represent a second industrial revolution—but this time, in space.

These commercial space programs and their ground and space infrastructure will rapidly become a vital portion of the Nation's economy, providing energy, information, and goods and services on which many people and entities will be dependent. In addition, they will be used by defense and intelligence agencies for routine as well as some strategic and tactical support of those agencies' objectives. In addition, new commercial programs and new uses for programs not even imagined will arise. For all these reasons, future commercial programs will become an inseparable aspect of national security and will have to be protected against attack, much as airports, planes, trains, and critical infrastructure need protection. Any spacepower theory must take this into account.

Chapter 10:

History of Civil Space Activity and Spacepower

Roger D. Launius

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The U.S. civil space program emerged in large part because of the pressures of national security during the Cold War.[1] In general, it has remained tightly interwoven with the national security aspects of space. As space policy analyst Dwayne A. Day noted, "The history of American civil and military cooperation in space is one of competing interests, priorities and justifications at the upper policy levels combined with a remarkable degree of cooperation and coordination at virtually all operational levels."[2] This has been the case throughout the first 50 years of the space age for myriad reasons. First, space employs dual-use technologies that are necessary for both military and civil applications. These technologies are developed mostly at government expense and sometimes with significant in-house government laboratory research by U.S.-owned and -based high technology firms, euphemistically called the military-industrial complex. Those firms do not much care whether the technologies' end uses are for civil or national security purposes, and indeed the same essential knowledge, skills, and technologies are required for both human spaceflight missions and national security space operations. The overlap of technologies and the related activities necessary to operate them explains much about the interwoven nature of civil-military space efforts.[3]

A second issue, closely related to the first, is that the military and civil space programs have represented essentially two central aspects of a concerted effort over the long haul to project national strength. The military component has represented "bare-knuckle" force, while the civil space program represented a form of soft power in which pride at home and prestige abroad accrued to the United States through successful space activities conducted with a sense of peace. Civil space operations also served, in the words of R. Cargill Hall, as a "stalking horse" for a clandestine national security effort in space. That cover served well the needs of the United States during the Cold War, diverting attention from reconnaissance and other national security satellites placed in Earth orbit.[4]

Observers certainly recognized the national prestige issue from the beginning of the space age. Vernon Van Dyke commented on it in his 1964 book, *Pride and Power: The Rationale of the Space Program,* making the case with scholarly detachment that prestige was one of the primary reasons for the United States to undertake its expansive civil space effort.[5] In the words of reviewer John P. Lovell, "Van Dyke marshals convincing evidence in support of the thesis that 'national pride' has served as the goal value most central to the motivation of those who have given the space program its major impetus."[6] Although his research is certainly dated, Van Dyke's conclusions hold up surprisingly well after the passage of more than 45 years. At a fundamental level, American Presidents have consciously used these activities as a symbol of national excellence to enhance the prestige of the United States throughout the world.[7]

Third, the gradual process whereby the political leadership of the United States—especially the Dwight D. Eisenhower and John F. Kennedy administrations—decided which governmental organizations should take responsibility for which space missions led to persistent and sometime sharp difficulties.[8] Several military entities, especially U.S. Air Force leaders, had visions of dominating the new arena of space, visions that were only partially realized. This proved especially troubling in the context of human spaceflight, when early advocates believed military personnel would be required. In essence, they thought of space as a new theater of conflict just like land, sea, and air and chafed under the decision of Eisenhower, reaffirmed to the present, to make space a sanctuary from armed operations. One important result of that decision was the elimination of military human missions in space, a bitter pill for national security space adherents even today. Indeed, the insistence on flying military astronauts on the space shuttle until the *Challenger* accident in 1986 represented an important marker for future developments. It may also be that in some advocates' minds, the current debate over space weaponization represents an opportunity to gain a human military mission in space.[9]

After a brief introduction to the space policy arena in the early years of the space age, the remainder of this chapter will explore these three themes— dual-use technology, the role of soft power and the prestige and pride issue in national security affairs, and the quest for military personnel in space.

National Security and the Space Program during the Cold War

Since the latter 1940s, the Department of Defense (DOD) has pursued research in rocketry and upper atmospheric sciences as a means of assuring American leadership in technology. The civilian side of the space effort can be said to have begun in 1952 when the International Council of Scientific Unions established a committee to arrange an International Geophysical Year (IGY) for the period of July 1, 1957, to December 31, 1958. After years of preparation, on July 29, 1955, the U.S. scientific community persuaded President Eisenhower to approve a plan to orbit a scientific satellite as part of the IGY effort. With the launch of Sputnik I and II by the Soviet Union in the fall of 1957 and the American orbiting of Explorer 1 in January 1958, the space race commenced and did not abate until the end of the Cold War—although there were lulls in the competition.[10] The most visible part of this competition was the human spaceflight program—with the Moon landings by Apollo astronauts as de rigueur—but the effort also entailed robotic missions to several planets of the solar system, military and commercial satellite activities, and other scientific and technological labors.[11] In the post–Cold War era, the space exploration agenda underwent significant restructuring and led to such cooperative ventures as the International Space Station and the development of launchers, science missions, and applications satellites through international consortia.[12]

Role of Adventure and Discovery

Undoubtedly, adventure, discovery, and the promise of exploration and colonization were the motivating forces behind the small cadre of early space program advocates in the

United States prior to the 1950s. Most advocates of aggressive space exploration efforts invoked an extension of the popular notion of the American frontier with its then-attendant positive images of territorial discovery, scientific discovery, exploration, colonization, and use.[13] Indeed, the image of the American frontier has been an especially evocative and somewhat romantic, as well as popular, argument to support the aggressive exploration of space. It plays to the popular conception of "westering" and the settlement of the American continent by Europeans from the East that was a powerful metaphor of national identity until the 1970s.

The space promoters of the 1950s and 1960s intuited that this set of symbols provided a vigorous explanation for and justification of their efforts. The metaphor was probably appropriate for what they wanted to accomplish. It conjured up an image of self-reliant Americans moving westward in sweeping waves of discovery, exploration, conquest, and settlement of an untamed wilderness. In the process of movement, the Europeans who settled North America became, in their own eyes, a people imbued with virtue and justness, unique from all the others of the Earth. The frontier ideal has always carried with it the principles of optimism, democracy, and right relationships. It has been almost utopian in its expression, and it should come as no surprise that those people seeking to create perfect societies in the 17th, 18th, and 19th centuries—the Puritans, the Mormons, the Shakers, the Moravians, the Fourians, the Icarians, the followers of Horace Greeley—often went to the frontier to carry out their visions.

It also summoned in the popular mind a wide range of vivid and memorable tales of heroism, each a morally justified step of progress toward the modern democratic state. While the frontier ideal reduced the complexity of events to a relatively static morality play, avoided matters that challenged or contradicted the myth, viewed Americans moving westward as inherently good and their opponents as evil, and ignored the cultural context of westward migration, it served a critical unifying purpose for the Nation. Those who were persuaded by this metaphor—and most white Americans in 1960 did not challenge it—embraced the vision of space exploration.[14]

Role ofPopular Conceptions of SpaceTravel

If the frontier metaphor of space exploration conjured up romantic images of an American nation progressing to something for the greater good, the space advocates of the Eisenhower era also sought to convince the public that space exploration was an immediate possibility. Science fiction books and films portrayed space exploration, but more importantly, its possibility was fostered by serious and respected scientists, engineers, and politicians. Deliberate efforts on the part of space boosters during the late 1940s and early 1950s helped to reshape the popular culture of space and to influence government policy. In particular, these advocates worked hard to overcome the level of disbelief that had been generated by two decades of "Buck Rogers"–type fantasies and to convince the American public that space travel might actually, for the first time in human history, be possible.[15]

The decade following World War II brought a sea change in perceptions, as most Americans moved from being skeptical about the probability of spaceflight to accepting it as a near-term reality. This shift can be seen in the public opinion polls of the era. For instance, in December 1949, Gallup pollsters found that only 15 percent of Americans believed humans would reach the Moon within 50 years, while a whopping 70 percent believed that it would not happen within that time. By 1957, 41 percent believed firmly that it would not take longer than 25 years for humans to reach the Moon, while only 25 percent believed that it would. An important shift in perceptions had taken place during that era, and it was largely the result of a public relations campaign based on the real possibility of spaceflight coupled with the well-known advances in rocket technology.[16]

The American public became aware of the possibility of spaceflight through sources ranging from science fiction literature and film that were closer to reality than ever before, to speculations by science fiction writers about possibilities already real, to serious discussions of the subject in respected popular magazines. Among the most important serious efforts were those of German émigré Wernher von Braun, who was working for the U.S. Army at Huntsville, Alabama. Von Braun, in addition to being a superbly effective technological entrepreneur, managed to seize the powerful print and communications media that the science fiction writers and filmmakers had been using in the early 1950s and became a highly effective promoter of space exploration to the public.[17]

In 1952, von Braun burst on the public stage with a series of articles in *Collier's* magazine about the possibilities of spaceflight. The first issue of *Collier's* devoted to space appeared on March 22, 1952. An editorial in that issue suggested that spaceflight was possible, not just science fiction, and that it was inevitable that mankind would venture outward. In his articles, von Braun advocated the orbiting of humans, development of a reusable spacecraft for travel to and from Earth orbit, construction of a permanently inhabited space station, and human exploration of the Moon and Mars by spacecraft departing from the space station. The series concluded with a special issue of the magazine devoted to Mars, in which von Braun and others described how to get there and predicted what might be found based on recent scientific data.[18]

The merging of the public perception of spaceflight as a near-term reality with the technological developments then being seen at White Sands and other experimental facilities created an environment conducive to the establishment of an aggressive space program. Convincing the American public that spaceflight was *possible* was one of the most critical components of the space policy debate of the 1950s. Without it, the aggressive exploration programs of the 1960s would never have been approved. For a concept to be approved in the public policy arena, the public must have both an appropriate vision of the phenomenon with which the society seeks to grapple and confidence in the attainability of the goal. Indeed, space enthusiasts were so successful in promoting their image of human spaceflight as being imminent that when other developments forced public policymakers to consider the space program seriously, alternative visions of space exploration remained ill formed, and even advocates of different futures emphasizing robotic probes and applications satellites were obliged to discuss space exploration using the symbols of the human space travel vision that its promoters had established so well in the minds of Americans.[19]

Role of ForeignPolicy and National Security Issues

At the same time that space exploration advocates, both amateurs and scientists, were generating an image of spaceflight as a genuine possibility and proposing how to accomplish a far-reaching program of lunar and planetary exploration, another critical element entered the picture: the role of spaceflight in national defense and international relations. Space partisans early began hitching their exploration vision to the political requirements of the Cold War, in particular to the belief that the nation that occupied the "high ground" of space would dominate the territories underneath it. In the first of the *Collier's* articles in 1952, the exploration of space was framed in the context of the Cold War rivalry with the Soviet Union and concluded that "the time has come for Washington to give priority of attention to the matter of space superiority. The rearmament gap between the East and West has been steadily closing. And nothing, in our opinion, should be left undone that might guarantee the peace of the world. It's as simple as that." The magazine's editors argued "that the U.S. must immediately embark on a long-range development program to secure for the West 'space superiority.' If we do not, somebody else will. That somebody else very probably would be the Soviet Union."[20]

The synthesis of the idea of progress manifested through the frontier, the selling of spaceflight as a reality in American popular culture, and the Cold War rivalries between the United States and the Soviet Union made possible the adoption of an aggressive space program by the early 1960s. The National Aeronautics and Space Administration (NASA) effort through Project Apollo, with its emphasis upon human spaceflight and extraterrestrial exploration, emerged from these three major ingredients, with Cold War concerns the dominant driver behind monetary appropriations for space efforts.

The Heroic Age of Space Exploration

Rivalry with the Soviet Union was the key that opened the door to aggressive space exploration, not as an end in itself, but as a means to achieving technological superiority in the eyes of the world. From the perspective of the 21st century, it is difficult to appreciate Americans' near-hysterical preoccupation with nuclear attack in the 1950s. Far from being the idyll portrayed in the television show "Happy Days," the United States was a dysfunctional nation preoccupied with death by nuclear war. Schools required children to practice civil defense techniques and shield themselves from nuclear blasts, in some cases by simply crawling under their desks. Communities practiced civil defense drills, and families built personal bomb shelters in their backyards.[21] In the popular culture, nuclear attack was inexorably linked to the space above the United States, from which the attack would come.

After an arms race with its nuclear component, a series of hot and cold crises in the Eisenhower era, and the launching of Sputniks I and II in 1957, the threat of holocaust felt by most Americans and Soviets seemed increasingly probable. For the first time, enemies could reach the United States with a radical new technology. In the contest over the ideologies and allegiances of the world's nonaligned nations, space exploration became contested ground.[22] Even while U.S. officials congratulated the Soviet Union for this accomplishment, many Americans thought that the Soviet Union had staged a tremendous coup for the communist system at U.S. expense. It was a shock, introducing the illusion of a technological gap and leading directly to several critical efforts aimed at catching up to the Soviet Union's space achievements. Among these efforts were:

- a full-scale review of both the civil and military programs of the United States (scientific satellite efforts and ballistic missile development)
- establishment of a Presidential science advisor in the White House who would oversee the activities of the Federal Government in science and technology
- creation of the Advanced Research Projects Agency (ARPA) in the Department of Defense, and the consolidation of several space activities under centralized management
- establishment of NASA to manage civil space operations
- passage of the National Defense Education Act to provide Federal funding for education in the scientific and technical disciplines.[23]

More immediately, the United States launched its first Earth satellite on January 31, 1958, when Explorer I documented the existence of radiation zones encircling the Earth. Shaped by the Earth's magnetic field, what came to be called the Van Allen radiation belt partially dictates the electrical charges in the atmosphere and the solar radiation that reaches Earth. It also began a series of scientific missions to the Moon and planets in the latter 1950s and early 1960s.[24]

Congress passed and President Eisenhower signed the National Aeronautics and Space Act of 1958, which established NASA with a broad mandate to explore and use space for "peaceful purposes for the benefit of all mankind."[25] The core of NASA came from the earlier National Advisory Committee for Aeronautics, which had 8,000 employees, an annual budget of $100 million, and research laboratories. It quickly incorporated other organizations into the new agency, notably the space science group of the Naval Research Laboratory in Maryland, the Jet Propulsion Laboratory managed by the California Institute of Technology for the Army, and the Army Ballistic Missile Agency in Huntsville, Alabama.[26]

The Soviet Union, while not creating a separate organization dedicated to space exploration, infused money into its various rocket design bureaus and scientific research institutions. The chief beneficiaries of Soviet spaceflight enthusiasm were the design bureau of Sergei P. Korolev (the chief designer of the first Soviet rockets used for the Sputnik program) and the Soviet Academy of Sciences, which devised experiments and built the instruments that were launched into orbit. With huge investments in spaceflight technology urged by premier Nikita Khrushchev, the Soviet Union accomplished one public relations coup after another against the United States during the late 1950s and early 1960s.[27]

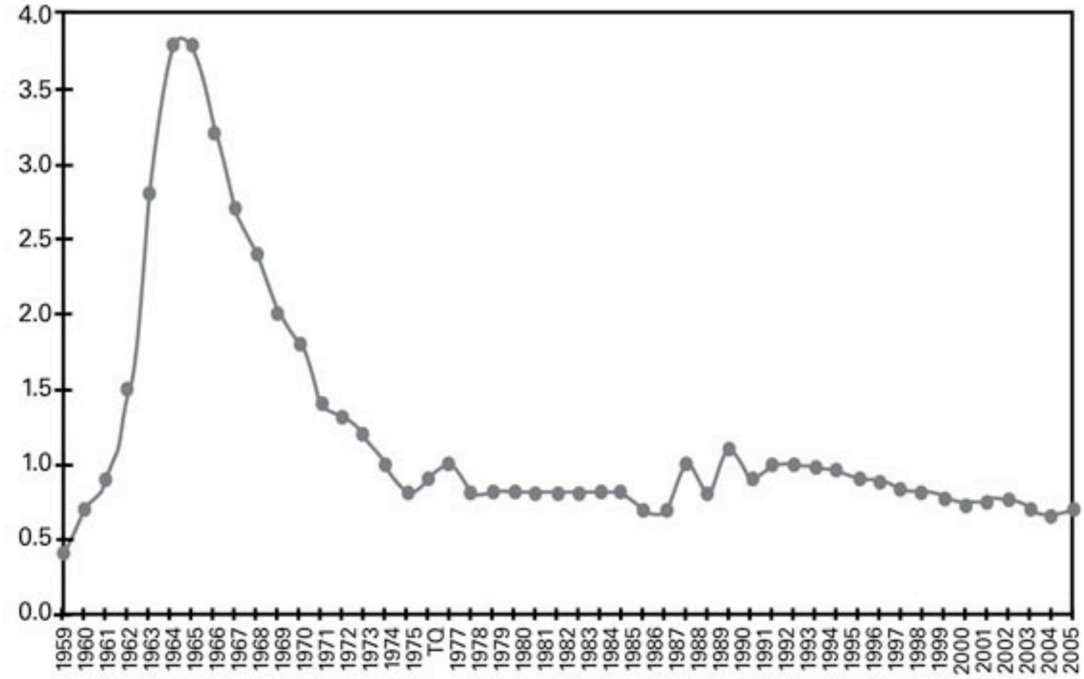
Within a short time of its formal organization, NASA also took over management of space exploration projects from other Federal agencies and began to conduct space science missions, such as Project Ranger to send probes to the Moon, Project Echo to test the possibility of satellite communications, and Project Mercury to ascertain the possibilities of human spaceflight. Even so, these activities were constrained by a modest budget and a measured pace on the part of NASA leadership.

In an irony of the first magnitude, Eisenhower believed that the creation of NASA and the placing of so much power in its hands by the Kennedy administration during the Apollo program of the 1960s was a mistake. He remarked in a 1962 article: "Why the great hurry to get to the moon and the planets? We have already demonstrated that in everything except the power of our booster rockets we are leading the world in scientific space exploration. From here on, I think we should proceed in an orderly, scientific way, building one accomplishment on another."[28] He later cautioned that the Moon race "has diverted a disproportionate share of our brain-power and research facilities from equally significant problems, including education and automation."[29] He believed that Americans had overreacted to the perceived threat.

During the first 15 years of the space age, the United States emphasized a civilian exploration program consisting of several major components. The capstone of this effort was, of course, the human expedition to the Moon, Project Apollo. A unique confluence of political necessity, personal commitment and activism, scientific and technological ability, economic prosperity, and public mood made possible the May 25, 1961, announcement by President John F. Kennedy of the intent to carry out a lunar landing program before the end of the decade as a means of demonstrating the Nation's technological virtuosity.[30]

Project Apollo was the tangible result of an early national commitment in response to a perceived threat from the Soviet Union. NASA leaders recognized that while the size of the task was enormous, it was technologically and financially within their grasp, but they had to move forward quickly. Accordingly, the space agency's annual budget increased from $500 million in 1960 to a high point of $5.2 billion in 1965. NASA's budget began to decline beginning in 1966 and continued on a downward trend until 1975. With the exception of a few years during the Apollo era, the NASA budget has hovered at slightly less than one percent of all money expended by the U.S. Treasury (see figure 10–1).[31]

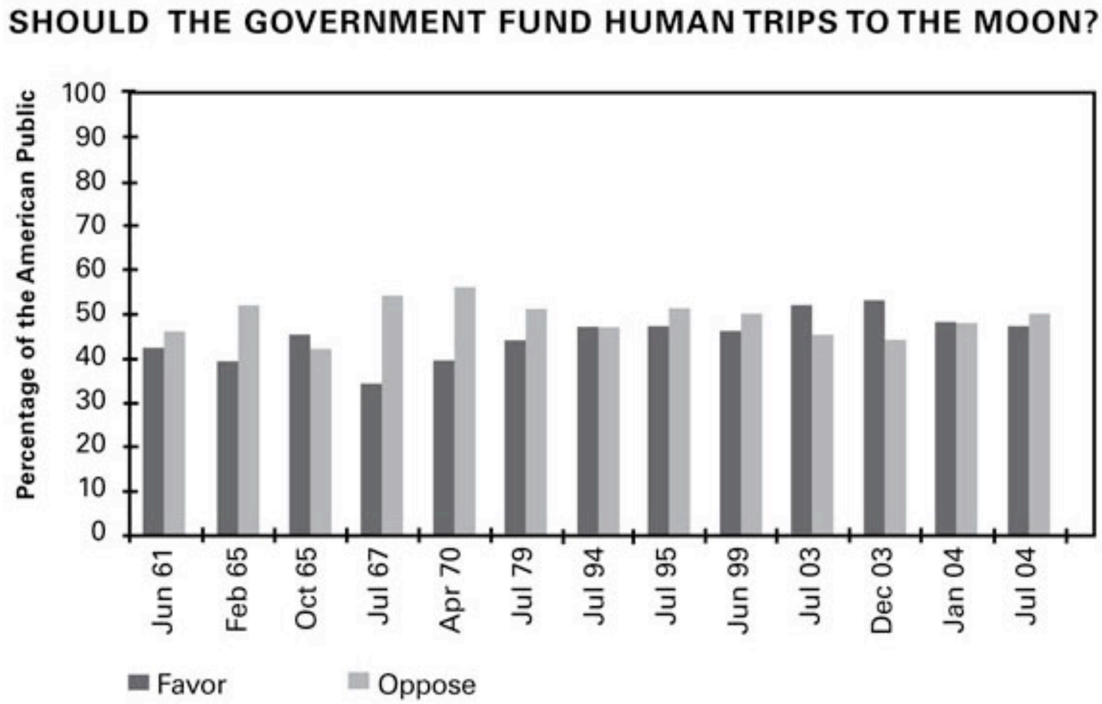
Figure 10–1. NASA Budgets as a Percentage of Federal Budget



While there may be reason to accept that Apollo was transcendentally important at some sublime level, assuming a rosy public acceptance of it is at best a simplistic and ultimately unsatisfactory conclusion. Indeed, the public's support for space funding has remained remarkably stable at approximately 80 percent in favor of the status quo since 1965, with only one significant dip in support in the early 1970s. However, responses to funding questions on public opinion polls are extremely sensitive to question wording and must be used cautiously.[32] Polls in the 1960s consistently ranked spaceflight near the top of those programs to be cut in the Federal budget. Most Americans seemingly preferred doing something about air and water pollution, job training for unskilled workers, national beautification, and poverty before spending Federal funds on human spaceflight. In 1967, *Newsweek* stated: "The U.S. space program is in decline. The Vietnam war and the desperate conditions of the nation's poor and its cities— which make spaceflight seem, in comparison, like an embarrassing national self-indulgence— have combined to drag down a program where the sky was no longer the limit."[33]

Nor did lunar exploration in and of itself inspire a groundswell of popular support from the general public, which during the 1960s largely showed hesitancy to "race" the Soviets to the Moon (see figure10–2). Polls asked, "Would you favor or oppose U.S. government spending to send astronauts to the moon?" and in virtually all cases, a majority opposed doing so, even during the height of Apollo. At only one point, October 1965, did more than half of the public favor continuing human lunar exploration. In the post-Apollo era, the American public has continued to question the validity of undertaking human expeditions to the Moon.[34]

Figure 10–2. Public Attitudes about Government Funding for Space Trips



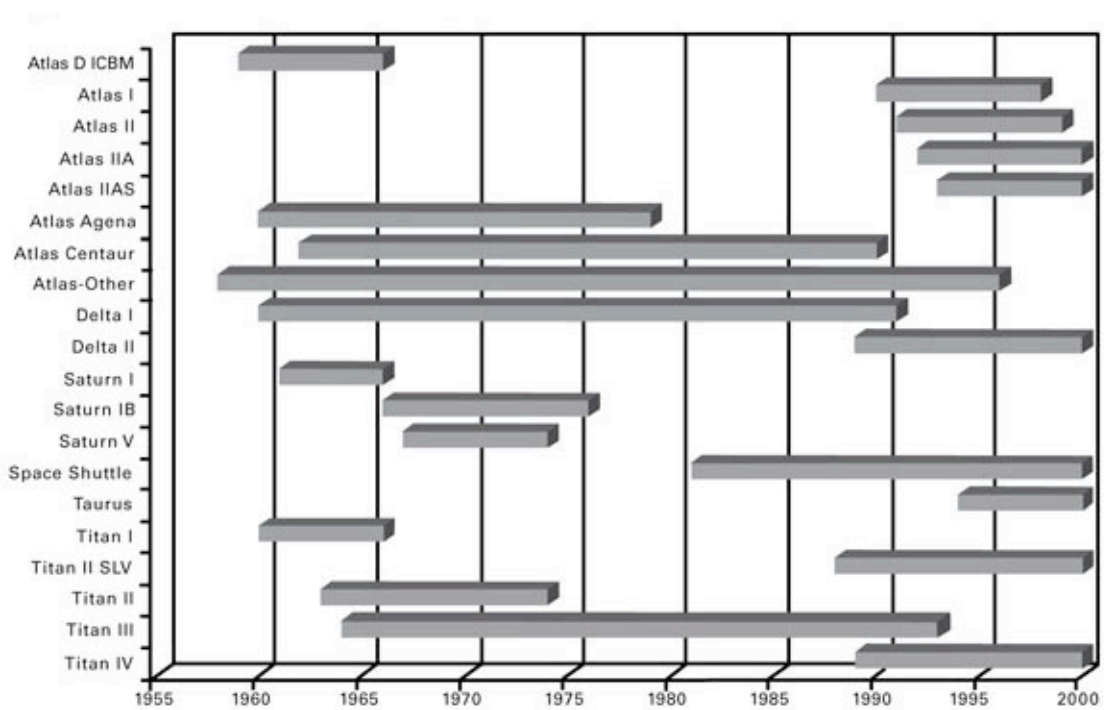
These statistics do not demonstrate unqualified support for NASA's effort to reach the Moon in the 1960s. They suggest, instead, that the Cold War national security crisis that brought public support to the initial lunar landing decision was fleeting, and within a short period the coalition that announced it had to retrench.[35] It also suggests that the public was never enthusiastic about human lunar exploration, and especially about the costs associated with it. What enthusiasm it may have enjoyed waned over time, until by the end of the Apollo program in December 1972, the program was akin to a limping marathoner straining with every muscle to reach the finish line before collapsing.

The Space Program and Dual-use Technology

The reality, if not the definition, of dual-use technology has existed since humanity first fashioned a weapon and then used it for some other nonviolent purpose. Certainly, spears, bows and arrows, swords, clubs, firearms, and a host of other implements have dual uses for both destructive and constructive purposes. Even as nondescript a tool as a shovel has a military use as an implement for digging fortifications and as a crude weapon in hand-to-hand combat. During the Cold War, this concept of dual-use technology reached a crescendo in the context of nuclear weapons in general and their delivery systems in particular. It also found explicit situating within international agreements such as the Nonproliferation Treaty, the 1987 Missile Technology Control Regime, and the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies.[36] The Wassenaar accord is by far the most sweeping in its attempt to govern the transfer of dual-use space technologies. Interestingly, remote sensing, navigation, and communications satellite policies emerged first as the technologies requiring governance, with launch vehicle technology being added later. This was in no small part because of the perception that nuclear weapons launchers did not present a problem for the enhancement of military capability. Only later in the 20th century did U.S. officials wake up to the realization that the spread of launcher technology to so-called rogue states such as North Korea, Iraq, and other potential enemies posed a threat to national interests.[37]

Launch vehicles developed for the delivery of nuclear weapons unquestionably had dual use as civil space launchers with minimum, if any, alteration. Most of the launchers used by NASA during its formative years originated as military ballistic missiles that DOD had developed (see figure10–3). It was, and remains, the fundamental technology necessary for civil space exploration, and it came largely from the military. Throughout the late 1940s and early 1950s, rocket technicians working for DOD conducted ever more demanding test flights, and scientists conducted increasingly complex scientific investigations made possible by this new dual-use technology.[38] The Army developed the Redstone rocket during this period, a missile capable of sending a small warhead a maximum of 500 miles, and its dual use became obvious when NASA used it to send the first U.S. suborbital Mercury missions with astronauts Alan B. Shepard and Gus Grissom into space in 1961.[39] The same was true for the Air Force's Atlas and Titan intercontinental ballistic missiles (ICBMs), originally developed to deliver nuclear warheads to targets half a world away. The Atlas found important uses as the launcher for the Mercury program's orbital missions, and the Titan served well as the launcher for the Gemini program human spaceflights in 1965–1966.[40]

Figure 10–3. Launch Vehicles, 1953-2000



But the application of military rocket technology to the civil space program was neither automatic nor especially easy. As a converted ICBM, for example, the Atlas had undergone on-again, off-again development since 1946. Canceled once and underfunded thereafter, the Air Force had been unable until the Sputnik crisis of 1957–1958 to secure sufficient resources to make serious progress on it. Because of this difficulty, U.S. Air Force officials had accepted a 20 percent failure rate. This rate offered the fundamental argument against using the Atlas in the civil space program; no one was willing to accept the loss of one out of five missions with astronauts aboard. But even that rate proved higher in the early going. By 1959, seven out of eight launches had failed. That would most assuredly not do with astronauts aboard. NASA's Robert R. Gilruth testified to Congress about this problem in mid-1959: "The Atlas . . . has enough performance . . . and the guidance system is accurate enough, but there is the matter of reliability. You don't want to put a man in a device unless it has a very good chance of working every time." Gilruth added, "Reliability is something that comes with practice."[41]

Incrementally, NASA, Air Force, and contract engineers improved the performance of the Atlas. They placed a fiberglass shield around the liquid oxygen tank to keep the engines from igniting it in a massive explosion, a rather spectacular failure that seemed to happen at least half the time. They changed out almost every system on the vehicle, substituting tried and true technology wherever possible to minimize problems. They altered procedures and developed new telemetry to monitor the operations of the system. Most important, they developed an abort sensing system (labeled ASS by everyone but the people involved in developing it) to monitor vehicle performance and to provide early escape for astronauts from the Mercury capsule.[42]

Transition to the Titan launcher for the Gemini program was also far from automatic. It experienced longitudinal oscillations, called the "pogo" effect because it resembled the behavior of a child on a pogo stick. Overcoming this problem required engineering imagination and long hours of overtime to stabilize fuel flow and maintain vehicle control. Other problems also led to costly modifications, increasing the estimated $350 million program cost to over $1 billion. The overruns were successfully justified by the space agency, however, as necessities to meet the Apollo landing commitment, but not without some sustained criticism.[43]

The dual-use nature of this launch technology has long presented serious challenges for the interrelations of the civil and national security space programs. Moreover, this reliance on the descendants of the three major ballistic missiles—Atlas, Titan, and what became the Delta—developed in the 1950s and 1960s for the bulk of the Nation's space access requirements has hampered space access to the present. Even though the three families of expendable space boosters—each with numerous variants—have enjoyed incremental improvement since first flight, there seems no way to escape their beginnings in technology (dating back to the 1950s) and their primary task of launching nuclear warheads. National defense requirements prompted the developers to emphasize schedule and operational reliability over launch costs.

Movement beyond these first-generation launchers is critical for the opening of space access to more activities. Like the earlier experience with propeller-driven aircraft, launchers have been incrementally improved for the last 40 years without making a major breakthrough in technology. Accordingly, the United States today has a very efficient and mature expendable launch vehicle (ELV) launch capability that is still unable to overcome the limitations of the first-generation ICBM launch vehicles.[44]

The overpowering legacy of the space shuttle has also dominated the issue of space access since Project Apollo, and it has enjoyed dual use as both a military and civil launcher. Approved in 1972 by President Richard M. Nixon as the major NASA follow-on program to the highly successful Moon landings, the space shuttle would provide routine, economical, and reliable indefinite access to space for the U.S. human spaceflight program.[45] With the first spaceflight of the *Columbia* in 1981, NASA's human spaceflight capability became wedded to the space shuttle, and moving beyond that basic coupling has required 20 years. In addition to forestalling debate on a shuttle replacement, the decision to build the space shuttle in 1972 short-circuited debate on the desirability of investment in new ELVs. At first, NASA and most other space policy analysts agreed that the shuttle would become the "one-size-fits-all" space launcher of the U.S. fleet. There would be, simply put, no need for another vehicle since the shuttle could satisfy all launch requirements, be they scientific, commercial, or military, human or robotic.[46] The military Services at first agreed to launch all of their payloads on the shuttle, and NASA aggressively marketed the shuttle as a commercial vehicle that could place any satellite into orbit.[47]

This was never a perfect situation, for in the truest sense of dual usage, the shuttle was shouldering the responsibility for all government launches and many commercial ones during the early Reagan years. It was, sadly, ill equipped to satisfy these demands. Even with the best of intentions and with attractive payload pricing policies, the space shuttle remained what it had been intended to be in the first place: a research and development vehicle that would push the frontiers of spaceflight and knowledge about the universe. The desire for the shuttle to be all things to all people—research and development aerospace vehicle, operational space truck, commercial carrier, scientific platform—ensured that it would satisfy none of these singular and mutually exclusive missions.[48]

Only with the loss of the *Challenger* on January 28, 1986, did this reliance on the space shuttle begin to change. It reinvigorated a debate over the use of the space shuttle to launch all U.S. satellites. In August 1986, President Reagan announced that the shuttle would no longer carry commercial satellites, a policy formalized in December 1986 in National Security Decision Directive 254, "United States Space Launch Strategy." A total of 44 commercial and foreign payloads that had been manifested on the space shuttle were forced to find new launchers.[49]

For the next 3 years, the U.S. Government worked to reinvigorate the American ELV production lines and to redesign and modify satellites to be launched on ELVs instead of the shuttle. The shift back to ELVs required additional government funding to fix the problems that had resulted from years of planning to retire these systems. The United States practically ceased commercial launch activities for several years, conducting just three commercial satellite launches (one just prior to the *Challenger* flight) for only 6 percent of U.S. space launches from 1986 to 1989.[50]

During this period, however, two actions were initiated that enabled the emergence of a legitimate U.S. launch industry. First, DOD committed to purchasing a large number of ELVs as part of a strategy to maintain access to space using a mixed fleet of both the space shuttle and ELVs. This reopened the dormant U.S. ELV production lines at government expense and helped provide economies of scale necessary to enable U.S. companies to effectively compete against Ariane. Second, in 1988, Congress amended the Commercial Space Launch Act (CSLA) to establish new insurance requirements whose effect was to limit liability for U.S. companies in case their launches caused damage to government property or third parties. The revised CSLA also established protections against government preemption of commercial launches on government ranges.[51]

As a result, the first U.S. commercial space launch took place in 1989— nearly 5 years after the CSLA was passed. Beginning in 1989, U.S. launches of commercial satellites were conducted by commercial launch companies (in most cases, the same companies providing launch services for DOD and NASA payloads as government contractors), not the U.S. Government.[52]

There is much more to this story of space access and the nature of dual-use technology, but I will conclude with these observations. The commonality of this technology has meant one of two things for both military and civil space efforts: either a competition for knowledge and capability among a limited pool of suppliers, or a cooperation to achieve a fleet of dual-use machines that satisfy all users. In many cases this has never happened, and the differences between NASA and DOD have been persistent and at times quite combative.

Only when there has been clear delineation of responsibilities has this absence of collaboration not been the case. For example, on April 16, 1991, the National Space Council directed NASA and DOD to jointly fund and develop the National Launch System to meet civil and military space access by the beginning of the 21st century at a cost of between $10.5 billion and $12 billion.[53] This effort failed. Most of the other efforts to cooperate have not been much more successful. It seems that the best results have come when either the civil or the military side of the space program develops its own technologies, at least in space launch, and the other adapts it for its own use. That was the case with NASA employing launchers originally designed as ballistic missiles in the 1960s and DOD using the space shuttle built by NASA in the 1980s. The landscape is littered with failed cooperative projects in space access.[54]

Prestige and Soft Power on the International Stage

From the early days of thought about the potential of flight in space, theorists believed that the activity would garner worldwide prestige for those accomplishing it. For example, in 1946, the newly established RAND Corporation published the study "Preliminary Design of an Experimental World-Circling Spaceship." This publication explored the viability of orbital satellites and outlined the technologies necessary for its success. Among its many observations, its comment on the prestige factor proved especially prescient: "A satellite vehicle with appropriate instrumentation can be expected to be one of the most potent scientific tools of the Twentieth Century. The achievement of a satellite craft would produce repercussions comparable to the explosion of the atomic bomb."[55]

This perspective is a classic application of what analysts often refer to as *soft power*. The term, coined by Harvard University professor Joseph Nye, gave a name to an alternative to threats and other forms of hard power in international relations.[56] As Nye contends:

> Soft power is the ability to get what you want by attracting and persuading others to adopt your goals. It differs from hard power, the ability to use the carrots and sticks of economic and military might to make others follow your will. Both hard and soft power are important . . . but attraction is much cheaper than coercion, and an asset that needs to be nourished.[57]

In essence, such activities as Apollo represented a form of soft power, the ability to influence other nations through intangibles such as an impressive show of technological capability. It granted to the nation achieving it first an authenticity and gravitas not previously enjoyed among the world community. In sum, this was an argument buttressing the role of spaceflight as a means of enhancing a nation's standing on the international stage.

Even so, few appreciated the potential of spaceflight to enhance national prestige until the Sputnik crisis of 1957–1958. Some have characterized this as an event that had a "Pearl Harbor" effect on American public opinion, creating an illusion of a technological gap and providing the impetus for increased spending for aerospace endeavors, technical and scientific educational programs, and the chartering of new Federal agencies to manage air and space research and development. This Cold War rivalry with the Soviet Union provided the key that opened the door to aggressive space exploration, not as an end in itself, but as a means to achieving technological superiority in the eyes of the world. From the perspective of the 21st century, it is difficult to appreciate the importance of the prestige factor in national thinking at the time. Although the initial response was congratulatory, American political and opinion leaders soon expressed a belief in the loss of national prestige. As the *Chicago Daily News* editorialized on October 7, 1957, "It must be obvious to everyone by now that the situation relative to Russian technology and our own has changed drastically. There can be no more underestimating Russia's scientific potential, either for war or for peace."[58]

Political leaders also used the satellite as an object lesson in prestige. Senate majority leader Lyndon B. Johnson recalled of the Soviet launch, "Now, somehow, in some new way, the sky seemed almost alien. I also remember the profound shock of realizing that it might be possible for another nation to achieve technological superiority over this great country of ours."[59]

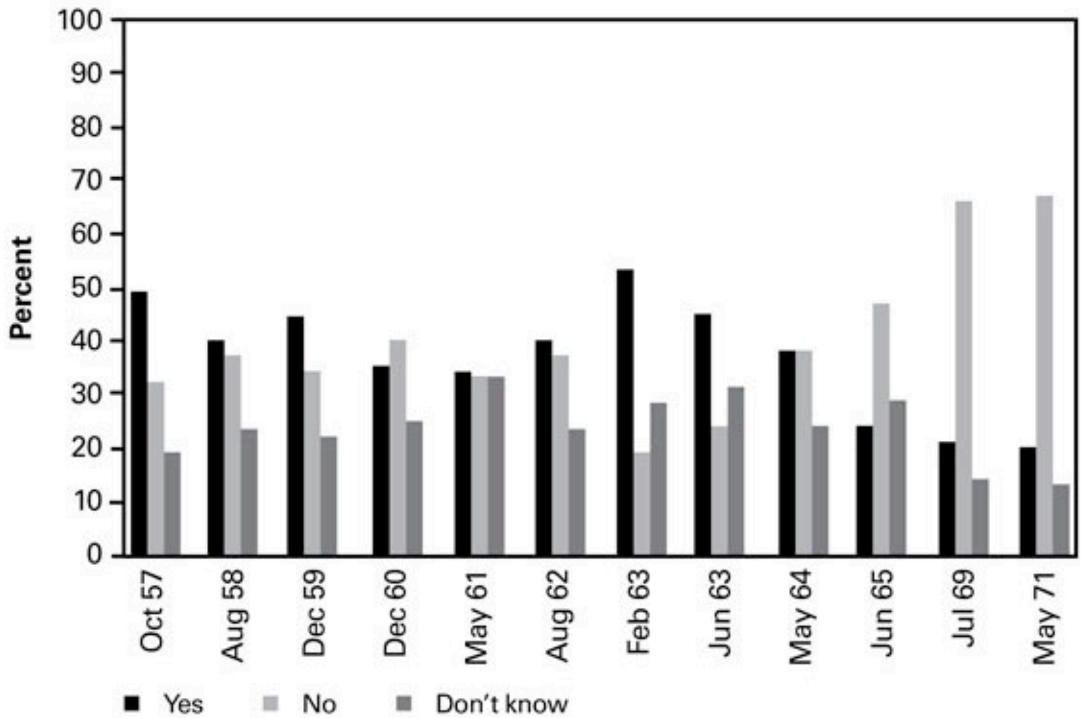
One of Johnson's aides, George E. Reedy, wrote to him on October 17, 1957, about how they could use the Sputnik issue to the party's advantage: "The issue is one which, if properly handled, would blast the Republicans out of the water, unify the Democratic Party, and elect you President." He suggested that "it is unpleasant to feel that there is something floating around in the air which the Russians can put up and we can't."[60]

Unquestionably, the Apollo program in particular and all of U.S. human spaceflight efforts in general were mainly about establishing U.S. primacy in technology. Apollo served as a surrogate for war, challenging the Soviet Union head on in a demonstration of technological virtuosity. The desire towin international support for the "American way" became the raison d'etre for the Apollo program, and it served that purpose far better than anyone imagined when first envisioned. Apollo became first and foremost a Cold War initiative and aided in demonstrating the mastery of the United States before the world. This motivation may be seen in a succession of Gallup polls conducted during the 1960s that asked, "Is the Soviet Union ahead of the United States in space?" Until the middle part of the decade— about the time that the Gemini program began to demonstrate American prowess in space—the answer was always *yes*. At the height of the Apollo Moon landings, world opinion had shifted overwhelmingly in favor of the United States.[61] The importance of Apollo as an instrument of U.S. foreign policy—which is closely allied to but not necessarily identical with national prestige and geopolitics—should not be mislaid in this discussion. It served, and continues to serve, as an instrument for projecting the image of a positive, open, dynamic American society abroad.

For decades, the United States launched humans into space for prestige, measured against similar Soviet accomplishments, rather than for practical scientific or research goals. This was in essence positive symbolism—each new space achievement acquired political capital for the United States, primarily on the international stage. As Caspar Weinberger noted in 1971, space achievements gave "the people of the world an equally needed look at American superiority."[62]

In this context, the civil space program, both its human and robotic components, was fully about national security. Demonstrations of U.S. scientific and technological capability were about the need to establish the credibility and reliability of nuclear deterrence in this new type of standoff with the Soviet Union (see figure10–4). If the Soviets did not believe that credibility was real, if the rest of the world thought it bogus, the American rivalry with the Soviet Union portended a dire future for humankind. American success in space offered a perception of credibility worldwide about its military might. "This contest was rooted in proving to the world the superiority of capitalism over communism, of the American and communist ways of life, and of cultural, economic, and scientific achievements," according to historian Kenneth Osgood. American civil space successes served to counteract those questioning the nature of the future.[63]

Figure 10–4. Is the Soviet Union Ahead of the United States in Space?



The importance of this prestige issue for civil space also worked at home. It conjured images of the best in the human spirit and served, in the words of journalist Greg Easterbrook, as "a metaphor of national inspiration: majestic,technologically advanced, produced at dear cost and entrusted with precious cargo, rising above the constraints of the earth." It "carries our secret hope that there is something better out there—a world where we may someday go and leave the sorrows of the past behind."[64] It may well be that space achievements, particularly those involving direct human presence, remain a potent source of national pride and that such pride is why the U.S. public continues to support human spaceflight. Certainly, space images— an astronaut on the Moon or the space shuttle rising majestically into orbit—rank just below the American flag and the bald eagle as patriotic symbols. The self-image of the United States as a successful nation is threatened when we fail in our space efforts, as we have seen from the collective loss when astronauts die before our eyes in space shuttle accidents. Americans expect a successful program of civil spaceflight as part of what the United States does as a nation. Americans are not overly concerned with the content or objectives of specific programs. But they are concerned that what is done seems worth doing and is done well. It is that sense of pride in space accomplishment that has been missing in recent years.[65]

The Military and the Quest for a Human Mission in Space

Even before the beginning of the space age, DOD had angled for the mission of placing humans in space for myriad tasks. In the early 1950s, Wernher von Braun had proposed a massive space station with more than 50 military personnel aboard to undertake Earth observation for reconnaissance and as an orbiting battle station. He even believed it could be used to launch nuclear missile strikes against the Soviet Union.[66] While von Braun could not get any Eisenhower administration authorities to adopt his space station plan, some senior DOD officials did see a role for military astronauts. The U.S. Air Force proposed the development of a piloted orbital spacecraft under the "Man-in-Space-Soonest" (MISS) program in 1957.[67] After the launch of Sputnik I, the Air Force invited Edward Teller and several other leading members of the scientific and technological elite to study the issue of human spaceflight and make recommendations for the future. Teller's group concluded that the Air Force could place a human in orbit within 2 years and urged that the department pursue this effort. Teller understood, however, that there was essentially no military reason for undertaking this mission and chose not to tie his recommendation to any specific rationale, falling back on a basic belief that the first nation to accomplish human spaceflight would accrue national prestige and advance, in a general manner, science and technology.[68]

Soon after the new year, Lieutenant General Donald L. Putt, the Air Force Deputy Chief of Staff for Development, informed National Advisory Committee for Aeronautics (NACA) Director Hugh L. Dryden of the Service's intention to pursue aggressively "a research vehicle program having as its objective the earliest possible manned orbital flight which will contribute substantially and essentially to follow-on scientific and military space systems." Putt asked Dryden to collaborate in this effort, but with the NACA as a decidedly junior partner.[69] Dryden agreed; however, by the end of the summer, Putt would find the newly created NASA leading the human spaceflight effort for the United States, with the Air Force being the junior player.[70]

Notwithstanding the lack of clear-cut military purpose, the Air Force pressed for MISS throughout the first part of 1958, clearly expecting to become the lead agency in any space program of the United States. Specifically, it believed hypersonic space planes and lunar bases would serve national security needs well in the coming decades. To help make that a reality, it requested $133 million for the MISS program and secured approval for the effort from the Joint Chiefs of Staff.[71] Throughout this period, a series of disagreements between Air Force and NACA officials rankled both sides. The difficulties reverberated all the way to the White House, prompting a review of the roles of the two organizations.[72] The normally staid and proper Hugh Dryden complained in July 1958 to the President's science advisor, James R. Killian, of the lack of clarity on the role of the Air Force versus the NACA. He asserted that:

> The current objective for a manned satellite program is the determination of man's basic capability in a space environment as a prelude to the human exploration of space and to possible military applications of manned satellites. Although it is clear that both the National Aeronautics and Space Administration and the Department of Defense should cooperate in the conduct of the program, I feel that the responsibility for and the direction of the program should rest with NASA.

He urged that the President state a clear division between the two organizations on the human spaceflight mission.[73]

As historians David N. Spires and Rick W. Sturdevant have pointed out, the MISS program became derailed within the Department of Defense at essentially the same time because of funding concerns and a lack of clear military mission:

> Throughout the spring and summer of 1958 the Air Force's Air Research and Development Command had mounted an aggressive campaign to have ARPA convince administration officials to approve its Man-in-Space-Soonest development plan. But ARPA balked at the high cost, technical challenges, and uncertainties surrounding the future direction of the civilian space agency.[74]

Dwight D. Eisenhower signed the National Aeronautics and Space Act of 1958 into law at the end of July and the next month assigned the Air Force's human spaceflight mission to NASA. Thereafter, the MISS program was folded into what became Project Mercury. By early November 1958, DOD had acceded to the President's desire that the human spaceflight program be a civilian effort under the management of NASA. For its part, NASA invited Air Force officials to appoint liaison personnel to the Mercury program office at Langley Research Center, and they did so.[75]

Everyone recognized that time was of the essence in undertaking the human spaceflight project that NASA would now lead. Roy Johnson, director of ARPA for DOD, noted in September 1958 that competition with the Soviet Union precluded taking a cautious approach to the human spaceflight initiative and advocated additional funding to ensure its timely completion. As he wrote to the Secretary of Defense and the NASA administrator:

> I am troubled, however, with respect to one of the projects in which there is general agreement that it should be a joint undertaking. This is the so-called "Man-in-Space" project for which $10 million has been allocated to ARPA and $30 million to NASA. My concern over this project is due (1) to a firm conviction, backed by intelligence briefings, that the Soviets' next spectacular effort in space will be to orbit a human, and (2) that the amount of $40 million for FY 1959 is woefully inadequate to compete with the Russian program. As you know our best estimates (based on some 12–15 plans) were $100 to $150 million for an optimum FY 1959 program.
>
> I am convinced that the military and psychological impact on the United States and its Allies of a successful Soviet man-inspace "first" program would be far reaching and of great consequence.
>
> Because of this deep conviction, I feel that no time should be lost in launching an aggressive Man-in-Space program and that we should be prepared if the situation warrants, to request supplemental appropriations of the Congress in January to pursue the program with the utmost urgency.[76]

Johnson agreed to transfer a series of space projects from ARPA to NASA but urged more timely progress on development of the space vehicle itself. Two weeks later, ARPA and NASA established protocols for cooperating in the aggressive development of the capsule that would be used in the human spaceflight program.[77]

To aid in the conduct of this program, ARPA and NASA created a panel for Manned Space Flight, also referred to as the Joint Manned Satellite Panel, on September 18, 1958. At its first meeting on September 24, the panel established goals and strategy for the program. Chaired by Robert Gilruth and including such NASA leaders as Max Faget and George Low, the panel focused on a wide range of technical requirements necessary to complete the effort. Under this panel's auspices, final specifications for the piloted capsule emerged in October 1958, as did procurement of both modified Redstone (for suborbital flights) and Atlas (for orbital missions) boosters.[78]

Even while cooperating with NASA on Project Mercury, DOD remained committed to the eventual achievement of human spaceflight. It pursued several programs aimed in that direction. The first was the X–20 Dynasoar, a military spaceplane to be launched atop a Titan launcher—a narrow mission, to be sure. The Air Force believed that the X–20 would provide a long-range bombardment and reconnaissance capability by flying at the edge of space and skipping off the Earth's atmosphere to reach targets anywhere in the world. The Air Force design for the Dynasoar project, which began on December 11, 1961, required the Titan IIIC to launch its military orbital spaceplane.[79] This winged, recoverable spacecraft did not possess as large a payload as NASA's capsule-type spacecraft and was always troubled by the absence of a clearly defined military mission. Accordingly, in September 1961, Defense Secretary Robert S. McNamara questioned whether Dynasoar represented the best expenditure of funds. This resulted in numerous studies of the program, but in 1963, McNamara canceled the program in favor of a Manned Orbiting Laboratory (MOL). This military space station, along with a modified capsule known as Gemini-B, would be launched into orbit aboard a Titan IIIM vehicle that used seven-segment solids and was human-rated. As an example of the seriousness with which the Air Force pursued the MOL program, the third Titan IIIC test flight boosted a prototype Gemini-B (previously used as GT–2 in the Gemini test program) and an aerodynamic mockup of the MOL laboratory into orbit. It was as close as MOL would come to reality. The new military space station plan ran into numerous technical and fiscal problems, and in June 1969, Secretary of Defense Melvin R. Laird informed Congress that MOL would be canceled.[80]

Military space policy analyst Paul Stares summarized the fallout from the loss of the X–20 and MOL programs upon the Air Force during the 1960s:

> With the cancellation of the Dynasoar and MOL, many believed in the Air Force that they had made their "pitch" and failed. This in turn reduced the incentives to try again and reinforced the bias towards the traditional mission of the Air Force, namely flying. As a result, the Air Force's space activities remained a poor relation to tactical and strategic airpower in its organizational hierarchy and inevitably in its funding priorities. This

> undoubtedly influenced the Air Force's negative attitude towards the various ASAT modernization proposals put forward by Air Defense Command and others in the early 1970s. The provision of satellite survivability measures also suffered because the Air Force was reluctant to propose initiatives that would require the use of its own budget to defend the space assets of other services and agencies.[81]

This setback did not dissuade DOD from further attempts to enter the realm of human spaceflight, although the next effort involved persuading NASA to alter its space shuttle concept and to include a military mission in its planning scenarios.

After Apollo, the human element of the U.S. civil space program went into a holding pattern for nearly a decade. During that time, it moved from its earlier heroic age to one characterized by more routine activities, perspectives, and processes; it was an institutionalizing of critical elements from a remarkably fertile heroic time.[82]

The space shuttle became the sine qua non of NASA during the 1970s, intended as it was to make spaceflight routine, safe, and relatively inexpensive. Although NASA considered a variety of configurations, some of them quite exotic, it settled on a stage-and-a-half partially reusable vehicle with an approved development price tag of $5.15 billion. On January 5, 1972, President Richard Nixon announced the decision to build a space shuttle. He did so for both political reasons and national prestige purposes. Politically, it would help a lagging aerospace industry in key states he wanted to carry in the next election, especially California, Texas, and Florida.[83] Supporters—especially Caspar Weinberger, who later became Reagan's defense secretary—argued that building the shuttle would reaffirm America's superpower status and help restore confidence, at home and abroad, in America's technological genius and will to succeed. This was purely an issue of national prestige.[84]

The prestige factor belies a critical component. U.S. leaders supported the shuttle not on its merits but on the image it projected. In so doing, the space shuttle that emerged in the early 1970s was essentially a creature of compromise that consisted of three primary elements: a delta-winged orbiter spacecraft with a large crew compartment, a cargo bay 15 by 60 feet in size, and three main engines; two solid rocket boosters; and an external fuel tank housing the liquid hydrogen and oxidizer burned in the main engines. The orbiter and the two solid rocket boosters were reusable. The shuttle was designed to transport approximately 45,000 tons of cargo into low Earth orbit, 115 to 250 statute miles above the Earth. It could also accommodate a flight crew of up to 10 persons (although a crew of 7 would be more common) for a basic space mission of 7 days. During a return to Earth, the orbiter was designed so that it had a cross-range maneuvering capability of 1,265 statute miles to meet requirements for liftoff and landing at the same location after only one orbit.[85]

Many of those design modifications came directly from the Department of Defense; in return for DOD monetary and political support for the project, which might have not been approved otherwise, military astronauts would fly on classified missions in Earth orbit. Most of those missions were for the purpose of deploying reconnaissance satellites.

The national security implications of the space shuttle decision must not be underestimated. Caspar Weinberger was key to the movement of the decision through the White House, and he believed the shuttle had obvious military uses and profound implications for national security. "I thought we could get substantial return" with the program, he said in a 1977 interview, "both from the point of view of national defense, and from the point of view [of] scientific advancement which would have a direct beneficial effect."[86] He and others also impressed on the President the shuttle's potential for military missions. John Ehrlichman, Nixon's senior advisor for domestic affairs, even thought it might be useful to capture enemy satellites.[87] The Soviets, who built the *Buran* in the 1980s and flew it without a crew only one time, pursued a shuttle project as a counterbalance to the U.S. program solely because they were convinced that the U.S. shuttle was developed for military purposes. As Russian space watcher James Oberg suggested: "They had actually studied the shuttle plans and figured it was designed for an out-of-plane bombing run over high-value Soviet targets. Brezhnev believed that and in 1976 ordered $10 billion of expenditures. They had the *Buran* flying within ten years and discovered they couldn't do anything with it."[88]

After a decade of development, on April 12, 1981, *Columbia* took off for the first orbital test mission. It was successful, and President Reagan declared the system "operational" in 1982 after only its fourth flight. It would henceforth carry all U.S. Government payloads; military, scientific, and even commercial satellites could all be deployed from its payload bay.[89] To prepare for this, in 1979, Air Force Secretary Hans Mark created the Manned Spaceflight Engineer program to "develop expertise in manned spaceflight and apply it to Department of Defense space missions." Between 1979 and 1986, this organization trained 32 Navy and Air Force officers as military astronauts.[90]

Even so, the shuttle soon proved disappointing. By January 1986, there had been only 24 shuttle flights, although in the 1970s NASA had projected more flights than that each year. Critical analyses agreed that the shuttle had proven to be neither cheap nor reliable, both primary selling points, and that NASA should never have used those arguments in building a political consensus for the program.[91] All of these criticisms reached crescendo proportions following the loss of the *Challenger* during launch on January 28, 1986.[92] A result of this was the removal from the shuttle of all commercial and national security payloads and the reinvigoration of the expendable launch vehicle production lines. It became another instance of DOD seeking a military human mission that eventually went awry.

This quest for military astronauts did not end there. In the 1980s, DOD along with NASA began work on a single-stage-to-orbit (SSTO) vehicle for military purposes. If there is a holy grail of spaceflight, it is the desire for reusable SSTO technology—essentially a vehicle that can take off, fly into orbit, perform its mission, and return to Earth, landing like an airplane. This is an exceptionally difficult flight regime with a multitude of challenges relating to propulsion, materials, aerodynamics, and guidance and control.

Fueled by the realization that the space shuttle could not deliver on its early expectations, DOD leaders pressed for the development of a hypersonic spaceplane. During the Reagan administration and its associated military buildup, Tony DuPont, head of DuPont Aerospace, offered an unsolicited proposal to the Defense Advanced Research Projects Agency (DARPA) to design a hypersonic vehicle powered by a hybrid integrated engine of scramjets and rockets. DARPA program manager Bob Williams liked the idea and funded it as a black program code-named COPPER CANYON between 1983 and 1985. The Reagan administration later unveiled it as the National Aero-Space Plane (NASP), designated the X–30. Reagan called it "a new Orient Express that could, by the end of the next decade, take off from Dulles Airport and accelerate up to twenty-five times the speed of sound, attaining low Earth orbit or flying to Tokyo within two hours."[93]

The NASP program initially proposed to build two research craft, at least one of which should achieve orbit by flying in a single stage through the atmosphere at speeds up to Mach 25. The X–30 would use a multicycle engine that shifted from jet to ramjet and to scramjet speeds as the vehicle ascended burning liquid hydrogen fuel with oxygen scooped and frozen from the atmosphere.[94] After billions of dollars were spent, NASP never progressed to flight stage. It finally died a merciful death, trapped as it was in bureaucratic politics and seemingly endless technological difficulty, in 1994.[95] Thus fell another military astronaut program.

Elements of DOD remain committed to this mission to the present. Throughout the 1990s, a succession of studies argued for the potential of military personnel in space. One 1992 study affirmed:

> It is absolutely essential for the well being of today's space forces as well as the future space forces of 2025, that DOD develop manned advanced technology space systems in lieu of or in addition to unmanned systems to effectively utilize military man's compelling and aggressive warfighting abilities to accomplish the critical wartime mission elements of space control and force application. National space policy, military space doctrine and common sense all dictate they should do so if space superiority during future, inevitable conflict with enemy space forces is the paramount objective. Deploying military man in space will provide that space superiority and he will finally become the "center of gravity" of the U.S. space program.[96]

Another analysis found 37 reasons why military personnel in space would be required in the future, ranging from problem-solving and decisionmaking to manipulation of sensors and other systems. It concluded that "a military space plane could play a key role in helping the United States Air Force transform itself from an air force into an aerospace force."[97] Yet another study found: "Our National Security Strategy must take full advantage of the full political, economic, and military power of this nation to be successful. That means soldiers, sailors and airmen able to operate in every region of the world critical to national security, whether it be on land, at sea, in the air, or in space. A strategy built on anything less is incomplete and shortsighted."[98] Of course, if *Aviation*

Week and Space Technology is to be believed, DOD not only wished for a military human mission in space but also developed a spaceplane named Blackstar and began flying missions as early as 1990.[99]

It is obvious the decision made initially by Eisenhower to split the civil and military space programs and to assign the human mission to the civil side has been a bitter pill that remains difficult for DOD to swallow. It represents one instance among many in which a continuum between cooperation and competition has taken place in the interrelationships between the civil and military space programs. It is one of the many policy decisions made in the 1950s that may be overturned in the post– Cold War environment.

Conclusion

The fact that this survey of civil space history in relation to the national security arena has been oriented largely toward human spaceflight does not mean that other areas are insignificant in these interrelations— tracking and recovery, launch complexes and ranges, technology development, and a host of other issues come to mind—but the overwhelming amount of the funding spent on the civil space side has been for human spaceflight. Well over half of the NASA budget since the agency's creation has been expended on the human program, and therefore an emphasis on the part of the civil program appears appropriate. We have seen that there has been a long mating dance between the civil and military space programs over the years, and it appears that in the post–Cold War era, there may be a much closer relationship than was allowed earlier.

In terms of lessons learned, what might spacepower analysts take from this discussion? First, spacepower possesses a major civil space, soft-power component that has been critical in the conduct of foreign policy during the last 50 years. It was a positive development in the winning of the Cold War, and the soft power element of spaceflight must be considered in the context of any policy issue. Second, there is so much overlap between the technology of civil and military spaceflight that it is critical that these two realms be kept as separate as possible. Finally, human spaceflight has long been a province of the civil space program in the United States, but the military has always wanted to become a part of it. There may well come a time when this becomes a reality, but probably not until humans have made their homes in space.

As scientists and entrepreneurs spread into space, military personnel are likely to accompany them. Although the space frontier differs considerably from the American West, one aspect of the military role on the American frontier is worth remembering. For most of the time during the era of expansion, military personnel on the American frontier performed many tasks. They restrained lawless traders, pursued fugitives, ejected squatters, maintained order during peace negotiations, and guarded Indians who came to receive annuities. This was largely peaceful work, with the military catalyzing the processes of economic and social development.

If humans develop a base on the Moon or even an outpost on Mars, the military may perform these duties once more. Remembering the role of the U.S. Corps of Topographical Engineers and the U.S. Army Corps of Engineers in opening the American West, military leaders may propose the creation of a U.S. Corps of Space Engineers. The role they could play would be analogous to military activities in Antarctica. The U.S. Navy oversees the American station at McMurdo Sound and, every winter, the U.S. Air Force conducts a resupply airdrop at the South Pole station. Similar arrangements could take place on the Moon. Military personnel could construct and maintain an isolated lunar outpost or a scientific station on the back side of the Moon. By providing support, military personnel would establish a presence in space and help secure national interests. This is a strikingly different perspective than what has been pursued militarily in space to date.

Notes

1. Solid overviews of the history of space exploration include William E. Burrows, *This New Ocean: The Story of the First Space Age* (New York: Random House, 1998); Howard E. McCurdy, *Space and the American Imagination* (Washington, DC: Smithsonian Institution Press, 1997); and Roger D. Launius, *Frontiers of Space Exploration* (Westport, CT: Greenwood Press, 1998).
2. Dwayne A. Day, "Invitation to Struggle: The History of Civilian-Military Relations in Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. II, *External Relationships*, ed. John M. Logsdon, Dwayne A. Day, and Roger D. Launius (Washington, DC: NASA SP–4407, 1996), 233.
3. No better example of dual-use technology may be found than launch vehicles; almost all of those in the American inventory began as ballistic missiles developed to deliver nuclear weapons. On the history of this subject, see Roger D. Launius and Dennis R. Jenkins, eds., *To Reach the High Frontier: A History of U.S. Launch Vehicles* (Lexington: University Press of Kentucky, 2002).
4. R. Cargill Hall, "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. I, *Organizing for Exploration*, ed. John M. Logsdon and Linda J. Lear (Washington, DC: NASA, 1995), 222.
5. Vernon Van Dyke, *Pride and Power: The Rationale of the Space Program* (Urbana: University of Illinois Press, 1964).
6. John P. Lovell, review of *Pride and Power: The Rationale of the Space Program,* in *Midwest Journal of Political Science* 9 (February 1965), 119.
7. This is the fundamental thesis of Van Dyke, *Pride and Power*; Derek Wesley Elliott, "Finding an Appropriate Commitment: Space Policy Development under Eisenhower and Kennedy, 1954–1963," Ph.D. dissertation, George Washington University, 1992. It is also borne out in several essays contained in Roger D. Launius and Howard E. McCurdy, eds., *Spaceflight and the Myth of Presidential Leadership* (Urbana: University of Illinois Press, 1997), especially chapters 2, 3, 6, and 7.
8. The best discussion of the evolution of space policy and the sorting of roles and missions for the various government entities remains John M. Logsdon, "The Evolution of U.S. Space Policy and Plans," in Logsdon and Lear, 377–393. See also Roger D. Launius, ed., *Organizing for the Use of Space: Historical Perspectives on a Persistent Issue*, vol. 18, AAS History Series (San Diego: Univelt, Inc., 1995); James R. Killian, Jr., *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge: MIT Press, 1977); George B. Kistiakowsky, *A Scientist in the White House* (Cambridge: Harvard University Press, 1976); T. Keith Glennan, *The Birth of NASA: The Diary of T. Keith Glennan*, ed. J.D.

Hunley (Washington, DC: NASA SP–4105, 1993); and Robert L. Rosholt, *An Administrative History of NASA, 1958–1963* (Washington, DC: NASA SP–4101, 1966).

9. On the grandiose visions of military personnel in space, see Wernher von Braun, "Crossing the Last Frontier," *Collier's*, March 22, 1952, 24–28, 72–73; Michael J. Neufeld, "'Space Superiority': Wernher von Braun's Campaign for a Nuclear-Armed Space Station, 1946–1956," *Space Policy* 22 (February 2006), 52–62; Curtis Peebles, *High Frontier: The U.S. Air Force and the Military Space Program* (Washington, DC: USAF History and Museums Program, 1997), 15–31; and Timothy D. Killebrew, "Military Man in Space: A History of Air Force Efforts to Find a Manned Space Mission," master's thesis, Air Command and Staff College, February 1987.
10. On Sputnik, see these important works: Rip Bulkeley, *The Sputnik Crisis and Early United States Space Policy: A Critique of the Historiography of Space* (Bloomington: Indiana University Press, 1991); Robert A. Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (New York: Oxford University Press, 1993); and Paul Dickson, *Sputnik: The Shock of the Century* (New York: Walker and Company, 2001).
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12. On the International Space Station, see Roger D. Launius, *Space Stations: Base Camps to the Stars* (Washington, DC: Smithsonian Institution Press, 2003). On the space shuttle, see Dennis R. Jenkins, *Space Shuttle: The History of the National Space Transportation System, the First 100 Missions*, 3d ed. (Cape Canaveral, FL: Dennis R. Jenkins, 2001); T.A. Heppenheimer, *The Space Shuttle Decision: NASA's Search for a Reusable Space Vehicle* (Washington, DC: NASA SP–4221, 1999); T.A. Heppenheimer, *Development of the Space Shuttle, 1972–1981*, vol. 2, *History of the Space Shuttle* (Washington, DC: Smithsonian Institution Press, 2002); and David M. Harland, *The Story of the Space Shuttle* (Chichester, UK: Springer-Praxis, 2004).
13. This is an expression of Frederick Jackson Turner's "Frontier Thesis" that guided inquiry into much of American history for a generation. It also continues to inform many popular images of the American West. Turner outlined the major features of the subject in *The Frontier in American History* (New York: Holt, Rinehart, and Winston, 1920), which included the seminal 1893 essay, "The Significance of the Frontier in American History."
14. This frontier imagery was overtly mythic. Myths, however, are important to the maintenance of any society, for they are stories that symbolize an overarching ideology and moral consciousness. As James Oliver Robertson observes in his book *American Myth, American Reality* (New York: Hill and Wang, 1980), xv, "Myths are the patterns of behavior, or belief, and/or perception—which people have in common. Myths are not deliberately, or necessarily consciously, fictitious." Myth, therefore, is not so much a fable or falsehood, as it is a story, a kind of poetry, about events and situations that have great significance for the people involved. Myths are, in fact, essential truths for the members of a cultural group who hold them, enact them, or perceive them. They are sometimes expressed in narratives, but in literate societies like the United States, they are also apt to be embedded in ideologies. Robertson's book is one of many studies that focus on American myths—such as the myth of the chosen people, the myth of a God-given destiny, and the myth of a New World innocence or inherent virtue.
15. This is the thesis of William Sims Bainbridge, *The Spaceflight Revolution: A Sociological Study* (New York: John Wiley and Sons, 1976). See also Willy Ley and Chesley Bonestell, *The Conquest of Space* (New York: Viking, 1949).
16. George H. Gallup, *The Gallup Poll: Public Opinion, 1935–1971* (New York: Random House, 1972), 1:875, 1152.
17. As an example of his exceptionally sophisticated spaceflight promoting, see Wernher von Braun, *The Mars Project* (Urbana: University of Illinois Press, 1953), based on a German-language series of articles appearing in the magazine *Weltraumfahrt* in 1952.

18. "What Are We Waiting For?" *Collier's*, March 22, 1952, 23; Wernher von Braun with Cornelius Ryan, "Can We Get to Mars?" *Collier's*, April 30, 1954, 22–28; Randy L. Liebermann, "The *Collier's* and Disney Series," in Frederick I. Ordway III and Randy L. Liebermann, *Blueprint for Space* (Washington, DC: Smithsonian Institution Press, 1992), 141; and Ron Miller, "Days of Future Past," *Omni*, October 1986, 76–81.
19. The dichotomy of visions has been one of the central components of the U.S. space program. Those who advocated a scientifically oriented program using nonpiloted probes and applications satellites for weather, communications, and a host of other useful activities were never able to capture the imagination of the American public the way the human spaceflight advocates did. For a modern critique of this dichotomy, see Alex Roland, "Barnstorming in Space: The Rise and Fall of the Romantic Era of Spaceflight, 1957–1986," in *Space Policy Reconsidered*, ed. Radford Byerly, Jr. (Boulder, CO: West-view Press, 1989), 33–52. That the human imperative is still consequential is demonstrated in William Sims Bainbridge's sociological study, *Goals in Space: American Values and the Future of Technology* (Albany: State University of New York Press, 1991).
20. "What Are We Waiting For?" 23.
21. Elaine Tyler May, *Homeward Bound: American Families in the Cold War Era* (New York: Basic Books, 1988), 93–94, 104–113.
22. See Roger D. Launius, John M. Logsdon, and Robert W. Smith, eds., *Reconsidering Sputnik: Forty Years Since the Soviet Satellite* (Amsterdam, The Netherlands: Harwood Academic Publishers, 2000).
23. Roger D. Launius, "Eisenhower, Sputnik, and the Creation of NASA: Technological Elites and the Public Policy Agenda," *Prologue: Quarterly of the National Archives and Records Administration* 28 (Summer 1996), 127–143; Roger D. Launius, "Space Program," in *Dictionary of American History: Supplement*, ed. Robert H. Ferrell and Joan Hoff (New York: Charles Scribner's Sons Reference Books, 1996), 2:221–223.
24. See James A. Van Allen, *Origins of Magnetospheric Physics* (Washington, DC: Smithsonian Institution Press, 1983); and Matthew J. Von Benke, *The Politics of Space: A History of U.S.-Soviet/Russian Competition and Cooperation in Space* (Boulder, CO: Westview Press, 1997).
25. "National Aeronautics and Space Act of 1958," Public Law 85–568, 72 Stat., 426, Record Group 255, National Archives and Records Administration, Washington, DC; and Alison Griffith, *The National Aeronautics and Space Act: A Study of the Development of Public Policy* (Washington, DC: PublicAffairs Press, 1962), 27–43.
26. Roger D. Launius, *NASA: A History of the U.S. Civil Space Program* (Malabar, FL: Krieger Publishing Co., 1994), 29–41.
27. The standard works on this subject are Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974* (Washington, DC: NASA SP–2000–4408, 2000); and James J. Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley and Sons, 1997).
28. Dwight D. Eisenhower, "Are We Headed in the Wrong Direction?" *Saturday Evening Post*, August 11, 1962, 24.
29. Dwight D. Eisenhower, "Why I Am a Republican," *Saturday Evening Post*, April 11, 1964, 19.
30. In addition to the above books on Apollo, see Edgar M. Cortright, ed., *Apollo Expeditions to the Moon* (Washington, DC: NASA SP–350, 1975); W. Henry Lambright, *Powering Apollo: James E. Webb of NASA* (Baltimore: The Johns Hopkins University Press, 1995); and David West Reynolds, *Apollo: The Epic Journey to the Moon* (New York: Harcourt, 2002).
31. These observations are based on calculations using the budget data included in the annual *Aeronautics and Space Report of the President, 2003 Activities* (Washington, DC: NASA Report, 2004), appendix E, which contains this information for each year since 1959; "National Aeronautics and Space Administration President's FY 2007 Budget Request," February 6, 2006, part I, NASA Historical Reference Collection, NASA History Division, NASA Headquarters, Washington, DC.
32. Stephanie A. Roy, Elaine C. Gresham, and Carissa Bryce Christensen, "The Complex Fabric of Public Opinion on Space," IAF–99–P.3.05, presented at the International Astronautical Federation annual meeting, Amsterdam, The Netherlands, October 5, 1999.

33. *The Gallup Poll: Public Opinion, 1935–1971*, part III: *1959–1971*, 1952, 2183–2184, 2209; *The New York Times*, December 3, 1967; *Newsweek* is quoted in *An Administrative History of NASA*, chap. II, 48, NASA Historical Reference Collection.
34. This analysis is based on a set of Gallup, Harris, NBC/Associated Press, CBS/*New York Times*, and ABC/*USA Today* polls conducted throughout the 1960s; copies are available in the NASA Historical Reference Collection.
35. Roger D. Launius, "Kennedy's Space Policy Reconsidered: A Post–Cold War Perspective," *Air Power History* 50 (Winter 2003), 16–29.
36. "Treaty on the Non-Proliferation of Nuclear Weapons," March 5, 1970, available at <http://disarmament.un.org/TreatyStatus.nsf>; "Missile Technology Control Regime," 1987, available at <www.mtcr.info/english/index.html>; and "Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies," available at <www.wassenaar.org/>.
37. A journalistic muckraking account of this story may be found in Bill Gertz, *Betrayal: How the Clinton Administration Undermined American Security* (Washington, DC: Regnery Publishing, Inc., 1999), which includes a useful collection of important government facsimile documents.
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40. Richard E. Martin, *The Atlas and Centaur "Steel Balloon" Tanks: A Legacy of Karel Bossart* (San Diego: General Dynamics Corp., 1989); Robert L. Perry, "The Atlas, Thor, Titan, and Minuteman," in Emme, 143–155; and John L. Sloop, *Liquid Hydrogen as a Propulsion Fuel, 1945–1959* (Washington, DC: NASA SP–4404, 1978), 173–177. See also Edmund Beard, *Developing the ICBM: A Study in Bureaucratic Politics* (New York: Columbia University Press, 1976); and Jacob Neufeld, *Ballistic Missiles in the United States Air Force, 1945–1960* (Washington, DC: Office of Air Force History, 1990).
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partnership did the European nations create the European Space Agency and embark on a launch vehicle of their own design, Ariane. See Roger D. Launius, "NASA, the Space Shuttle, and the Quest for Primacy in Space in an Era of Increasing International Competition," in *L'Ambition Technologique: Naissance d'Ariane*, ed. Emmanuel Chadeau (Paris: Institut d'Histoire de l'Industrie, 1995), 35–61.

47. Hans Mark, *The Space Station: A Personal Journey* (Durham, NC: Duke University Press, 1987), 61–65; Heppenheimer, *Space Shuttle Decision*, 275–280; and David M. Harland, *The Space Shuttle: Roles, Missions and Accomplishments* (Chichester, England: Praxis Publishing, Ltd., 1998), 411–412.
48. Few individuals have yet discussed the competing priorities that the shuttle was asked to fulfill. It seems truer as time passes, however, that the "one-size-fits-all" approach to technological challenges that the shuttle was asked to solve was unfair to the launch vehicle, the people who made it fly, and the organization that built and launched it. This would not be the first time in American history when such an approach had been used. The Air Force had been forced in the 1960s to accept a combination fighter and bomber, the FB–111, against its recommendations. That airplane proved a disaster from start to finish. The individuals operating the space shuttle soldiered on as best they could to fulfill all expectations but the task was essentially impossible. See Michael F. Brown, *Flying Blind: The Politics of the U.S. Strategic Bomber Program* (Ithaca: Cornell University Press, 1992); and David S. Sorenson, *The Politics of Strategic Aircraft Modernization* (Westport, CT: Praeger, 1995).
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51. "Commercial Space Launch Act Amendments of 1988," in *Exploring the Unknown*, vol. IV, 458–465.
52. Isakowitz, Hopkins, and Hopkins, *International Reference Guide to Space Launch Systems*, 3d ed., passim.
53. [53] Office of the President, National Security Presidential Directive 4, "National Space Launch Strategy," July 10, 1991, available at <http://fas.org/spp/military/docops/national/nspd4.htm>; William B. Scott, "ALS Cost, Efficiency to Depend Heavily on Process Improvements," *Aviation Week and Space Technology*, October 23, 1989, 41.
54. This problem is discussed in some detail in Roger D. Launius, "After Columbia: The Space Shuttle Program and the Crisis in Space Access," *Astropolitics* 2 (July–September 2004), 277–322; and John M. Logsdon, "'A Failure of National Leadership': Why No Replacement for the Space Shuttle?" in *Critical Issues in the History of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington, DC: NASA SP–2006–4702, 2006), 269–300.
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56. The term was coined in Joseph S. Nye, *Bound to Lead: The Changing Nature of American Power* (New York: Basic Books, 1990). See also Joseph S. Nye, *Soft Power: The Means to Success in World Politics* (New York: PublicAffairs, 2004).
57. Joseph S. Nye, "Propaganda Isn't the Way: Soft Power," *The International Herald Tribune*, January 10, 2003.
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59. Lyndon B. Johnson, *The Vantage Point: Perspectives of the Presidency, 1963–1969* (New York: Holt, Rinehart, and Winston, 1971), 272.
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61. Gallup polls, October 1, 1957, August 1, 1958, December 1, 1959, December 1, 1960, May 1, 1961, August 1, 1962, February 1, 1963, June 1, 1963, May 1, 1964, June 1, 1965, July 1, 1969, and May 1, 1971.

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63. Kenneth Osgood, *Total Cold War: Eisenhower's Secret Propaganda Battle at Home and Abroad* (Lawrence: University Press of Kansas, 2006), 353.
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74. David N. Spires and Rick W. Sturdevant, "' . . . to the very limit of our ability . . . ': Reflections on Forty Years of Civil-Military Partnership in Space Launch," in *To Reach the High Frontier: A History of U.S. Launch Vehicles*, ed. Launius and Jenkins, 475.
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NASA Deputy Administrator, "Conversation with Al Haig," December 2, 1971, NASA History Division Reference Collection.

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Chapter 11:

Victory from Mars

Robert Zubrin

The discovery of America ultimately made the fortune of this island, transformed our situation in the world. . . . As America prospered and became more important, so did we. . . . Within that community there is a natural shift of power and emphasis to the western side of the Atlantic. But already twice in our lifetime our country's existence has been assured by the preponderant partner. What sort of future could our small island expect looking out on a world riven between East and West, in the conflicts of giant land masses, without that assurance? . . . We owe this factor in our safety, the very condition of our lives, to the ambition and foresight, the enterprise and persistence, of our common ancestors, the Elizabethans.

—A.L. Rowse, *The Elizabethans and America*, 1959

The game of life is played not for money, but for children. The same is true of the contest of nations. Ultimately, victory can only be secured, and defined, by the generation of progeny.

In other chapters in this volume, authors have addressed the utility of space assets for pursuing military objectives such as support of communications, navigation, reconnaissance, missile or aircraft interception, or strike. Although the importance of such tactical applications of space technology for achieving superiority on the terrestrial battlefield can in no way be disparaged, this chapter considers the significance of the space endeavor and space itself with respect to the central strategic goal of securing ultimate victory for the American cause.

To use a naval analogy, the battlefield advantages offered by space technology compare to the application of superior seapower for such purposes as shore bombardment or close-in port blockade, both of which were of some utility to Britain in various European conflicts during its age of naval dominance. In contrast, the purposes addressed in this chapter compare to those by which the British took advantage of their maritime capacity to expand their language, culture, values, and society across the globe.

Anticipating the conflicts to come, a prescient late 19th-century writer once drew a pointed comparison between the strategic thinking styles of the contending European elites.[1] The German General Staff, he observed, calculated their wars with regard to fortresses and railway schedules. The British, however, laid their plans in terms of "continents and centuries," and by virtue of this broader strategic grasp, would always ultimately defeat their more mentally limited opponents. Looking back today on both the course and outcomes of the two major wars of the 20^{th} century, one cannot but be forcefully impressed by the penetrating nature of his assessment.

"Fortresses and railway schedules," or their modern-day equivalents, certainly have a place in military thinking. But if a nation is to prevail over the long haul, those entrusted with its fate must also consider matters of "continents and centuries." This is the central truth that must guide U.S. space policy if it is to be formulated adequately.

In the mid-1500s, at the time of accession of Queen Elizabeth I, England was a very minor power, insignificant in comparison with Spain, France, Poland, Austria, or the Ottoman Empire, inferior in significance even to Portugal or Venice. But as a result of the vision of leaders like Richard Hakluyt, Walter Raleigh, Humphrey Gilbert, and Elizabeth herself, a set of policy decisions was made and implemented at great cost and sacrifice to challenge Spain upon the high seas and thus make possible the creation of a new England on the other side of the Atlantic. If not for that and the colonization initiatives that followed, the individualistic humanist culture that Tudor England was in seed form would not have propagated to become the basis of advanced global society today. Indeed, if not for that, William Shakespeare, the Magna Carta, the Common Law, trial by jury, and other portentous aspects of Tudor society would today be mere historical footnotes, of no greater interest to the present age than the literature and culture of late medieval Croatia. If not for that, no one in the present age would likely be discoursing on space strategy at all.

In considering the success of the British program of overseas colonization in transforming both the English polity and English culture from insignificance to world dominance, it is useful to compare it not only with the policies of nonplaying contemporary great powers such as Turkey and Poland, but also to apparent colonizers such as Spain and France. While in retrospect it is clear enough that those powers that chose to obsess over affairs internal to the European arena while ignoring the continents to be won elsewhere were writing themselves out of the future, the difference in overseas colonization policies between those powers that did venture abroad is not as obvious. However, upon closer inspection, a dramatic difference between the overseas ventures of England and those of its transoceanic competitors emerges. Specifically, while Spain, France, Portugal, and Holland (as well as England) all set up overseas outposts for the purpose of extracting profits for the benefit of investors in Europe, only the English also set about seriously creating daughter countries, true new branches of English civilization. The Spanish sent conquistadors to Mexico and Peru to rule over natives enslaved to mine gold or silver, while the French sent adventurous traders to network with Canadian Indian tribes to obtain valuable fur pelts. However, the English sent families of settlers abroad to build farms, towns, universities, legislatures, and ultimately cities and nations. As a result, despite the fact that the population of the France of Louis XIV was four times that of contemporary England, by 1750 there were 2 million English-speaking people in North America but only 50,000 French. It was thus that the future of this continent and, to a significant degree, this planet, was decided.

But what about the rest of the planets? The Earth is not the only world. In the vast reaches of space, there are myriad others. The true prize in the great game is not the Persian Gulf, but the universe. The nation that first reaches out to colonize it is the one that will put its stamp upon the future.

Our New World

Among extraterrestrial bodies in our solar system, Mars is singular in that it possesses all the raw materials required to support not only life, but also a new branch of human civilization. This uniqueness is illustrated most clearly if Mars is contrasted with the Earth's Moon, the most frequently cited alternative location for extraterrestrial human colonization.

Unlike the Moon, Mars is rich in carbon, nitrogen, hydrogen, and oxygen, all in biologically readily accessible forms such as carbon dioxide gas, nitrogen gas, water ice, and permafrost.[2] Carbon, nitrogen, and hydrogen are only present on the Moon in parts per million quantities. Oxygen is abundant on the Moon, but only in tightly bound oxides such as silicon dioxide, ferrous oxide, magnesium oxide, and alumina oxide, which require very high-energy processes to reduce.[3] Current knowledge indicates that if Mars were smooth and all its ice and permafrost melted into liquid water, the entire planet would be covered with an ocean over 200 meters deep.[4] This scenario contrasts strongly with the Moon, which is so dry that if concrete were found there, lunar colonists would mine it to get the water out. Thus, if plants could be grown in greenhouses on the Moon (an unlikely proposition, as the Moon's 2-week-long dark spell is unsuitable for most plants, and the absence of any atmosphere would make necessary very thick glass for solar flare shielding), most of their biomass material would have to be imported.

The Moon is also deficient in about half the metals of interest to industrial society (copper, for example), as well as many other elements of interest such as sulfur and phosphorus. Mars has every required element in abundance. Moreover, on Mars, as on Earth, hydrologic and volcanic processes have occurred that are likely to have consolidated various elements into local concentrations of high-grade mineral ore. Indeed, the geologic history of Mars has been compared to that of Africa, with very optimistic inferences as to its mineral wealth implied as a corollary.[5] In contrast, the Moon has almost no history of water or volcanic action, with the result that it is basically composed of trash rocks with little differentiation into ores that represent useful concentrations of anything interesting.

Power could be generated on either the Moon or Mars with solar panels, and here the advantages of the Moon's clearer skies and closer proximity to the Sun than Mars roughly balance the disadvantage of large energy storage requirements created by the Moon's 28-day light/dark cycle. But if the desire was to manufacture solar panels so as to create a self-expanding power base, Mars holds an enormous advantage, as only Mars possesses the large supplies of carbon and hydrogen needed to produce the pure silicon required for making photovoltaic panels and other electronics. Also, there is no geologically purified source of silicon dioxide, such as sand, on the Moon. In addition, Mars has the potential for wind-generated power, while the Moon clearly does not. But both the Sun and wind offer relatively modest power potential—tens or at most hundreds of kilowatts here or there. To create a vibrant civilization, a richer power base is needed, and Mars has this both in the short and medium term in the form of its geothermal power resources, which offer the potential for large numbers of locally created electricity-generating stations in the 10 megawatt (10,000 kilowatt) class. In the long term, Mars will enjoy a power-rich economy based upon exploitation of its large domestic resources of deuterium fuel for fusion reactors. Deuterium is five times more common on Mars than it is on Earth, and tens of thousands of times more common on Mars than on the Moon.[6]

But the biggest problem with the Moon, as with all other airless planetary bodies and proposed artificial free-space colonies, is that sunlight is not available in a form useful for growing crops. A single acre of plants on Earth requires 4 megawatts (MW) of sunlight power; a square kilometer needs 1,000 MW. The entire world put together would not produce enough electric power to illuminate the farms of the state of Rhode Island. Growing crops with electrically generated light is economically hopeless. But natural sunlight cannot be used on the Moon or any other airless body in space unless the walls on the greenhouse are thick enough to shield out solar flares, a requirement that enormously increases the expense of creating crop land. Even accomplishing this requirement would do no good on the Moon, because plants will not grow in a light/dark cycle lasting 28 days.

But Mars has an atmosphere thick enough to protect crops grown on the surface from solar flares. Therefore, thin-walled inflatable plastic greenhouses protected by unpressurized ultraviolet-resistant hard-plastic shield domes can be used to rapidly create crop land on the surface. Even without the problems of solar flares and a month-long diurnal cycle, such simple greenhouses would be impractical on the Moon as they would create unbearably high temperatures. On Mars, in contrast, the strong greenhouse effect created by such domes would be precisely what is necessary to produce a temperate climate inside. Such domes up to 50 meters in diameter are light enough to be transported from Earth initially, and they eventually could be manufactured on Mars out of indigenous materials. Because all the resources to make plastics exist on Mars, networks of such 50- to 100-meter domes could be manufactured and deployed rapidly, opening up large areas of the surface to both shirtsleeve human habitation and agriculture. Looking further into the future, it will eventually be possible for humans to thicken Mars' atmosphere substantially by forcing the regolith to outgas its contents through a deliberate program of artificially induced global warming. Once that has been accomplished, the habitation domes could be almost any size, as they would not have to sustain a pressure differential between their interior and exterior. In fact, once that has been done, it will be possible to raise specially bred crops outside the domes.

The point is that unlike colonists on any other known extraterrestrial body, Martian colonists will be able to live on the surface, not in tunnels, and move about freely and grow crops in the light of day. Mars is a place where humans can live and multiply to large numbers, supporting themselves with products of every description made out of indigenous materials. Mars is thus a place where an actual civilization, not just a mining or scientific outpost, can be developed. And it is this civilization, grown in size and technological potency on a frontier planet with a surface area as large as all the continents of Earth put together, that will both radically tip the balance among those who remain behind on Earth and provide the pioneers with the craft and outlook required to push the human reach much further.

Thus, for our generation and those soon to follow, Mars is the new world. The nation that settles it is one whose culture, values, social forms, and ideas will provide the point of departure for the further development of human civilization as our species expands outward from its planet of origin to the innumerable others awaiting us in the infinite reaches of space.

The central strategic imperative of American space policy can thus be summarized in two words: colonize Mars.

The Question of Means

Some have said that sending humans to Mars is a venture for the far future. Such a point of view has no basis in fact. On the contrary, such a program is entirely achievable.[7] From the technological point of view, we are ready. Despite the greater distance to Mars, we are much better prepared today to send humans to Mars than we were to launch humans to the Moon in 1961 when John F. Kennedy challenged the Nation to achieve that goal—and we were there 8 years later. Given the will, we could have our first teams on Mars within a decade.

The key to success will be to reject the policy of continued stagnation represented by shuttle-era thinking and return to the destination-driven Apollo method of planned operation that allowed the space agency to perform so brilliantly during its youth. In addition, we must take a lesson from our own pioneer past and adopt a "travel light and live off the land" mission strategy similar to the type that well served terrestrial explorers for centuries. The plan to explore the Red Planet in this way is known as Mars Direct (see figure 11–1). First, an unfueled Earth Return Vehicle (ERV) would be delivered to Mars, where it would manufacture its propellant from the Martian atmosphere. The crew then would fly to Mars in a tuna-can-shaped habitation module, which would also provide living quarters, a laboratory, and a workshop for a 1½-year Mars stay.

Figure 11–1. Artist concept of the Mars Direct plan.

Source: Robert Murray, Pioneer Astronautics

At an early launch opportunity—for example, 2014—a single heavy lift booster with a capability equal to that of the Saturn V used during the Apollo program is launched off Cape Canaveral and uses its upper stage to throw a 40-ton unmanned payload onto a trajectory to Mars. (Such a booster could be readily created by converting the shuttle launch stack, by deleting the Orbiter and replacing it with a payload fairing containing a hydrogen/oxygen rocket stage.) Upon arrival at Mars 8 months later, the spacecraft uses friction between its aeroshield and Mars' atmosphere to brake itself into orbit around the planet and then lands with the help of a parachute. This payload is the ERV. It flies out to Mars with its two methane/oxygen-driven rocket propulsion stages unfueled. It also carries 6 tons of liquid hydrogen cargo, a 100-kilowatt nuclear reactor mounted in the back of a methane/oxygen-driven light truck, a small set of compressors and an automated chemical processing unit, and a few small scientific rovers.

As soon as the craft lands successfully, the truck is telerobotically driven a few hundred meters away from the site, and the reactor is deployed to provide power to the compressors and chemical processing unit. The hydrogen brought from Earth can be quickly reacted with the Martian atmosphere, which is 95 percent carbon dioxide gas (CO_2), to produce methane and water, thus eliminating the need for long-term storage of cryogenic hydrogen on the planet's surface. The methane so produced is liquefied and stored, while the water is electrolyzed to produce oxygen, which is stored, and hydrogen, which is recycled through the methanator. Ultimately, these two reactions (methanation and water electrolysis) produce 24 tons of methane and 48 tons of oxygen. Since this is not enough oxygen to burn the methane at its optimal mixture ratio, an additional 36 tons of oxygen is produced via direct dissociation of Martian CO_2. The entire process takes 10 months, at the conclusion of which a total of 108 tons of methane/oxygen bipropellant will have been generated. This represents a leverage of 18:1 of Martian propellant produced compared to the hydrogen brought from Earth needed to create it. Ninety-six tons of the bipropellant will be used to fuel the ERV, while 12 tons are available to support the use of high-powered, chemically fueled long-range ground vehicles. Large additional stockpiles of oxygen can also be produced, both for breathing and for turning into water by combination with hydrogen brought from Earth. Since water is 89 percent oxygen (by weight), and since the larger part of most foodstuffs is water, this greatly reduces the amount of life support consumables that need to be hauled from Earth.

The propellant production having been successfully completed, in 2016 two more boosters lift off and throw their 40-ton payloads toward Mars. One of the payloads is an unmanned fuel-factory/ERV just like the one launched in 2014; the other is a habitation module carrying a crew of four, a mixture of whole food and dehydrated provisions sufficient for 3 years, and a pressurized methane/oxygen-powered ground rover. On the way to Mars, artificial gravity can be provided to the crew by extending a tether between the habitat and the burnt-out booster upper stage and spinning the assembly.

Upon arrival, the manned craft drops the tether, aerobrakes, and lands at the 2014 landing site, where a fully fueled ERV and fully characterized and beaconed landing site await it. With the help of such navigational aids, the crew should be able to land right on the spot. However, if the landing is off course by tens or even hundreds of kilometers, the crew can still achieve the surface rendezvous by driving over in their rover. If they are off by thousands of kilometers, the second ERV provides a backup.

However, assuming the crew lands and rendezvous as planned at site number one, the second ERV will land several hundred kilometers away to start making propellant for the 2018 mission, which in turn will fly out with an additional ERV to open up Mars landing site number three. Thus, every other year, two heavy-lift boosters are launched—one to land a crew, and the other to prepare a site for the next mission—for an average launch rate of just one booster per year to pursue a continuing program of Mars exploration. Since in a normal year, we can launch about six shuttle stacks, this would only represent about 16 percent of the U.S. launch capability and would clearly be affordable. In effect, this "live off the land" approach removes the manned Mars mission from the realm of mega-spacecraft fantasy and reduces it in practice to a task of comparable difficulty to that faced in launching the Apollo missions to the Moon.

The crew will stay on the surface for 1½ years, taking advantage of the mobility afforded by the high-powered, chemically driven ground vehicles to accomplish a great deal of surface exploration. With a 12-ton surface fuel stockpile, they have the capability for over 24,000 kilometers worth of traverse before they leave, giving them the kind of mobility necessary to conduct a serious search for evidence of past or present life on Mars—an investigation key to revealing whether life is a phenomenon unique to Earth. Since no one has been left in orbit, the entire crew will have available to them the natural gravity and protection against cosmic rays and solar radiation afforded by the Martian environment, and thus there will not be the strong driver for a quick return to Earth that plagues alternative Mars mission plans based upon orbiting mother ships with small landing parties. At the conclusion of their stay, the crew returns to Earth in a direct flight from the Martian surface in the ERV. As the series of missions progresses, a string of small bases will be left behind on the Martian surface, opening up broad stretches of territory to human cognizance.

In essence, by taking advantage of the most obvious local resource available on Mars—its atmosphere—the plan allows accomplishment of a manned Mars mission with what amounts to a lunar-class transportation system. By eliminating any requirement to introduce a new order of technology and complexity of operations beyond those needed for lunar transportation to accomplish piloted Mars missions, the plan can reduce costs by an order of magnitude and advance the schedule for the human exploration of Mars by a generation.

Exploring Mars requires no miraculous new technologies, no orbiting spaceports, and no gigantic interplanetary space cruisers. We do not need to spend the next 30 years with a space program mired in impotence, spending large sums of money, and taking occasional casualties while the same missions to nowhere are flown over and over again and professional technologists dawdle endlessly without producing any new flight hardware. We simply need to choose our destination and, with the same combination of vision, practical thinking, and passionate resolve that served us so well during Apollo, do what is required to get there.

We can establish our first small outpost on Mars within a decade. We and not some future generation can have the eternal honor of being the first pioneers of this new world for humanity. All that is needed is present-day technology, some 19th-century industrial chemistry, a solid dose of common sense, and a little bit of moxie.

The Question of Morale

Of the requirements for a successful Mars program, it is the moxie that currently seems hardest to come by. NASA recently made what was intended to be a grand announcement that it was setting its sights on returning astronauts to the Moon by 2020—just a bit over half a century after Americans landed there the first time. NASA gave various reasons for its Moonbase plan, none of which made any sense. The stated scientific goals were trivial compared to those that could be addressed on Mars, and due to its extreme poverty of resources, the Moon is a very poor candidate for human settlement. NASA's claim that nevertheless, the Moon might be a good place to practice space exploration and settlement in preparation for going to Mars (where such activities might actually be possible) was risible. Practice for Mars missions could be done for a tiny fraction of the cost (or three orders of magnitude more practice could be accomplished for the same cost) in the Arctic, so NASA clearly is not aiming for the Moon in order to practice for Mars. On the contrary, the primary purpose of the Moon program appears to be to give NASA a driving programmatic goal that does *not* require embracing the challenge of Mars. Indeed, given the lengthy schedule to the first return landing as advertised for the lunar program (roughly twice as long as it took NASA to accomplish the same feat during the age of slide rules and rotary telephones), one may question whether the current NASA lunar program even includes a willingness to take on the challenge of going to the Moon.[8]Rather, like President George W. Bush's announcement of a plan to balance the Federal budget by 2012 (that is, 4 years *after* he left office), it seems more like a recommendation that somebody else should take on the responsibility of acting bravely.

The question of the reassertion of the American spirit thus emerges as the critical variable that will determine victory or defeat for our nation. How can the space program contribute toward that end? Certainly not by choosing timid goals. Our military space activities can do much to assist national defense, but what we really need is a space program that makes it clear to all that ours is a nation that is truly worth defending.

In September 1962, even as the United States headed toward a decisive confrontation with the Soviet Union in the Cuban missile crisis, President John F. Kennedy gave a speech concerning space policy at Rice University:

> We choose to go to the Moon! We choose to go to the Moon in this decade and do the other things, not because they are easy but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win. . . . This is in some measures an act of faith and vision, for we do not know what benefits await us. . . . But space is there and we are going to climb it.

That is the spirit that built this nation, won the West, achieved our victories, and really got us to the Moon. It is the spirit we desperately need to find again today. But if we are to be as great a people as we once were, we need to act as we once did. For the present age, that means choosing to accept the challenge of Mars. A humans-to-Mars program would be a direct reassertion of the American pioneer spirit. It also would be a profound statement that we, both as a species and as a nation, are living not at the end of our history, but at the beginning of our history—that we choose to continue to be a people whose great deeds will be reported in newspapers, and not just in museums. It is by making and honoring that statement that we will create the means for victory, both now and for ages to come.

Notes

1. The writer in question was Karl Marx. While he may have been incompetent as a designer of economic systems, as a journalistic observer of contemporary political events he was frequently very astute.
2. Michael H. Carr, *The Surface of Mars* (New Haven: Yale University Press, 1981).
3. Michael H. Carr, *Water on Mars* (New York: Oxford University Press, 1996).
4. Grant Heiken, David Vaniman, and Bevan M. French, eds., *Lunar Sourcebook: A User's Guide to the Moon* (Cambridge, UK: Cambridge University Press, 1991).
5. Bruce M. Cordell, "A Preliminary Assessment of Martian Natural Resource Potential," in *The Case for Mars II,* ed. C.P. McKay, AAS Science and Technology Series, vol. 62 (San Diego: Univelt Publishers, 1985).
6. Tobias Owen, Jean Pierre Maillard, Catherine de Bergh, and Barry Lutz, "Deuterium on Mars: The Abundance of HDO and the Value of D/H," *Science* 24, no. 4860 (June 24, 1988), 1767.
7. For details, see Robert Zubrin with Richard Wagner, *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (New York: The Free Press, 1996).
8. Robert Zubrin, "Getting Space Exploration Right," *The New Atlantis*, no. 8 (Spring 2005).

Chapter 12:

The Moon: Point of Entry to Cislunar Space

Paul D. Spudis

If God wanted man to become a space-faring species,
He would have given man a Moon.

— Krafft Ehricke[1]

One can imagine many possible missions and destinations for America's civil space program.Voyages to the planets, large scientific instruments at orbital libration points, and continued use of the International Space Station (ISS) are all possible missions of both machines and people from many countries in the coming decades.With the imminent completion of the ISS and retirement of the space shuttle, a national discussion has emerged as to both the purpose and rationale for human spaceflight.

The Vision for Space Exploration (VSE) outlined by President George W. Bush in 2004[2] and endorsed by Congress in 2005[3] and 2008[4] (under different parties) called for human missions beyond low Earth orbit (LEO), including a return to the Moon.The inclusion of the Moon has drawn comment from the space community, many of whom think that since the Apollo program ended over three decades ago, it was included as a way to regain valuable experience.In fact, the Moon is the critical element of the VSE.It is where we will learn how to use what we find in space to create new spacefaring capability.

Why the Moon?

The Moon has a major advantage over other potential destinations beyond LEO as it is both close and easily accessible.Only a 3-day trip from Earth, the Moon is close enough for existing space systems to reach.Additionally, it is only a 3-light-second round trip between Earth and Moon, which allows robotic missions on the lunar surface to be controlled remotely from the Earth in near real time.The Moon's low gravity permits landing and operations with a minimal expenditure of energy.

The Moon is a scientific laboratory of unique character.Its location near Earth ensures that it records the geological history of this part of the solar system.Such history includes the impact of solid objects and the solar wind and their possible changes with time.It holds a historical record of cosmic radiation, including nearby supernovae. The Moon's timeless surface preserves a record of ancient events, and whatever is preserved on the lunar surface must have also affected the Earth.This record is long gone from our dynamic terrestrial surface but remains preserved on the static, ancient lunar surface.

The Moon has the material and energy resources needed to support human presence and to begin building a long-lasting transportation infrastructure.Its surface is covered by a very fine-grained soil that is useful as radiation shielding and building material.[5]Oxygen extracted from lunar materials can support life and be used for rocket propellant.Light elements, such as hydrogen, helium, and nitrogen, are present in the lunar soil in low concentrations, but in enough quantity to permit their extraction and use.More importantly, we now find that significant amounts of hydrogen are present in soils at high latitudes and that the polar areas may contain water ice in permanently dark areas.Because the spin axis of the Moon is nearly perpendicular to its orbit around the Sun, some areas at the poles are in near-permanent sunlight.This is a unique asset: areas in constant sunlight for power generation are proximate to shadowed terrain enriched in the light elements, such as hydrogen.Another asset unique to the Moon is its far side, the only place in our solar system permanently shielded from Earth's radio noise.Here we can scan the sky to observe the universe in entirely new areas of the spectrum.

The Moon is the first, but not the last, destination in the VSE.It is not only an important destination in its own right, but also an enabling asset.The objective of this program is to go to the Moon to learn how to use off-planet resources to create new capability and to make future space flight easier and cheaper.[6]Rocket propellant made on the Moon permits routine access to cislunar space by both people and machines, and is vital to the servicing and protection of national strategic assets and for the repair and refurbishing of commercial satellites.The United States cannot afford to forfeit its lead in the access of cislunar space.There are serious national security and economic ramifications if our leaders fail to recognize the importance of the Moon to our future in space and here on Earth.

Spaceflight: The Current Template

Fifty years of space travel have been possible because we accepted the iron rules of spaceflight that are dictated by the rocket equation.[7]In brief, this requires a significant expenditure of energy to get something out of the deep gravity well in which the Earth resides.As it is very expensive to escape this gravity field, the things we launch into space are made as small and low in mass as possible.As long as this mode of operation prevails, we are mass- and power-limited in space and therefore, capability-limited.These limitations greatly restrict what we can do in space.

The prevailing rules of spaceflight have led to the development of a template of operations for satellites and other space assets.For a given mission, a specialized, usually custom, spacecraft is designed.The spacecraft is built to exceedingly fine standards, with numerous environmental tests and retests.It is launched on an expendable vehicle into a specially designed orbit and in most cases is unreachable by other spacecraft.If all goes well, it is operated for as long as possible and ultimately abandoned.The entire process is then repeated.Sometimes, by incorporating the results from previous missions, the design is improved.

Because each satellite is eventually thrown away, space operations are expensive and difficult.If it were possible, these assets would benefit greatly from servicing, maintenance, and expansion.A system that routinely accesses orbiting satellites with servicing robots and people would fundamentally change our approach to spaceflight.The difficulty in developing this capability is that the machines and propellant we would need to do this must also be lifted up from the deep gravity well, again at great cost and difficulty.The greatest mass of this system is rocket propellant.

If we develop a source of rocket propellant in space (so that we do not have to lift it up from Earth's surface), a new type of operational template might be possible. Instead of one-off designs and throwaway assets, we would think about long-term, extensible, and maintainable modular systems.The availability of a source of rocket propellant in LEO would completely change the way engineers design spacecraft and the way companies and the government think about investing in space assets.It would serve to dramatically reduce the cost of infrastructure in space to both government and the private sector, thus spurring economic investment (and profit).

Cislunar Space: Where All Our Assets Reside

The various altitudes and levels of orbit around the Earth[8] create very different environments and capabilities and hence are utilized by many different types of satellites designed to take advantage of the opportunities they offer.The closest zone is LEO, a space lying roughly within 2,000 kilometers (km) from the Earth, with most satellites operating around 200 to 300 km.It is within this zone most human and robotic space activity occurs.All satellites must at least pass through this zone before arriving at their final destinations.

LEO has many advantages for a variety of missions, including being where orbits are closest and easiest to get to.It is largely below the Van Allen radiation belts, so spacecraft and instruments are protected from hard radiation.Robotic satellites carry out a variety of scientific missions including orbital remote sensing of Earth and its atmosphere.Extended human missions are undertaken in LEO, both on temporary orbital spacecraft such as the shuttle and permanent facilities such as the ISS.Orbital periods are low (on the order of 90 minutes) and repeat passes occur at least twice a day over the same area from inclined orbits (and on every pass from an equatorial orbit).

Medium Earth orbits (MEO) range from 2,000 km up to about 35,000 km altitude.Orbital periods become much longer, which is useful for space applications that require long visibility times, such as global positioning systems (GPS).Typically, such applications are achieved using constellations of multiple satellites, such that two or more assets can work in tandem to achieve the desired result.MEO comprises the Van Allen radiation belts and thus is a difficult environment in which to maintain satellite life.

Highly elliptical orbits (HEO) are very elongated (thousands of kilometers at apogee, the high point of such an orbit) and have very long orbital periods.Because of their very long dwell times at apogee, these orbits are used in some national security missions, as they can "hover" over specific areas for long periods of time. Satellite radio also uses this zone of cislunar space.

Geosynchronous orbits occur around 35,000 km altitude; their periods coincide with the rotation period of the Earth, and thus the satellites appear twice a day over the same spot on the Earth's surface.A perfectly equatorial orbit at 35,786 km is a geostationary orbit (GEO), in which a satellite appears to be stationary in the sky.These orbits are widely used by all nations for a variety of communications purposes and for global weather observation and monitoring.GEO is one of the most valuable places in Earth orbit.

Beyond GEO are the Earth-Moon libration points (also called Lagrange points)[9]; L1 through L3 are in line with the Earth-Moon baseline, while L4 and L5 trail and lead the Moon in its orbit around the Earth.Except for the occasional scientific mission, such as a solar wind monitor, the L-points are not used by spacefaring nations at present.These points are of great value for transportation nodes and logistics depots.Because they are gravitational equipotential points (or weak stability boundaries),[10] all points in cislunar space can be reached from the L-points with minimal changes in velocity.After the L-points, the Moon is the next dominant feature in cislunar space.Both lunar orbit and the lunar surface are possible destinations; both are easily accessed using minimal additional energy from GEO or the Lagrange points.

All zones of cislunar space have practical and theoretical uses.[11]All are accessible with existing systems, but only once.To continually revisit a given space asset, we must build a duplicate of the system that originally got us there.For example, if a communications satellite in GEO stops working, the only alternative is to design, build, and launch a completely new satellite.There is no way to send either servicing crews or machines to repair or upgrade the balky equipment.In short, if the fundamental premise of being a spacefaring nation is the ability to routinely conduct missions anywhere in space for a variety of purposes, we are actually quite far from that capability.

The Value of the Moon

Rock and soil samples returned by the Apollo missions taught us the fundamental chemical makeup of the Moon.It is a very dry, chemically reduced object, rich in refractory elements but poor in volatile elements.Its composition is rather ordinary, made up of common rock-forming minerals such as plagioclase (an aluminum-calcium silicate), pyroxene (a magnesium-iron silicate), and ilmenite (an iron-titanium oxide).The Moon is approximately 45 percent oxygen by weight,[12] but this oxygen is tightly bound to metals in the surface rocks.Light elements, including hydrogen and carbon, are present in small amounts—in a typical soil, hydrogen makes up between 50 and 90 parts per million by weight, with similar quantities of carbon and nitrogen.Soils richer in titanium appear to be also richer in hydrogen, thus allowing us to infer the extent of hydrogen abundance from the titanium concentration mapped from orbit.

Lunar materials offer many possible uses.Because radiation is a serious problem for human spaceflight beyond LEO, the simple expedient of covering surface habitats with soil can protect future inhabitants from both galactic cosmic rays and even solar flares.Lunar soil (regolith) can be sintered by microwave into very strong building materials, including bricks and anhydrous glasses that have strengths many times that of steel.[13]When we return to the Moon, we will have no shortage of useful building materials.

Because of its abundance on the Moon, oxygen is likely to be an important early product.The production of oxygen from lunar materials simply involves breaking the very tight chemical bonds between oxygen and various metals in minerals.[14]Many different techniques to accomplish this task have been developed; all are based on common industrial processes easily adapted to use on the Moon.Besides human life support, the most important use of oxygen in its liquid form is rocket fuel oxidizer.Coupled with the extraction of solar wind hydrogen from the soil, this processing can make rocket fuel the most important commodity of a new lunar economy.[15]

The Moon has no atmosphere or global magnetic field, so solar wind (the tenuous stream of gases emitted by the Sun, mostly hydrogen) is directly implanted onto surface dust grains.Although solar wind hydrogen is present in very small quantities over most of the Moon, it too can be extracted from the soil.Soil heated to about 700°C releases more than 90 percent of its adsorbed solar gases.[16]Such heat can be obtained from collecting and concentrating solar energy using focusing mirrors.Collected by robotic processing rovers, solar wind hydrogen can be harvested from virtually any location on the Moon.The recent discovery that hydrated minerals are abundant at higher latitudes suggests that water is being created constantly at the lunar surface.[17]Some of this water migrates to the poles where it may be concentrated in abundance, thereby making its potential collection and use much easier.

The Department of Defense–National Aeronautics and Space Administration (NASA) Clementine mission in 1994 made global maps of the mineral and elemental content of the Moon.It mapped the shape and topography of its surface with a laser altimeter and gave us our first good look at the intriguing and unique polar regions.[18] Clementine did not carry instruments specifically designed to look for water but an ingenious improvisation used the spacecraft communications antenna to beam radio waves into the polar regions; the resulting radio echoes, which were observed using antennas on Earth, indicate that material with reflection characteristics similar to ice is found in the permanently dark areas near the south pole.[19]This discovery was supported subsequently by the discovery of large amounts of hydrogen near both poles[20] by a neutron spectrometer flown on NASA's Lunar Prospector spacecraft[21] in 1998.

Water is added to the Moon over geological time by the impact of comets and water-bearing asteroids.Because the Moon's axis of rotation is nearly perpendicular to the plane of the ecliptic (the plane in which Earth and Moon orbit the Sun), the Sun is always near the horizon at the poles.If you are in a hole, you never see the Sun, and if you are on a peak, you always see it—the Sun goes around, not up and down.Depressions near the poles never receive sunlight; these dark areas are very cold—only a few degrees above absolute zero.[22]Any water that gets into these polar cold traps cannot get out, and over time, significant quantities can accumulate.Our current best estimate is that over 10 billion cubic meters of water exist at the poles,[23] an amount roughly equal to the volume of Utah's Great Salt Lake.Although hydrogen and oxygen can be extracted directly from the soil as described above, such processing is difficult and energy-intensive.Polar water has the advantage of being in an already concentrated form, greatly simplifying scenarios for lunar return and habitation.Broken down into hydrogen and oxygen, water is a vital substance both for human life support and rocket propellant.

The poles of the Moon are useful from yet another vital resource perspective: the areas of permanent darkness are proximate to areas of near-permanent sunlight.We have identified several areas near both the north and south poles that offer near-constant illumination by the Sun.[24] Moreover, such areas are in darkness for short periods, interrupting longer periods of illumination.An outpost or establishment in these areas will have the advantage of being in sunlight for the generation of electrical power (via solar cells) and in a benign thermal environment (because the sun is always at grazing incidence, the surface temperature remains a near-constant -50° ± 10°C);[25] such a location never experiences the temperature extremes found on the equator (from 100° to –150°C) and thus, thermal control is much easier, making the poles of the Moon inviting "oases" in near-Earth space.

Besides its material and energy resources, the Moon is an operational laboratory where we can experiment with and learn how to conduct planetary surface exploration, utilization, and habitation.The Moon is a world, alien yet familiar, that allows us to learn the skills needed to make other worlds part of humanity's universe.Those skills can be summarized by the words "arrive, survive, and thrive."We need to develop a system that allows access to the lunar surface on a routine basis.Thus, we require long-lived reusable subsystems and equipment that can take advantage of products made from lunar resources.To survive on the Moon, we must protect humans and equipment from the harsh surface environment and make consumables.Water production protects habitats and supports people with drinking water and breathable oxygen.But for permanent human presence on the Moon, we must not only survive, but also thrive.This means that we must make "a profit": some product that we make on the Moon must exceed the value of the investment in building surface infrastructure.In the near term, such a product is likely to be lunar water, the currency of cislunar space.Water exported from the Moon can be used to make rocket propellant to fuel a transportation infrastructure and thereby lower the costs of spaceflight.

Lunar Return: Incremental Steps

Although we possess enough information now to plan a lunar return, we should conduct new robotic missions to reduce programmatic risk and to generate program milestones.The Lunar Reconnaissance Orbiter (LRO)[26] is now mapping the Moon in detail—collecting information on the physical nature of the surface, especially the exotic and poorly understood environment of the polar regions.LRO is mapping the polar deposits of the Moon using imaging radar to "see" into the dark regions.Such mapping will establish the details of water ice locations as well as its thickness, purity, and physical state.The next step is to land small robotic probes to conduct chemical analyses of the polar deposits.Although we expect water ice to dominate the deposit, comets are made of many different substances, including methane, ammonia, and organic molecules, all preserved in the polar regions and all potentially useful resources.We need to inventory these substances and determine their chemical and isotopic properties as well as their physical nature and local environment.Just as robotic missions such as Ranger and Surveyor[27] paved the way for Apollo, a new set of robotic precursors will make subsequent human missions safer and more productive.

As soon as robotic orbiters and landers have documented the nature of the deposits, focused exploration and research should be undertaken to develop the machinery needed to harvest and process the resources of the Moon.We must understand the physical nature of the polar deposits and how we might extract water from its (currently unknown) native state.This could mean excavating and moving dirt and/or developing schemes that remove the water in place.A variety of mining and extraction processes can be experimented with using robotic missions, thus paving the way to industrial-scale activities and commercialization of the production of hydrogen and oxygen from lunar materials.

Forty years ago, America built the mighty Saturn V to launch men and machines to the Moon in one fell swoop.This technical approach was so successful that it has dominated the thinking on lunar return for decades.One feature of nearly all architectures of the past 20 years is the initial requirement to build or rebuild the heavy lift launch capability of the Saturn V or its equivalent.However, parts of the Saturn V were literally handmade,[28] making it a very expensive spacecraft.Development of any new launch vehicle is an enormously expensive proposition.What is needed is an architecture that permits lunar return with the least amount of new vehicle development possible (and hence, the lowest possible cost.)Such a plan will allow concentration of effort and energy on the most important aspects of the mission: learning how to use the Moon's resources to support space flight beyond low Earth orbit.[29]

To deliver the pieces of the lunar spacecraft to Earth orbit—lander, habitat, and transfer stage—the architecture should use existing launch assets, including shuttle-derived components augmented by existing expendable boosters.Assembled into a package in space, these items are then transferred to the Moon-Earth L1.The L1 point orbits the Earth with the Moon such that it appears "motionless" in space to both bodies.Because there is no requirement for quick transit, cargo and unmanned mission elements can take advantage of innovative technologies such as solar electric propulsion and the weak stability boundaries between Earth, Sun, and Moon to make long, spiraling trips out to L1, thus requiring less propellant mass launched from Earth.[30]These unmanned cargo spacecraft can take several months to get to their destinations.The habitat module can be landed on the Moon by remote control and activated to await the arrival of its occupants from Earth.Previously landed robotic rovers and robots become part of the surface infrastructure and can be used telerobotically to prepare and emplace outpost elements.

The human crew is launched separately in the crew exploration vehicle and uses a chemical stage and a quick transfer trajectory to reach the L1 depot in a few days.There, the crew can transfer to the lunar lander, descend to the surface, and occupy the pre-emplaced habitat.Because the outpost elements are already on the Moon, the lunar lander does not have to be the 50-metric-ton behemoth called for by the Exploration Systems Architecture Study,[31] but rather a much smaller, reusable version—its only job is to transfer the crew from L1 to the lunar surface.

The preferred site for a lunar outpost is at one of the almost permanently sunlit areas near a pole of the Moon.The south pole is attractive from the perspective of both science and operations, but final selection should await complete surveys of the poles, so as to locate the outpost as close as possible to the highest grade resources.The strategy on the Moon is to learn how to mine its resources and build up surface infrastructure to permit ever-increasing scales of operation.Each mission brings new components to the surface, and the size and capability of the outpost grows over time.

Resource utilization on the Moon will expand with time.Initially, demonstration production levels of a few kilograms of product (water, oxygen) will document the difficulty of mining and processing.After we determine the optimum techniques, our initial production goals are to make consumables (water for drinking, air, and shielding, in that order); this requires production levels of hundreds of kilograms.Once this is well established, we can begin to make rocket propellant.Initial propellant production at the metric ton level can support extended exploration around the lunar outpost and perhaps ballistic flights to other locations on the Moon.A major breakpoint will come with the production of tens to hundreds of tons of propellant; at such a level, we can export our surplus propellant to depots in cislunar space, making it available for commercial sale to many different users.It is the ultimate realization of this act that creates a cislunar economy and demonstrates a positive return on investment.[32]

In addition to its technical advantages, this architecture offers important programmatic benefits.It does not require the development of a new heavy lift launcher.Costs in space launch are almost completely dominated by the costs of people and infrastructure.Creating a new launch system requires new infrastructure, new people, and new training.Such costs make up significant fractions of the total program.By using existing systems,[33] we concentrate our resources on new equipment and technology, all focused toward the goal of finding, characterizing, processing, and using lunar resources as soon as possible.The use of the L1 point as a staging depot allows us to depart at any time for both the Earth and Moon; the energy required to go nearly anywhere beyond this point is very low.The use of existing, low-thrust propulsion technology (that is, solar-electric) for cargo elements permits us to use time as an asset, not an enemy.We will acquire new technical innovation as a byproduct of the objective, not as a critical requirement of the architecture.

A New Template for Spacefaring

By mining the Moon for water, we establish a robust transportation infrastructure capable of delivering people and machines throughout cislunar space.Make no mistake: learning to use the resources of the Moon or any other planetary object will be a challenging technical task.We must learn to use machines in remote, hostile environments while working under difficult conditions to extract ore bodies of small concentration.The unique polar environment, with its zones of near-permanent illumination and permanent darkness, provides its own challenges.But for humanity to live and work in space, we must learn to use the material and energy resources available off-planet.We are fortunate that the Moon offers us a nearby "safe" laboratory where we can take our first steps toward using space resources.Initial blunders in operational approach or feedstock processing are better practiced at a location 3 days from the Earth than one many months away.

A return to the Moon to learn how to use its resources is scalable in both level of effort and the types of commodities to be produced.We begin by using the resources that are easiest to extract.Thus, the logical first product is water derived from the polar deposits.Water can be produced there regardless of the nature of the polar volatiles; ice of cometary origin is easily collected and purified.If the polar materials are composed instead of molecular hydrogen, this substance can be combined with oxygen extracted through a variety of processes from rocks and soil to make water.Water is easily stored and will be used as a life-sustaining substance or retained in a separated, cryogenic state for use as rocket propellant.

The world relies on a variety of satellites in cislunar space—weather satellites, GPS, communications systems, and a wide variety of reconnaissance platforms. Commercial spacecraft makes up a multi-billion-dollar market, providing telephone, Internet, radio, and video services.America has invested billions in space hardware.Yet at the moment, we have no infrastructure to service, repair, refurbish, or protect any of these spacecraft. They are vulnerable to severe damage or permanent loss by accident or intentional action.If we lose a satellite, it must be replaced.From redesign though fabrication and launch, such replacement takes years and involves extraordinary investment in the design and fabrication to make them as reliable as possible.

We cannot access these spacecraft because it is not feasible to maintain a human-tended servicing capability in Earth orbit; at thousands of dollars per pound, the costs of launching orbital transfer vehicles and propellant are excessive. Creating the ability to refuel in orbit by using propellant made from lunar materials will revolutionize the way nations view and use space.Satellites will be repaired rather than abandoned.Assets can be protected rather than written off. Very large satellite complexes can be built and serviced over long periods, creating new capabilities and expanding bandwidth (a critical commodity of modern society) for a wide variety of purposes.And along the way, there will be new opportunities and discoveries.We will become a true spacefaring species.

A return to the Moon with the purpose of learning to extract and use its resources creates a new paradigm for space operations.Space becomes a realm in our economic sphere, not an exotic environment for arcane studies.Such a mission ties the American space program to its original roots, making us more secure and more prosperous.It also enables new and broader opportunities for science and exploration.A transportation infrastructure that can routinely access various points of cislunar space can take humanity to the planets.We will learn to use what we find in space to create new spacefaring capabilities.A cislunar transportation system, fueled by lunar propellant, will be the transcontinental railroad of the new millennium.[34]

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Chapter 13:

Spacepower and the Environment

Eligar Sadeh

This chapter focuses on the unique environmental concerns that can both inhibit and enhance space as a domain of national security power. A number of concerns are examined, including the links between space and the environment on Earth, the orbital environment, and the environment of space beyond the orbital paths of space assets. Within this context, several important questions are raised:

- What roles will space play in the advancement of life on Earth and the future of humanity?
- How susceptible are civil, commercial, and military space assets to interference, disablement, and destruction from environmental threats in space?
- What is the importance of spacepower to scientific exploration?
- What are the political and legal paths to spacepower projection as a result of dealing with space and environmental concerns?

The first part of the chapter investigates the "global dimension" of space and environment. It begins with a discussion of environmental security and reviews a number of global environmental dangers. The environmental degradation of the Earth and anthropogenic influences on global climate change directly relate to the advancement of life on Earth and the future of humanity. The exploitation of natural resources is linked to economic stress, instability, and conflict. Earth observations from space play a role in monitoring and helping to assess changes in the Earth's environment that are applicable to security issues.

Although there is little agreement among scholars and practitioners on the definition of *environmental security*—just as there is little coherence on the definitions of *spacepower*, as this book makes clear—environmental security involves the issues of conflict and its prevention and state authority or control over sovereignty as they are linked to national, regional, and global environmental factors.[1] The second part of the chapter probes these issues of environmental security. How conflicts are prevented is first examined through the role of international and regional environmental agreements and the role of Earth observation satellites in monitoring the global environment. State authority is scrutinized through an assessment of Earth observations in the civil and commercial sectors and of implications for national security in terms of a loss of state control over sovereignty.

The third part of this chapter analyzes the issues of space situational awareness (SSA) and the use of space to project power and to provide for national, regional, and international security. Specific to the focus of space and the environment are the threats to space assets as a result of orbital debris and near Earth objects (NEOs) that may impact

Earth (potentially hazardous NEOs). The evolution of the orbital debris issue is surveyed, and the political measures by which it is managed are explained. The issue of NEOs is one of providing for planetary defense, an important end for the advancement of life on Earth. Planetary defense is investigated within the scope of spacepower as it applies to detection and mitigation strategies to deal with potentially hazardous NEOs.

Finally, spacepower deals with control of the space environment to achieve superiority there. This suggests a relationship between spacepower and protecting the environment in space. Protection of the environment concerns SSA and orbital debris as well as making sure that harmful contamination in space, on planetary bodies, or on Earth resulting from the introduction of extraterrestrial matter is managed and prevented. This problem of harmful contamination, which is discussed in the last part of the chapter, is one of planetary protection.

Environmental Security and Global Environmental Dangers

There are several noteworthy views regarding environmental security. One view is represented by United Nations (UN) programs and associated nongovernmental organizations dealing with the environment and development.[2] These organizations stress the state of environmental degradation on a global scale, and they see that degradation as a security threat. The very nature of the global environmental dangers that exist imperils national security by undermining natural support systems on which all human activity depends. Table 13–1 lists a selected set of global environmental dangers.

Table 13–1. Global Environmental Dangers

- Ozone layer depletion
- Global climate change due to greenhouse gas emissions
- Extreme weather events
- Sea level rise
- Retreating glaciers
- Spread of life-threatening diseases
- Radioactive spills from leaking nuclear submarines or nuclear waste storage tanks
- Nuclear bomb tests
- Accidents in nuclear plants
- Environmental impacts of and modification during war
- Spills from stockpiles of old weapons
- Oil spills and pollution
- Food security
- Water scarcity and pollution including ground water contamination
- Increasing international river usage
- Soil erosion and salinization
- Deforestation and desertification
- Human migration
- Human population growth
- Loss of biodiversity

- Habitat shifts
- Industrial development and contamination of air and oceans
- Fishery depletion due to over-fishing
- Transplantation of alien species into new ecosystems
- Disposal of hazardous and toxic wastes
- Destruction of coral reefs

A second view on environmental security emerges from scholarly work on the subject. Since the 1970s, scholars have argued that environmental concerns should be incorporated into the national security calculations of the state.[3] The argument is that ecological integrity plays a role in the economic, social, and political stability of states. Environmental scarcity, as a result of many of the environmental dangers listed in table 13–1, is inextricably linked to socioeconomic and sociopolitical instability, which can engender conflicts between states.

Scholarly attention to the globalization phenomenon further links the issue of ecology into the national security equation. Globalization represents the integration of capital, technology, trade, and information across national borders.[4] This integration manifests itself as a set of complex interdependencies characterized by linkages among politics, national security, cultures, markets, technology, and ecology. National security power projection as viewed through the lens of globalization is about maintaining the stability of the international system, which is linked to maintaining the ability to cope with and adapt to global environmental changes. This can be conceptualized through the national security notion of systems administration.[5] This aspect of national security power is the basis of one significant view of environmental security within the national security establishment in the United States.

Global environmental dangers can undermine the stability of the international system and lead to political, economic, and violent conflicts. To illustrate, a North Atlantic Treaty Organization (NATO) study from 1996 and a report published by the CNA Corporation (CNAC)[6] in 2007 that was authored by a number of retired flag officers identified several problem areas of environmental conflict.[7] The NATO study assessed potential conflicts over natural resource scarcities, which are a cause for intrastate and interstate migrations that trigger political, ethnic, and cultural conflicts. In addition, scarcities are tied to poverty and health problems due to limited food supplies, unavailability of fresh water, famine, and the spread of infectious diseases. Anthropogenic global environmental change and degradation—for example, greenhouse gas pollution, ozone depletion, climate change, loss of biodiversity, desertification, and deforestation—alter the availability and distribution of natural resources. In this perspective on environmental security, the systems administrator must deal with cooperative paths to power projection. The cooperative paths entail collective action and collective security arrangements.

The CNAC report examined climate change as an issue for national and international security. Climate change as a cause for many of the global environmental dangers listed in table 13–1 leads to "sustained natural and humanitarian disasters that will likely foster instability where societal demands exceed the capacity for governments to cope."[8] In this regard, climate change is a threat multiplier for instability and conflict. The threat multiplier manifests itself as "geostrategic" and regional implications analogous to what was assessed with the NATO study. The CNAC report recommends that climate change be fully integrated into national defense strategies and that the United States commit to a role as systems administrator to help stabilize climate change and to help other governments cope with global environmental dangers. This indicates that spacepower calculations, as part of national defense strategies, need to account for climate change and that a U.S. leadership role on the issues of climate change is part and parcel of the national and international security equations. One central concern that flows from these suggestions, denoted with the NATO study as well, has to do with conflict prevention. Spacepower is a factor that can facilitate conflict prevention.

Conflict Prevention

Collective action as a basis for power projection is a consequence of the fact that the global environment and the environment in outer space are each a commons. These environmental commons lie outside the jurisdiction and sovereignty of any individual state and are valued resources globally. In the case of the global environment, agreed upon commons include the global climate system and the stratospheric ozone layer. In the case of outer space, they are free space itself, orbital paths around the Earth, and celestial bodies. These environmental resources are in joint supply and nationally nonappropriable. *Joint supply* signifies equal potential availability to the commons by all states. *Nonappropriability* specifies that states cannot extend their jurisdiction and sovereignty to the commons. It is impossible to exclude states from sharing in the benefits of the commons or from suffering the consequences caused by damage to the commons. Together, joint supply and nonappropriability constitute free access and free use and, as it concerns spacepower, the policy of freedom of action in space.

A commons that is unregulated can result in a "tragedy of the commons."[9] This situation is rooted in the rational self-interested state behavior regarding commons resources. It is a function of damage to the environment caused by free access and free use, like the release of greenhouse gases into the Earth's biosphere, the proliferation of orbital debris, or the possibility of harmful contamination of outer space or celestial bodies. To mitigate these tragedies, collective action is necessary. The environmental commons posits a collective action problem as to how to formulate and implement international cooperation to regulate at some level free access and free use.

This point in the chapter focuses on the global environment and international cooperation directed at managing the root causes of environmental change that lead to instability and conflict. The collective action response as observed in international environmental laws and laws that limit military activities in space portends for a collective "rules of the road" approach to spacepower as one way to mitigate tragedies of the commons, such as orbital debris proliferation and other harmful contamination of space (the rules of the road theme is discussed in chapter 20 of this book).[10] Later in this chapter, collective action and freedom of action in space are explored in the cases of orbital debris, planetary defense, and planetary protection.

International environmental law regulates how states and their entities interact with the environmental commons. The onset of the development of international environmental law dates back to the UN Conference on the Human Environment held in Stockholm in 1972. This conference elevated the environment to a major issue at the international level. Stockholm focused on the degradation of the biophysical environment of the Earth due to human activities. The conference led to the establishment of the UN Environmental Program, which is at the forefront globally in calling for sustainable development—that is, human and economic development that mitigates further degradation of the environment and natural resources.[11]

Within the context of sustainable development, the World Commission on Environment and Development issued a report in 1987 entitled *Our Common Future*.[12] The report offered a definition of *sustainable development* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," and highlighted global warming and ozone layer depletion as environmental problems. Following this, in 1992, under the auspices of the UN Conference on the Environment and Development, an Earth Summit was held in Rio de Janeiro, Brazil. The summit led to the Rio Declaration on the Environment and Development and an action plan, called Agenda 21, to realize the ideas of sustainable development therein.[13] Agenda 21 is the most significant and influential political instrument in the environmental field, serving as the blueprint for environmental management throughout the world. The whole notion of sustainable development and its implementation and management is in part a security issue in that it addresses the root cause of environmental security issues discussed earlier.

Two areas of development in international environmental law dealing with ozone depletion and global warming are examples of how global environmental dangers can result in collective paths to agreement and management. The paths to the respective agreements, the Montreal Protocol on Substances that Deplete the Ozone Layer and the Kyoto Protocol to the United Nations Framework Convention on Climate Change, are a story of how the state of knowledge—that is, science on the global issues—influences states to act in collective ways to manage global environmental problems.[14] Earth observation satellites, which play a critical role in monitoring the state of global environmental dangers, resulted in many of the advances in knowledge. Table 13–2 maps the cooperative path in the case of the Montreal Protocols and highlights the role of Earth observation satellites.

Table 13–2. Cooperative Paths to the Montreal Protocols

Year	**Event**
1956	First Antarctic ozone measurements
1971	Congress terminates Supersonic Transport funding
1973	Space shuttle exhaust linked to ozone destruction (chlorine loading)
1974	Chlorofluorocarbons (CFCs)-ozone depletion hypothesis published in *Nature*
1974	Antarctic measurements regularly conducted

1975	National Aeronautics and Space Administration (NASA) conducts upper atmosphere research as directed by U.S. Congress
1976	First discussion of ozone at United Nations Environmental Program (UNEP)
1977	UNEP and World Meteorological Organization (WMO) establish coordinating committee on ozone
1977	U.S. Congress amends Clean Air Act to report on status of ozone
1978	U.S. Congress bans CFCs in aerosol sprays
1978	**Nimbus-7 launched, Total Ozone Mapping Spectrometer (TOMS) (returned data to 1993)**
1978	First CFC replacement announced (replacements economically profitable)
1981	International negotiations begin on ozone issue
1985	Vienna Convention (precautionary principle collective action)
1985	UNEP Ozone Secretariat established
1985	British Antarctic Survey publishes ozone hole data in *Nature*
1985–1989	**Nimbus-7 TOMS data transmitted to public (record ozone hole in 1987 and 1989)**
1986	**Comprehensive report on ozone depletion (NASA and WMO); 85 percent restriction**
1987	Alignment of U.S.–European Community (EC) positions on CFC reductions
1987	Montreal Protocol; 50 percent restriction (compromise solution); in force 1989
1988	United States, Europe, and Japan ratify Montreal Protocol
1988	**Report on ozone trends (NASA, UNEP, WMO); more stringent control measures**
1988	DuPont agrees on phaseout of CFCs (industry agreement with problem)
1988	UNEP workshops that resolved modeling discrepancies in relation to ozone
1988-89	Global climate change on the U.S. political agenda (Global Change Research Program in 1989)
1989	EC calls for phasing out CFCs
1989	Synthesis Report (chlorine-loading issue); revisions in Montreal Protocol
1990	London Amendment to Montreal Protocol (scientific consensus, equity, controls); in force 1992
1990	U.S. Environmental Protection Agency (EPA) issues further restrictive CFC guidelines
1990-92	Brazil, China, and India accessions to Montreal Protocol
1991	**NASA announced severe ozone depletion, lowest values in 13 years of monitoring**
1991-92	U.S. Senate calls for CFC phaseout; 1992 Executive order to end use of CFCs
1991	**NASA launches Upper Atmosphere Research Satellite (returned data to 2005)**
1992	**NASA announced severity of problem for Arctic (up to 30 percent ozone loss)**
1992	Copenhagen Amendments to Montreal Protocol (controls); in force 1994; CFC phaseout by 1995

1993	Trade sanctions against nonsignatory countries
1994	**NASA indicates conclusive evidence of ozone depletion-chlorine link**
1996	**NASA report shows concentrations of ozone depleting chemicals beginning to level off**
1997	Montreal Amendments to Montreal Protocol (licensing system for trade issue); in force 1999
1998	Sweden first country to ban all CFC uses
1999	Beijing Amendments (control measures, bromide loading issue); in force 2002
2000	Largest ever Antarctic ozone hole detected
2001	UNEP reports results in nearly eliminating production of CFCs
2002	**European Space Agency launches Envisat with ozone measuring sensors**
2004	**NASA launches Aura to study ozone (Earth atmospheric chemistry)**

In addition to the examples of international environmental law discussed above, there are international laws that place specific limits on military uses of space. These laws constrain the means a state can use to realize freedom of action in space and spacepower projection. The relevant laws and constraints include:

- the *Limited Test Ban Treaty of 1963* and the *Comprehensive Test Ban Treaty of 1996* (which supplanted the 1963 one), which prohibit the conduct of nuclear weapons tests in outer space. Neither the United States nor China has signed or ratified the Comprehensive Test Ban Treaty as of 2009.
- the *Outer Space Treaty of 1967*, which prohibits the deployment of weapons of mass destruction in space and the stationing of military bases, but not military personnel, in space or on celestial bodies, and calls for "peaceful uses" of space, which is understood as no aggressive uses of space that harm or interfere with another state's access and use of space.
- the bilateral *Anti-Ballistic Missile (ABM) Treaty of 1972* between the United States and Russia, which many legal experts viewed as preventing a weaponization of space since it prohibited the deployment of space-based ABM systems, which do include most types of kinetic-kill space weapons that could be developed and deployed. The United States withdrew from this treaty in 2002.
- the *Convention on Registration of Objects Launched into Outer Space of 1974*, which requires states to register objects launched into space with the United Nations. This obligation helps to enable SSA and supports the view that such awareness should be shared and transparent to the extent possible without harming national security. This is the policy and practice of SSA in the United States.
- the *Environmental Modification Convention of 1980*, which prohibits military use of environmental modification techniques in space. The Outer Space Treaty also prohibits harmful contamination of the space environment.

- the *Moon Agreement of 1984*, which sought to demilitarize the Moon and celestial bodies and declare the Moon the "Common Heritage of Mankind."[15] It has little to no legal validity since no space powers have ratified it.

Earth Observation Satellites

The development of remote sensing satellite systems—Earth observation platforms—was driven initially by national security policies aimed at acquiring intelligence from the use of space assets. This led to the intelligence space program that is in place in the United States. At the same time, satellite use for weather monitoring emerged as a valuable asset for civil and military use. Beginning in the 1970s, remote sensing systems evolved to deal with environmental monitoring. The Landsat program in the United States began in 1972 with a focus on natural resource monitoring. The success of the Landsat program, which exists to this day with Landsat 7, and the issues associated with global change and global warming led to the U.S. Global Change Research Act of 1990. This act established an Earth observation program, the U.S. Global Change Research Program, aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, and at promoting discussion toward international agreements in global change research.[16]

At the national level, the National Aeronautics and Space Administration (NASA) was tasked as the key implementing agency for the U.S. Global Change Research Program. This led to the development of NASA's Earth Sciences mission area and the Earth Observing System (EOS) that NASA implemented.[17] At the international level, agreements were reached on Earth observation data policies, which generally endorse open access to Earth observation data on the premises of nonexclusion and nondiscrimination. The 1986 UN Principles Relating to Remote Sensing of the Earth from Outer Space adopt such an open access policy. The principles state that as soon as the primary data and the processed data concerning the territory under its jurisdiction are produced, the sensed state shall have access on a nondiscriminatory basis.[18] This very principle forms the basis for the data policy agreement reached through the Committee on Earth Observation Satellites (CEOS), established in 1984 to coordinate data management and policy issues for all spaceborne Earth observation missions. Membership in CEOS is open to all international and national organizations responsible for Earth observation satellites currently operating or in development phases.[19] The United States applies nondiscriminatory open access policies for Earth observation data at the national level through the Land Remote Sensing Policy Act of 1992 and the subsequent final rules issued by the U.S. Department of Commerce for Licensing of Private Land Remote Sensing Space Systems.

The evolution of Earth observations in the civil sector resulted in the political and legal view that data acquired through remote sensing is a public good marked by nonexclusion and nondiscrimination. Data as a public good has implications for national security as to the control over knowledge and information. Historically, states controlled knowledge through the concept of sovereignty. Earth observation satellites make sovereignty "transparent" because data acquired on the natural resources of a state are public goods that are available to any user either free of charge, as in the case of NASA's EOS program, or at a minimal processing fee per user request. This represents a constraint on the projection of national security power in the sense that the state is forced to sacrifice some control over knowledge about its territory in exchange for the benefits in use of that knowledge. Concomitantly, this "sovereignty bargain" can mitigate the constraints of sovereignty and national interests in trying to achieve cooperative paths to spacepower. Formulating rules of the road to preserve freedom of action in space so that the benefits of Earth observations can be attained is one example.

The theme of Earth observations and collective action is an important one. International cooperation pertaining to Earth observations by satellites directed at assessing global environmental change is represented by a collective action milieu (see table 13–3). The goal of this collaborative milieu is to advance scientific knowledge of the Earth's environment to understand and predict human-induced and natural global environmental change phenomena. Science serves as the end, while politics, a broad-based institutional structure of states, international organizations, and scientific communities, provides the means. One of the crucial factors in this case of international cooperation is the ability of transnational networks of Earth system scientists to work together in analyzing global change data and to translate those analyses into policy-relevant actions. This involves both coordinating missions and addressing data policy issues dealing with conditions and access to data, data pricing, periods of exclusive data use, and data archiving.[20] Cooperation aims to meet scientific and operational needs as well as satisfy data access and data exchange requirements for all parties as effectively as possible.

Table 13–3. Collective Action Milieu for Global Change Science

Level of Activity	**Political Actors**
Subnational ***(United States)***	American Meteorological Society; American Geophysical Union; Center for Global Change; Electric Power Research Institute; Environmental Defense Fund; Federation of American Scientists; Global Tomorrow Coalition; National Academy of Sciences; Goddard Institute for Space Studies; National Center for Atmospheric Research; Natural Resources Defense Council; National Climatic Data Center; Physicians for Social Responsibility; Sierra Club; Union of Concerned Scientists; World Resources Institute; Worldwatch Institute
National ***(United States)***	**U.S. Global Change Research Program— Subcommittee on Global Change Research** Department of Agriculture; National Oceanic and Atmospheric Administration; Department of Defense; Department of Energy; National Institute of Environmental Health Sciences; U.S. Geological Survey; Department of State; Environmental Protection Agency; National Aeronautics and Space Administration; National Science Foundation; Smithsonian Institution
Transnational	Greenpeace; International Council for Science (ISCU); International Geosphere Biosphere Program
International	UN Committee on the Peaceful Uses of Outer Space; UN Conference on Environment and Development; Economic and Social Commission of Asia and the Pacific; UN Education, Scientific and Cultural Organization (UNESCO); UN Environmental

	Program (UNEP); Food and Agricultural Organization (FAO); UN Framework Convention on Climate Change; Intergovernmental Oceanographic Commission (IOC); World Climate Research Program; World Commission on the Environment and Development; World Meteorological Organization (WMO)
Cross-Level ***(National, Transnational, International)***	**Committee on Earth Observation Satellites** Global Climate Observing System: ICSU, UNESCO, UNEP, IOC, WMO Global Ocean Observing System: ICSU, UNEP, WMO Global Terrestrial Observing System: ICSU, UNESCO, UNEP, FAO, WMO Intergovernmental Panel on Climate Change: UNEP, WMO

Political considerations concerned with data policy, national sovereignty, and national security issues influence collective action in the area of Earth observations.[21] The existence of disparate and incompatible data access policies among various satellite types and programs is reinforced in the retention of data by its producers, the requirement of licenses to use data, and the pricing of data above marginal costs of fulfilling user requirements. Harmonizing policies over these issues is one of the most difficult hurdles to surmount in fashioning international cooperation.[22]

The Committee on Earth Observation Satellites plays a central role in advancing the harmonization issue. The primary objectives of CEOS are to optimize the benefits of Earth observations through cooperation of its members in mission planning and in developing compatible data products, formats, services, applications, and policies; aid both its members and the international user community through international coordination of Earth observation activities; and exchange technical information to encourage compatibility among the different Earth observation systems.[23] CEOS data exchange principles have been adopted for global environmental change research use and for operational public benefit use with the agreement to make data available to each member in these user categories with no period of exclusive use and on a nondiscriminatory basis. There is a commitment to provide data at the lowest possible cost to bona fide researchers and to harmonize and preserve all data needed for long-term global change research and monitoring.

The concern with sovereignty and national security is that remote sensing data undercuts the ability of the state to control both the creation and the application of knowledge.[24] One important sovereignty concern is the proliferation of commercial remote sensing systems. This gives rise to the knowledge diffusion and sovereignty bargains mentioned earlier. Proliferation of high-resolution imagery has potential national security repercussions of particular concern since the events of September 11 and the ensuing global war on terrorism. First, increased certainty of an adversary's capabilities may negate the foundation for deterrence. Second, the possibility exists of misinterpretation and international deception leading to shifts in balances of power and conflict. And third, asymmetrical access to satellite imagery and processing capabilities could provide substantial advantages for some states over their neighbors—for example, developed states over developing ones—with destabilizing effects on the international system.

The development of a remote sensing commercial sector exacerbates the control of knowledge by advancing "global transparency." In the civil or public sector, it is well understood that remote sensing data primarily serves scientific research use and value-added uses for natural resource management. Further, such data is at relatively low spatial resolutions, limiting its utility for intelligence use. Data is an economic commodity in the commercial sector, which has developed and deployed systems with high spatial resolutions at less than 1 meter (m) that can be used for intelligence purposes. In fact, it is the policy of the U.S. Government, under the Land Remote Sensing Policy Act of 1992, Presidential Decision Directive (PDD) 23 issued by the Clinton administration, and the U.S. Commercial Remote Sensing Policy put forward by President Bush in 2003, to foster the development of commercial imagery systems with spatial resolutions of less than 1 m.

While the policies support the development of a remote sensing industry and mandate government data buyout contracts with commercial remote sensing operators in the United States, the threats that commercial systems pose to national security were recognized as well. After all, information dominance enables spacepower projection. This recognition was manifested in PDD 23 and reiterated in the 2003 Bush policy as "shutter control" directed to protect U.S. national security and foreign policy interests. Shutter control allows the Secretaries of Defense and State to determine when national security, international obligations, and/or foreign policy could be compromised as a result of commercial remote sensing and mandate specific restrictions as to where on Earth the commercial systems can acquire data. The shutter control policy attempts to mitigate the loss of control of knowledge that can harm national security. Despite this concern, shutter control is difficult to apply and for the most part has not proven to be a viable policy, although it remains a concern for the commercial interests of the remote sensing sector.

Since the emergence of commercial uses of remote sensing, resolution limitations imposed to protect national security have lessened. In the late 1970s, the Carter administration lowered the spatial resolution limit on nonmilitary remote sensing systems to 10 m. After the U.S. Congress passed the Land Remote Sensing Policy Act of 1992 directed to end the Federal monopoly on remote sensing technology and data distribution, numerous commercial interests began to apply for remote sensing satellite licenses and lobbied for lower spatial resolution restrictions. PDD 23 removed spatial resolution restrictions on commercial remote sensing satellites, making the resolution limit a decision to be made by the Department of Commerce, the authority licensing the system, on a case-by-case basis. This stood in stark contrast to the previous national security protection elements of imposing spatial resolution limits and access to remotely sensed data.[25]

U.S. Government authorities have continuously debated shutter control since PDD 23 was issued. In an attempt to further clarify when and how shutter control might be implemented, the Department of Commerce signed a memorandum of understanding (MOU) with the U.S. Departments of State, Defense, and Interior and the Intelligence Community as to how they would work together during the licensing process to make certain that all the elements of national security are taken into consideration. The MOU discussed when and how shutter control restrictions could be placed upon a system. In response to the concern of commercial satellite operators, the MOU makes the shutter control decision occur at the highest levels of the respective governmental departments. If they cannot agree, the issue is sent to the President for a decision.[26]

In the aftermath of September 11 and during subsequent military operations in Afghanistan, the United States opted not to exercise shutter control as specifically described in PDD 23 and the MOU. However, it did make use of alternative means to control the use of remotely sensed data. In October 2001, the National Imagery and Mapping Agency (NIMA) signed a contract with Space Imaging, whose Ikonos satellite was the only U.S. commercial high-resolution satellite operating at the time, for the exclusive rights to Ikonos imagery collected over Afghanistan and the surrounding areas.[27] This arrangement established a way to control data distribution from U.S. commercial operators and data providers, albeit via methods other than what was originally intended with the shutter control policy.

During the blackout on the distribution of high-resolution Ikonos data outside the U.S. Intelligence Community, ImageSat International, an Israeli firm, sold high-resolution imagery to news media and other organizations on the open market. As the U.S. war efforts in Afghanistan continued, NIMA discontinued the imagery buyout of Ikonos data. Furthermore, DigitalGlobe successfully launched and continues to operate QuickBird and Worldview 1 at lower panchromatic spatial resolutions than Ikonos (0.6 m for Quickbird and 0.5 m for Worldview versus 1 m for Ikonos).

Commercial remote sensing systems also existed prior to Ikonos, such as Spot Image in France, ImageSat, and commercial remote sensing entities and commercial data products in Canada, Europe, India, and Russia. These developments further indicate that shutter control may not be a viable policy, and that global transparency and the associated factor of loss of control over sovereignty represent new international norms with which national security power and spacepower projection must contend. For spacepower, this implies that true information dominance cannot be achieved, and counterspace operations or applications of force aimed at preserving freedom of action in space would not be applied to commercial assets absent a global scale conflict. As a result, the state is forced into a sovereignty bargain that reiterates the theme of collective action and cooperation as ways to further spacepower interests.[28]

Orbital Debris

The fact that space is legally defined as a commons underlies freedom of action there—that is, the free use of and free access to the space environment for peaceful purposes that include military uses for self-defense and for collective defense as stipulated in the Outer Space Treaty and the UN Charter. Free access to and free use of the space commons, not unlike the global environment, can lead to a potential tragedy of the commons in that a resource that people share can become exploited to the detriment of all users.

Space is subject to joint use and availability. Therefore, any user may exploit the resource since exclusion is impossible or impractical. As a consequence, the resource value of space may diminish as a result of overuse or misuse. The costs and benefits associated with commons' use are likely to be distributed asymmetrically, and it is even conceivable that those who benefit may not pay a use cost.[29] For space, the problem of the commons is perhaps most notable in the growing problem of space debris.

The U.S. Air Force Space Command, through the Space Surveillance Network, routinely tracks and catalogues all human-made debris objects. This information is provided to and used by the civil, commercial, and military space sectors. For example, NASA uses the data on every space shuttle flight and has made numerous orbital corrections over the years to avoid collision. The same holds true for the International Space Station even though the ability for orbital correction is more limited. The space environment is populated by millions of pieces of orbital debris from a range of sources, such as inactive spacecraft, spent rocket bodies, operational debris from satellites and other payloads, fragmentation debris as a result of debris collisions, paint flakes, and particulates from propellant fuels. Collisions with pieces of debris greater than 10 millimeters (mm) in size can produce catastrophic damage to spacecraft. Even smaller debris ranging from 1 mm to 10 mm can be destructive as it can produce impact damage that can be serious depending upon system vulnerabilities and defensive design provisions against debris. Orbital debris smaller than 1 mm can cause surface pitting and erosion of materials; for example, 0.1 mm debris can potentially penetrate a spacesuit. The International Space Station is shielded to protect from smaller debris, and military space assets are hardened in many cases for such protection.

The millions of debris particles smaller than 1 mm are beyond detection capabilities from satellite or ground-based radar observing systems. Despite the fact that technical capabilities exist to systematically track debris at about 50 mm in size, the U.S. Air Force Space Command nominally tracks and catalogues debris of about 100 mm or greater in size.[30] This discrepancy between what is possible and what is accomplished is one of the key political issues facing SSA and the need for additional budgetary allocations to upgrade capabilities. Space Command's SSA mission also aims at information transparency and "deconfliction."[31] To these ends, Space Command shares debris data with space users worldwide in the civil, commercial, and military sectors and provides space users with modeling and predictions for debris avoidance. Information transparency is a tool to deconflict any potential national security issues or threats that the debris issue may posit. Deconfliction implies diplomatic and cooperative paths to address problems.

The larger issue here is one of space as a commons for peaceful and cooperative purposes versus contested space scenarios that involve spacepower projection in the space medium. The functional necessity of dealing with the space debris problem to ensure free access to and use of space and the civil, commercial, and military benefits that space offers advances a cooperative approach to maintain the peaceful uses of space as the status quo. All this is made clear when one considers that fragmentation debris shifts linear debris growth patterns to exponential ones assuming no active mitigation measures are implemented. The Chinese antisatellite (ASAT) weapons test conducted in January 2007, which destroyed a Chinese satellite, and the February 2009 collision between an operational Iridium satellite and a dysfunctional Russian Cosmos communications satellite resulted in thousands of additional debris fragments that can potentially threaten space assets. The seriousness of the debris issue is compounded when one realizes the time it takes debris to deorbit. For instance, the last debris from U.S. ASAT tests in the 1980s only deorbited in 2004.

Though the majority of operational and active satellites are impacted by debris, impact has occurred without consequence except for the Iridium/Cosmos case mentioned above and one additional documented case in 1996 that involved a French satellite and Ariane upper rocket body. Modeling of the debris threat has also shown low risk of debris impacts on large spacecraft that could cause harm—for example, there is a 1 in 100,000 chance of debris impact with the space shuttle. This is not to undercut the argument that debris is a potential commons problem. The failure to prevent debris proliferation in low Earth orbit (LEO) could severely restrict use of the more commonly used orbital paths and inclinations. Most experts have indicated that some degree of mitigation is needed in LEO and that there is a need for improved detection and modeling of the risks.[32] The latter issue is one very central to spacepower as manifested in freedom of action in space and SSA and the need to upgrade debris tracking capabilities as denoted earlier. Further, the debris issue in geostationary orbit (GEO) is potentially serious and costly, due to the relative permanency of orbit (no passive debris removal through orbital decay), narrow orbital bands, and the high economic values of GEO slot allocations with lucrative footprints on Earth for telecommunications.

The evolution in policy as it relates to orbital debris in the United States emphasizes the need to prevent debris proliferation and to take measures, such as SSA enabling debris avoidance maneuvers based on potential impact predictions, to reduce the harm that debris causes.[33] In 1982, NASA and the U.S. Department of Defense (DOD) initiated debris mitigation practices, such as passivation of upper rocket bodies and the placement of end-of-lifetime GEO satellites in parking orbits outside the GEO orbital band. Since 1987, DOD policy has been to minimize or reduce accumulation of space debris and to mitigate the impact of space debris on missions and operations in space. NASA formed a space debris research group in 1993 with the aim of limiting debris generation, and U.S. national space policy has also stated positions on the debris issue. Ronald Reagan called for all space sectors to prevent debris proliferation, and George H. W. Bush said the United States would encourage other spacefaring nations to prevent proliferation. Congress has taken this stance since 1991, laying the groundwork for international cooperation on debris mitigation guidelines. Bill Clinton called for an extension of debris mitigation guidelines to the commercial sector, leading to a requirement in the U.S. licensing process for commercial space launch vehicles and commercial remote sensing for operators to submit and adhere to debris mitigation plans. George W. Bush reiterated all these positions in his 2006 national space policy.[34]

The functional necessity of addressing the debris issue advances collective action. This is no better illustrated than by the information transparency and deconfliction goals of the

U.S. Air Force Space Command. In addition to this, the U.S. Government and foreign governments have convened working groups, in particular the Inter-Agency Space Debris Coordination Committee (IADC), to identify, plan, and assist in the implementation of cooperative activities in space debris research and mitigation options.[35] The approach taken by the IADC encompasses alternatives ranging from the promulgation of voluntary actions that states and industries can take to reduce debris—passivation, parking orbits, hardware designs like shielding and fasteners—to the establishment of guidelines and standards to govern launch vehicles and their payloads. The IADC has also been successful in drawing attention to the issue before the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) Legal Subcommittee, which has made it an agenda item, and there is international interest in formulating orbital debris principles in international space law.[36] Such a formulation is important as the Outer Space Treaty regime deals with space objects that are registered as a legal remedy for dealing with liability issues. Hence, questions remain as to how one would determine a legal definition of debris, how registration of debris is to be dealt with, and whose debris is causing harm, especially if that harm is in the space environment and under a fault-based liability regime per the Convention on Registration of Objects Launched into Outer Space of 1974.

Planetary Defense

Planetary defense deals with the detection and possible mitigation of potentially hazardous NEOs. This is central to the question of what role space will play in the advancement of life on Earth and in the future of humanity. Planetary defense is ultimately about providing for the security of Earth similar to avoiding nuclear war and global environmental destruction. The focus in this section is on the link between the space enterprise and planetary defense.

Near Earth objects were first discovered in 1932, and the first photographic surveys began in the 1960s and 1970s. Of particular concern are potentially hazardous asteroids. These are asteroids of 150 m in diameter and larger that approach within 7.5 million kilometers (km) of Earth and have the potential for impacting it. The type of event caused by a collision between NEOs and Earth is determined by the diameter of the asteroid impactor. In the 1980s, geologists established the fact that impacts with global effects (asteroids that are 300 m in diameter or larger) have occurred in the past and do take place in intervals of as little as 25,000 years.[37] Given the typical pattern of collisions that scientists have discovered in the history of Earth, the statistical risk of death from NEO impacts is the same as that of dying in a passenger aircraft accident and greater than that of death from natural disasters like floods and tornados.[38]

Most of the potentially hazardous NEOs travel in predictable orbits and can be detected decades in advance. One important issue surrounding NEOs deals with political support for detection and surveying efforts and with governance and authority over them. An arrangement aimed at more systematic detection and surveying began in 1988 with the Spacewatch survey, which involved detection efforts ongoing at NASA and a network of amateur astronomers. In 1989, detection efforts documented a NEO near-miss with Earth.

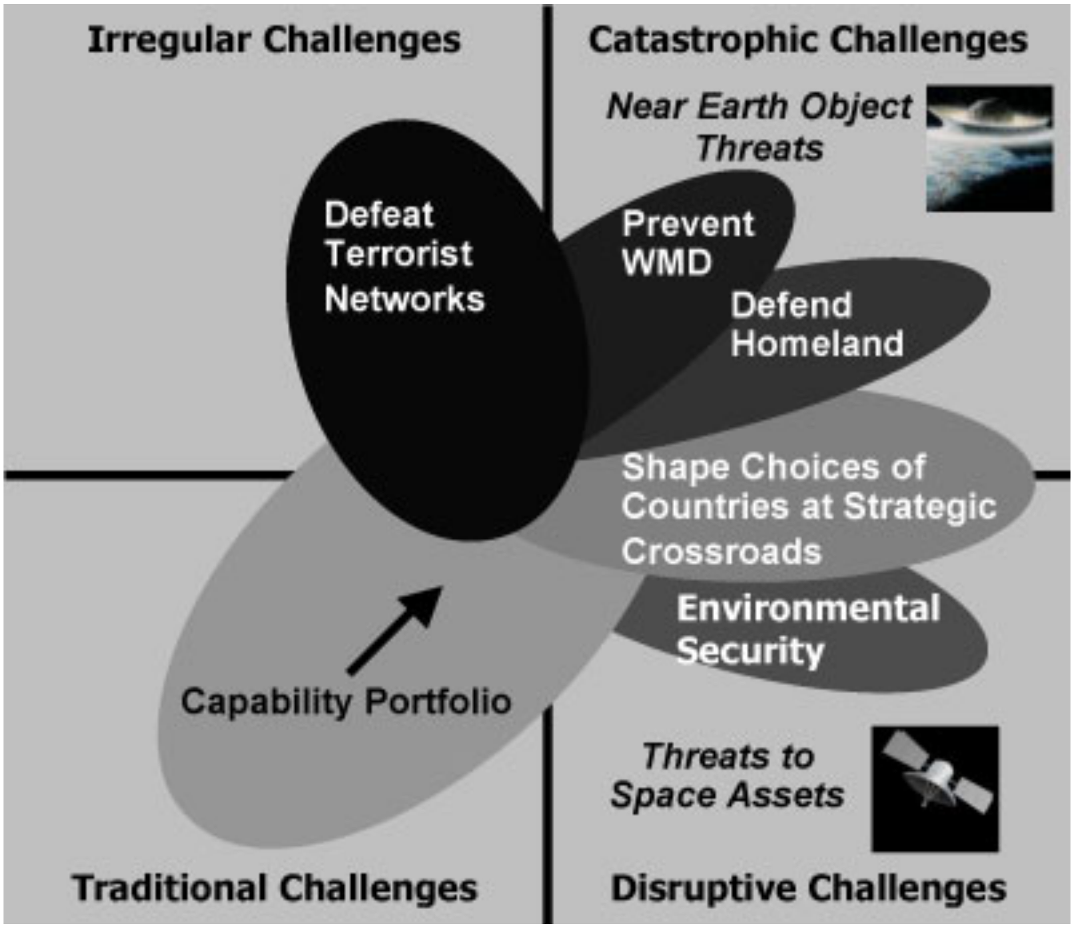
This led to political advocacy before the U.S. Congress that resulted in a NASA Multiyear Authorization Act of 1990 that called for NASA to increase the detection rate of NEOs on an international basis. Following this, in 1991, the House Committee on Science and Technology directed NASA to conduct workshops and studies on the issue. The findings of the workshops were presented to Congress, and in 1994 the Committee on Science and Technology amended the NASA Authorization Act and called for NASA to cooperate with DOD and foreign national space agencies to identify and catalogue within 10 years potentially hazardous NEOs greater than 1 km in diameter.

The plan to carry out identification and cataloguing, known as the Spaceguard survey, was initiated by NASA in 1998 in cooperation with U.S. Space Command Space Surveillance Networks. As of May 2009, NASA had identified 6,242 NEOs and the orbits of 1,047 potentially hazardous asteroids.[39] However, NEOs between 150 m and 1 km can have global effects.[40] As such, a new program was called for in the NASA Authorization Act of 2005 to detect, track, catalogue, and characterize the physical characteristics of NEOs larger than 140 m in size, with the goal to achieve 90 percent completion of the survey by 2020. In 2007, NASA studied the option of such a program and determined that at current budgetary allocations, it can continue to fund the Spaceguard program through 2012, but it cannot initiate a new program as suggested in the 2005 Authorization Act.[41] Obviously, budgetary allocations and priorities are not congruous with what is directed by policy and what is needed to provide for a more robust planetary defense mission. This also begs the question of who is in charge of such a mission.

The political evolution of the NEO issue demonstrates problems of authority and governance. NASA has taken the lead on this and cooperates with DOD for detection, but no one has authority over the problem.[42] No U.S. agency—not NASA, DOD, Air Force Space Command, or the Department of Homeland Security—has been assigned the mission of planetary defense. There are no formal plans or procedures to deal with the NEO issue as it relates to mitigation or to counter the fallout from an impact. This raises the concern of whether planetary defense should be a DOD mission.[43] In other words, should DOD assume a mission to secure the global commons in relation to NEOs, as figure 13–1 below suggests? If this was the case, then should this be part of the calculus with spacepower projection? Is it logical to include in counterspace operations the possible deployment of space weapons, even the use of standoff nuclear weapons, for planetary defense? These are questions that require answers within the context of spacepower theory development.

Figure 13–1. Challenges of the Security Environment

Source: Developed by Eligar Sadeh; adapted and updated from Department of Defense, Quadrennial Defense Review Report (Washington, DC: Department of Defense, 2006), 19.



The nature of space as a commons does set up the NEO issue as one of collective action. Evidence of this exists with international efforts on the issue. For example, in 1995 and 1999, the United Nations hosted workshops on NEOs. The Spacewatch and Spaceguard survey programs noted above entail international efforts, and Europe has put forward a long-term policy commitment on NEOs. More recently, in April 2009, the International Academy of Astronautics held a planetary defense conference.[44] Although these international efforts lack any formal mechanism for cooperation, they do not attempt to coordinate a common or collective view to planetary defense. The NEO subject has also been discussed at UNCOPUOS meetings,[45] and the space preservation treaty efforts that have been part of the UN Prevention of an Arms Race in Outer Space process through the UN Conference on Disarmament have at times made the point that one caveat should be to allow for space weapons for planetary defense.[46]

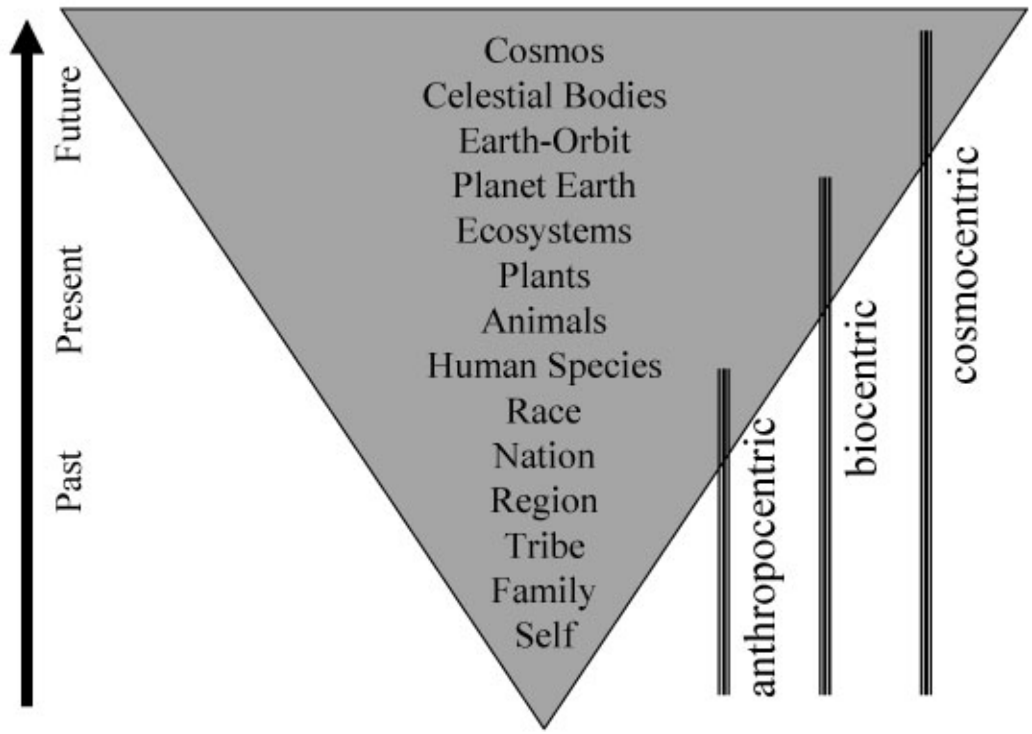
This possible caveat raises interesting tensions among space weapons use, orbital debris, and planetary defense. Earlier, the rational argument was that mitigating orbital debris demands that weapons not be deployed, limiting spacepower projection and counterspace operations. Here, the argument is that space weapons may in fact be one option to provide for planetary defense. If this option is realized, can space weapons technologies be managed as to provide for a "common good?" Could this common good notion be extended to legitimize the use of space weapons for collective security? And is it legitimate for the United States to deploy space weapons to facilitate its role as a systems administrator?

These questions deal with the search for schemes to manage space weapons technologies as part of any spacepower calculus. Philosophical debates on the problems associated with managing technology emanate from a schism between *techne* and *logos*. Ideally, *technology*—as a combination of *logos*, meaning reason or study, and *techne*, meaning the production of something, the skill or the method—implies an articulate thinking turned toward production and making. In these terms, technology is the thinking of technique, while technique is the productive transformation of that thinking. What is obvious with technique is that it may be lacking *logos* or reason and thinking. Since the technique (that is, the operational understanding and application) for space weapons exists, an interesting question that requires answers emerges. Will space weapons techniques become the driving power for space weapons development and use, or will a *logos* guide the use and development of space weapons technologies to the benefit of humankind?[47]

Planetary Protection

An important issue within the context of the environmental theme of this chapter is to spread life in a responsible fashion throughout the solar system. A failure to take environmental considerations into account could lead to a scenario whereby civil, commercial, and military uses of space produce a new extraterrestrial environmental crisis. A useful way of ascertaining the evolution of environmental considerations in space is illustrated in figure 13–2. There is a continuous evolving system in which concepts of environmental protection beyond humans are extended to all animals, plants, entire ecosystems, the Earth, and finally to the entire cosmos. In this regard, three distinct views on planetary protection are identified and discussed: anthropocentric, biocentric, and cosmocentric.

Figure 13–2. Space and Environmental Considerations



In the anthropocentric view, humans are treated as ends in and of themselves and act as moral agents in relation to the environment. Nature is of instrumental value in that it contributes to human life. Anthropocentrism is rooted in the principle of nature as a utility for human ends. In this vein, the environment can be both exploited and protected to safeguard and further human interests and the persistence of human civilization.

The exploitation-of-nature argument is based on the exploitation of the environment to enhance human well being. This view allows humans to extract resources from space and planetary bodies and to create human-supported biospheres in space and on planetary surfaces and terraform celestial bodies. In the realm of national security, such a view suggests spacepower projection without regard for the contamination of the space environment. This is the unregulated view that can lead to a tragedy of the commons of space. The perpetuation of the human species that is linked to spacepower considerations suggests that extending a human presence in space takes place without regard for environmental protection.[48]

The exploitation-of-nature argument underlies the view on spacepower discussed in chapter 9 in this book, which examines the use of the Moon's resources for national economic development. Indicative of this is the new U.S. policy "to incorporate the Solar System in our economic sphere," with the fundamental goal of exploration being to advance scientific, security, and economic interests through a robust space exploration program.[49]

The protection-of-nature argument begins to limit the extent to which resources in space can be incorporated exclusively into the U.S. economic sphere. The argument is that the environment needs to be protected, not because it has intrinsic value of its own, but to safeguard human ends. Environmental protection of some sort is consequently promoted due to instrumental ends that include preventing contamination of planets hospitable to life forms for scientific inquiry;[50] conserving natural resources in space for economic development purposes (that is, a measured distribution of resources so that all can partake and benefit); preserving resources for future generations; preserving aesthetics of planetary surfaces and interplanetary space for human enjoyment; and mitigating environmental contamination, such as orbital debris, to ensure freedom of action in space. International space law is in congruence with these views and designates space and celestial bodies as common resources to be protected from contamination by anthropogenic activities.

Indicative of international space law and environmental protection are the planetary protection provisions advanced by the International Council for Science Committee on Space Research (COSPAR), with the first formal guidelines established in 1969 and most recently updated in 2005. COSPAR planetary protection policies are directed at fulfilling the provisions of the 1967 Outer Space Treaty to avoid the harmful contamination of the Moon and other celestial bodies, with foremost thought given to preserving the scientific integrity of planetary bodies. These policies set the context for NASA's planetary protection policies that establish formal guidelines for planetary protection and stipulate that NASA will not participate in international missions unless all partners agree to follow COSPAR's planetary protection policies. COSPAR also formed a panel on planetary protection that is concerned with the development, maintenance, and promulgation of planetary protection knowledge, policy, and plans to prevent the harmful effects of biological contamination on celestial bodies.

Both the biocentric and cosmocentric views are informative for what they may imply for the use of space. However, they are theoretical in that the anthropocentric view dominates space policy and spacepower projection calculations. This is due in part to the fact that the further one departs from anthropocentrism toward biocentrism and cosmocentrism, the greater is the constraint on human freedom of action within the space environment.[51] The biocentric dimension is based on maximizing the well being of the totality of living existence. With this approach, value is assigned to all of living biology. From this vantage point, humanity has a direct obligation to the welfare of that biology. By way of illustration, the need to maintain and value extraterrestrial indigenous life forms would take precedence over the right of life from Earth to exploit and destroy those life forms. This notion is rooted in the principle of the value of life. Humans have a responsibility to respect and support the interests of life whether animal, biota, or microbes. This is an extension of the aim to preserve the scientific integrity of planetary bodies discussed above, but with a value or ethical commitment to that end that transcends the anthropocentric view.

The logical extension of biocentrism is a cosmocentric ethic characterized by the entirety of the cosmos as an environmental priority. An intrinsic value permeates all levels of both ecological and geomorphological hierarchies; all "named" features and those yet to be discovered have an inherent right to exist. This view is rooted in the principle of the sanctity of existence. Behavior under such a system involves nonviolation of the extraterrestrial environment and the preservation of its existing state, whether that state is biological, ecological, or geomorphological. On a more practical level, a cosmocentric ethic implies that environmental considerations directly inform and determine the planning for the exploration and development of the solar system and any spacepower projection considerations. An extension of the concept of environmental security to spacepower is one practical implication of this view.

Conclusion

The conclusion of this chapter highlights the implications of viewing spacepower through the lens of environmental factors. One implication broadens the scope of spacepower from a focus solely on national concerns to include regional and global concerns. While global environmental dangers and their environmental security aspects—orbital debris, planetary defense, and planetary protection—are all issues that affect national security considerations, they are at the same time issues that posit a collective action problem and require collective action solutions. The collective action solutions discussed herein—international environmental laws, international laws that limit military activities in space, orbital debris mitigation guidelines, planetary defense detection programs, and planetary protection policies—offer paths for viewing spacepower through cooperation, rules of the road, and ultimately, collective security arrangements.

A second implication extends the scope of spacepower through the incorporation of environmental factors into spacepower projection. Remote sensing directed at Earth observations links spacepower to that of identifying, tracking, and assessing global environmental dangers that underlie environmental security. A role, then, for the projection of spacepower is to provide the means for global stability (that is, systems administration) by working to mitigate environmental factors that can cause instability and conflict between and within states. The example of orbital debris as it relates to the space situational awareness mission exemplifies an inclusion of environmental issues in spacepower. The extent to which space situational awareness can be tied to planetary defense is an issue for spacepower projection. Planetary protection plays a possible role in the spacepower calculus, since contamination is a topic that links to environmental security, especially if contamination of Earth occurs from space. It is also a subject that is tied to realizing freedom of action in space, since contamination of the space environment needs to be mitigated if free access to and free use of space are to be ensured.

The final implication within the context of the chapter relates to a strategic view on spacepower. From a strategic "high ground" perspective, spacepower is ultimately about space control that involves control of cislunar space. Due to geography, technological advantage, and global strategic and economic power positions, the United States historically has had far greater success in, reach to, and reliance on cislunar space than any other state. This suggests that space control is more than just a focus on Earth-bound, geocentric strategies like counterspace operations, responsive space, and control of low

Earth orbit, to an integrated strategy based upon building long-term, unconstrained security in cislunar space and in the solar system.[52] The development of spacepower to achieve this end would undoubtedly need to take into account the environmental issues that were the themes of this chapter.

Notes

1. This definition is derived by the author from Environmental Security Studies at <www.acunu.org/millennium/env-sec1.html>.
2. For a list of some of these groups, see table 13–3 in this chapter.
3. Gerald B. Thomas, "U.S. Environmental Security Policy: Broad Concern or Narrow Interests," *Journal of Environment and Development* 6, no. 4 (1997).
4. Thomas Friedman, *The Lexus and the Olive Tree* (New York: Farrar, Straus and Giroux, 1999).
5. Thomas P.M. Barnett, *The Pentagon's New Map* (New York: G.P. Putnam's Sons, 2004).
6. The CNA Corporation is a nonprofit research organization that operates the Center for Naval Analyses and the Institute for Public Research. See <www.cna.org>.
7. Alexander Carius, Melanie Kemper, Sebastian Overturn, and Detlef Sprinz, *Environment and Security in an International Context: State of the Art and Perspectives* (NATO/CCMS Pilot Study, October 1996); The CNA Corporation, *National Security and the Threat of Climate Change*, 2007, available at <http://securityandclimate.cna.org>.
8. *National Security and the Threat of Climate Change*, Executive Summary.
9. "Each man [actor] is locked into a system [an international system] that compels him [the individual actor] to increase his herd [to use, obtain collective good] without limit—in a world that is limited. Ruin is the destination toward which all men [actors] rush, each pursuing his own best interest [self-interest based on rational choice, actor model] in a society [an international system] that believes in the freedom of the commons [free access and free use of the commons]. Freedom in a commons brings ruin [tragedy] to all." Garrett Hardin, "The Tragedy of the Commons," *Science* 162 (1968).
10. See Theresa Hitchens, *Future Society in Space: Charting a Cooperative Course* (Washington, DC: Center for Defense Information, September 2004).
11. See <hwww.unep.org>.
12. Gro Harlem Bruntland, ed., *Our Common Future: The World Commission on Environment and Development* (Oxford, UK: Oxford University Press, 1987).
13. See <www.un.org/esa/sustdev/documents/agenda21/index.htm>.
14. See <http://ozone.unep.org> and <http://unfccc.int>.
15. The Outer Space Treaty declares space as the "province of all mankind." As a province, space is viewed as *res nullius*, that is, belonging to no one (non-appropriable), open to free use and access, and subject to limited claims, like right of use for specific orbital slots for telecommunications purposes. The Moon Agreement's declaration of the Moon as the "Common Heritage of Mankind" differs in that it establishes the natural resources of the Moon as a common property resource for all mankind. If this is accepted, the Moon Agreement requires that lunar resources, once exploitation commences, be shared equitably through an international arrangement, such as an international regime. For an analogous approach that is an accepted part of international law, see the International Seabed Authority at <www.isa.org.jm/en/home>.
16. See <www.gcrio.org/gcact1990.html> and <www.usgcrp.gov/usgcrp>.
17. See <http://eos.nasa.gov>.
18. United Nations, Article XII, *Principles Relating to Remote Sensing of the Earth from Outer Space*, adopted December 3, 1986.
19. The membership of CEOS includes national space agencies and space-based research organizations of Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, Sweden, Ukraine, United Kingdom, and the United States. Belgium, Canada, New Zealand, and

Norway are observers; and affiliates include the Economic and Social Commission of Asia and Pacific, Food and Agricultural Organization, Global Climate Observing System, Global Ocean Observing System, Intergovernmental Oceanographic Commission, International Council of Scientific Unions, International Geosphere-Biosphere Program, United Nations Environmental Program, United Nations Office of Outer Space Affairs, World Climate Program, and World Meteorological Organization.

20. For the issues of mission coordination and the relevant actors and data policy issues, see Eligar Sadeh, "Harmonization of Earth Observation Data: Global Change and Collective Action Conflict," *Astropolitics*: *International Journal of Space Politics and Policy* 3, no. 2 (2005).
21. Gerald B. Thomas, James P. Lester, and Willy Z. Sadeh, "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations," *Space Policy* 1, no. 2 (1995).
22. Sadeh, "Harmonization of Earth Observation Data."
23. *Committee on Earth Observation Satellites toward an Integrated Global Observing Strategy, 1997 Yearbook* (Surrey, UK: Smith System Engineering Limited, 1997).
24. Earth remote sensed data have the potential to engender sovereignty transparency and the "unbundling of territoriality." For a further discussion on this unbundling concept and international relations, see John G. Ruggie, "Territoriality and Beyond: Problematizing Modernity in International Relations," *International Organization* 47, no. 1 (1993).
25. Michael R. Hoversten, "U.S. National Security and Government Regulation of Commercial Remote Sensing from Outer Space," *Air Force Law Review*50 (Winter 2001).
26. Attempting to clarify when shutter control might occur, the memorandum of understanding states: "Conditions should be imposed for the smallest area and for the shortest period necessary to protect national security [defense and intelligence], international obligations, or foreign policy concerns at issue. Alternatives to prohibitions on collection and/or distribution shall be considered such as delaying the transmission or distribution of data, restricting the field of view of the system, encryption of the data if available, or other means to control the use of the data." U.S. President, National Science and Technology Council, "Fact Sheet: Regarding the Memorandum of Understanding Concerning the Licensing of Private Remote Sensing Satellite Systems," November 1, 2001.
27. Orbimage acquired Space Imaging, and the company today is named GeoEye.
28. The facts suggest that there may be no choice but for the U.S. military to accept certain sovereignty bargains, which implies constraints and limits on the use of spacepower projection. An important argument that emerges from this conclusion has to do with what set of constraints is acceptable. For example, is the body of international space law and other international agreements that limit military uses of space as explained in this chapter a sufficient set of constraints, or will the sovereignty bargain force other constraints, like "rules of the road" that could impact the use of spacepower to preserve freedom of action in space?
29. Molly K. Macauley, "Economics of Space," in *Space Politics and Policy: An Evolutionary Perspective*, ed. Eligar Sadeh (The Netherlands: Kluwer Academic Publishers, 2002).
30. Hitchens, *Future Society in Space*; and author correspondence with General James E. Cartwright, USMC, Commander, U.S. Strategic Command, Space and Telecommunications Law Conference, University of Nebraska, Lincoln, Nebraska, March 2, 2007.
31. Author correspondence, General James E. Cartwright.
32. See, for example, *Technical Report on Space Debris* (New York: United Nations, 1999).
33. Attaining zero debris growth, or even cleaning up all debris to achieve zero debris, is likely to be prohibitively expensive and may well require cessation of doing *anything* in space. Further, it probably is not economically practical or technically feasible. Pinpointing a "livable" amount of debris requires a comprehensive social benefit and cost calculus, informed by engineering data about debris populations and their probable growth over time, to weigh the benefits of space activity against the costs of debris production and mitigation. Finally, debris issues, like all space activity, are inherently global. Choosing the best way to manage debris requires the consensus of all parties: those now using space, those who will use space in the future, and those who may never use space directly but who indirectly benefit from space activity. Macauley, "Economics of Space," in Sadeh, ed., *Space Politics and Policy*.

34. U.S. National Space Policy, August 31, 2006, available at <www.ostp.gov/html/US%20National%20Space%20Policy.pdf>, states:

    Orbital debris poses a risk to continued reliable use of space-based services and operations and to the safety of persons and property in space and on Earth. The United States shall seek to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations. Toward that end: Departments and agencies shall continue to follow the United States Government Orbital Debris Mitigation Standard Practices, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the operation of tests and experiments in space; the Secretaries of Commerce and Transportation, in coordination with the Chairman of the Federal Communications Commission, shall continue to address orbital debris issues through their respective licensing procedures; and the United States shall take a leadership role in international fora to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization and shall cooperate in the exchange of information on debris research and the identification of improved debris mitigation practices.

35. IADC members include British National Space Centre, *Centre National d'Etudes Spatiales*, China National Space Administration, European Space Agency, German Aerospace Center, Indian Space Research Organisation, Italian Space Agency, Japan, NASA, National Space Agency of Ukraine, and the Russian Federal Space Agency. Also see <www.iadc-online.org>.
36. One potential obstacle to any new formulation in international space law has to do with the U.S. concern that any "new" legal agreements could limit U.S. military options and spacepower projection. The National Space Policy issued in October 2006 clearly states that the "United States will oppose the development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space." See U.S. National Space Policy.
37. *Report of the Task Force on Potentially Hazardous Near Earth Objects*, September 2000, available at <www.nearearthobjects.co.uk/report/resources_task_intro.cfm>.
38. Clark R. Chapman, "The Hazard of Near-Earth Asteroid Impacts on Earth," *Earth and Planetary Science Letters* 222 (2004).
39. See <http://neo.jpl.nasa.gov>.
40. *Report of the Task Force on Potentially Hazardous Near Earth Objects*.
41. National Aeronautics and Space Administration, "Near-Earth Object Survey and Deflection Analysis of Alternatives," report to Congress, March 2007.
42. Peter Garretson and Douglas Kaupa, *Planetary Defense: Potential Department of Defense Mitigation Roles* (Colorado Springs: U.S. Air Force Academy, December 2006).
43. The U.S. Air Force recently conducted an interagency exercise dealing with a scenario of a near Earth object (NEO) impact with Earth. See AF/A8XC Natural Impact Hazard (Asteroid Strike) Interagency Deliberate Planning Exercise After Action Report (December 2008). The major insights of this effort include: the NEO impact scenario is not captured in existing plans; the NEO impact scenario should be elevated to higher level exercises with more senior government players; proper planning and response to a NEO emergency requires delineation of organizational responsibilities including lead agency and notification standards; government players were not able to achieve consensus on which agency should lead the NEO deflection/mitigation effort; there is a deficit in software tools to support senior decisionmaking and strategic communication for disaster response and mitigation for a NEO scenario; there are significant regional and global effects a NEO impact would generate that are not adequately captured in existing models; the public may be aware of an impending NEO impact before senior decisionmakers; lead time for evacuation requires decisions be made before best information is available; public safety and tranquility require that the U.S. Government be able to rapidly establish a single authoritative voice and tools to present critical information; and the preferred approach for short-notice NEO deflection was standoff nuclear.
44. See <www.congrex.nl/09c04/>. The 2009 conference discussed detecting and tracking NEO asteroids and comets that might be hazardous to Earth, physical characteristics of NEOs,

deflecting a threatening NEO should one be detected, the nature of impact disasters, and political, legal, and policy issues that must be considered as part of an overall mitigation strategy.

45. See <www.b612foundation.org>.
46. The use of any technology to counter the threat of NEO impacts has to consider the lead time before impact and the physical type and characteristics of the NEO. Whether a space weapon or another type of technology could be effective is a matter of debate in the space community.
47. Everett C. Dolman, in *Astropolitik: Classical Geopolitics in the Space Age* (London: Frank Cass, 2002), argues for spacepower projection by the United States to safeguard and advance its values of freedom and democracy.
48. Molly K. Macauley, "Environmentally Sustainable Human Space Activities: Can Challenges of Planetary Protection Be Reconciled," *Astropolitics: International Journal of Space Politics and Policy* 5, no. 3 (2007).
49. John Marburger, keynote address, 44th Robert H. Goddard Memorial Symposium, Greenbelt, MD, March 15, 2006, available at <www.spaceref.com/news/viewsr.html?pid=19999>.
50. NASA has addressed some of these issues by establishing a Planetary Protection Office and instituting policy guidelines regarding planetary protection. These guidelines incorporate both "forward" and "backward" contamination issues. Forward contamination seeks to prevent Earth organisms from contaminating another celestial body, and possible backward contamination is contamination forthcoming from another planet to Earth.
51. Eligar Sadeh, "Space and the Environment," in Sadeh, ed., *Space Politics and Policy*.
52. Thomas Cremins and Paul D. Spudis, "The Strategic Context of the Moon: Echoes of the Past, Symphony of the Future," *Astropolitics: International Journal of Space Politics and Policy* 5, no. 1 (2007). The cislunar perspective also informs the development of this spacepower theory project. Dennis Wingo argues in chapter 9 in this book that a geocentric mindset has become an embedded assumption in the development of national spacepower theory. *Geocentric* is defined as a mindset that sees spacepower and its application as focused primarily on actions, actors, and influences on Earthly powers, the Earth itself, and its nearby orbital environs. Wingo argues that this is a mindset and worldview that must be expanded in the development of spacepower theory. The expanded view can be defined as cislunar based on a "cosmographic" outlook. See presentation by Charles D. Lutes, "Towards a Theory of Spacepower," *The Influence of Spacepower on History and the Implications for the Future*, Institute for National Security Studies, National Defense University, Washington, DC, April 25–26, 2007.

Chapter 14:

Neither Mahan nor Mitchell: National Security Space and Spacepower, 1945-2000

James Andrew Lewis

Beginning in the 1950s, the United States extended its military activities into space to provide for its defense in a global conflict with the Soviet Union. Over the next four decades, the Nation put in place an impressive array of satellites that provided remote sensing, communications, and geospatial location services. The first task for these military satellites was to obtain strategic information that neither aircraft nor human agents could access. The development of other space services (in communications and navigation) enabled a responsive global defense. Over time, the data and services provided by satellites became an integral part of U.S. military operations and of national power. The salient points of the history of this effort can be summarized as follows:

- In 1944, German scientists build and launch medium-range, suborbital missiles against Allied targets and begin to design an intercontinental missile for use against the United States. At the end of the war, the Soviets and Americans coopt scientists and seize missiles and factories and incorporate them into their own national military programs.
- In 1945, Army Air Force Commander Hap Arnold recommends to the Secretary of War that the United States pursue the development of long-range missiles and "space ships" capable of launching missiles against terrestrial targets.
- The RAND Corporation, at the request of General Curtis LeMay, issues a report in 1946 on the "Preliminary Design of an Experimental World Circling Spaceship." The Navy and Army begin programs to develop launch capabilities and satellites.
- In 1957, embarrassed by the launch of Sputnik and the shooting down of a U–2 reconnaissance aircraft over the Soviet Union, the United States manages (after 13 consecutive failures) to launch the Corona reconnaissance satellite, opening the era of spacepower as a component of strategic military power. Satellite reconnaissance solves an immediate and pressing national security problem: the U.S. inability to infiltrate the Soviet Union with agents. After a delay, Corona is followed by the first U.S. electronic intelligence satellite.
- For the next 30 years, driven by its conflict with the Soviet Union, the United States refines and expands the range of satellite services available to support national security to include military communications, navigation and timing, intelligence collection, and reconnaissance.
- Sputnik also prompts the United States to reorganize its national space effort, and the organizational steps taken between 1958 and 1962 shape how America will operate in space. The 1958 National Aeronautics and Space Act splits the U.S. space program into civil and military components and mandates that military space activities be conducted by the Department of Defense. The creation of the

National Aeronautics and Space Administration (NASA) gives space exploration a home outside of the military and diverts thousands of engineers from military programs. National space security is further divided into military and intelligence programs. The National Reconnaissance Office (NRO) is established and given oversight of classified programs. President Dwight Eisenhower's decision bifurcates the national space effort, and diffusion of responsibility for space missions becomes the norm.

- In response to a call from President Eisenhower to the United Nations, an international legal framework for space activities is created in the 1960s. This allows satellites to operate freely over other nations. There are parallels to international law as applied to the sea and to warships but also some significant differences. National sovereignty does not extend limitlessly into space, and the right of overflight is established. There is significant ambiguity over the use of weapons—nuclear weapons and other weapons of mass destruction are clearly forbidden; other classes of weapons are not.
- Secretary of Defense Robert McNamara attempts to streamline organization and budgetary oversight for national security space within the Department of Defense (DOD). He designates the Air Force as the Executive Agent for Space (the decision was rescinded in 1970 and then restored in 2003), but the other Services continue their own space programs, and early proposals to create a separate command for space fall victim to Service rivalries.
- Threats by Soviet leader Nikita Khrushchev to deploy nuclear-armed orbital bombardment systems lead in 1959 to the first U.S. antisatellite program. The Soviets begin similar programs and deploy a system in the early 1970s. U.S. efforts to develop antisatellite weapons are helped by work on missile defense and hindered by concerns over the legality of such weapons.
- McNamara cancels the Air Force X–20 space plan project in 1963, citing budgetary concerns and lack of a clear mission. This is a seminal moment for spacepower and diverts it from the vision of Arnold and other Air Force pioneers. Manned flight becomes the domain of NASA, and the United States shelves the idea of an aircraft-like manned platform capable of delivering weapons from orbit.
- The United States flirts with the idea of manned orbital military missions in the 1970s, but the Air Force's planned Manned Orbital Laboratory (conceived as a replacement to the cancelled X–20) is rapidly abandoned as impractical.
- A key development for spacepower occurs in 1976, when real-time imagery from space becomes available. Instead of dropping film canisters for aerial recovery, reconnaissance satellites convert images into electronic signals and relay them to Earth in near real time. The change ultimately allows for the creation of software to refine and better exploit imagery and creates the possibility for tactical application of dynamic (rather than stored) imagery.
- In another effort to improve coordination among Air Force, Navy, and Army space efforts, the United States establishes in 1985 a new joint command, the United States Space Command (merged into the U.S. Strategic Command in 2003). The new unified command is part of the sweeping U.S. military

reorganization aimed at improving inter-Service cooperation prompted by the Goldwater-Nichols Act Department of Defense Reorganization Act.

- In 1986, the *Challenger* shuttle explosion prompts DOD to restart its own launch programs, reversing the earlier U.S. policy to rely solely on the shuttle for access to space.[1] In 1994, the White House makes DOD the lead agency for expendable launch vehicles.
- In the 1991 Persian Gulf War, the United States discovers, almost by accident, that it has assembled a collection of space services that provide real advantages on the battlefield.The operation of space assets and the delivery of their services are poorly integrated from the combatant commander's point of view, but space provides new capabilities and improved performance. The successful use of space assets in the Gulf reflects earlier efforts to improve joint operations, such as the changes prompted by the Goldwater-Nichols Act, and to emphasize intangible factors—information superiority and coordination—in gaining military superiority over the massive forces of the Soviet Union.
- The end of the Cold War eliminates the peer competition that drove much of the change in military and intelligence activities in space. While the budget and personnel cuts that follow the end of the conflict damage U.S. space and intelligence capabilities, DOD begins to articulate a broader concept of spacepower and begins to change organizations and doctrine to take full advantage of space for national security.
- In 1995, after prompting from Congress, DOD again reorganizes to improve management and unity of effort in space. As part of this complex reorganization, it creates a Deputy Under Secretary of Defense for Space, a Joint Space Management Board, and the position of Space Architect. DOD releases the first Space Architecture, for military communications, in 1996. Perhaps the best comment on the reorganization effort is that 3 years later, Congress feels compelled to create another commission to assess and recommend changes for the management and organization of national security space.
- The United States declassifies the existence of the National Reconnaissance Office (NRO) in 1992 and releases thousands of Corona photographs. Space becomes routine rather than exotic and experimental; for example, the National Commission to Review the National Reconnaissance Office lamented in 2000 that "most unfortunately, the NRO no longer commands the personal attention of the President, the Secretary of Defense, the DCI [Director of Central Intelligence], or senior White House officials."
- In 1996, a new agency, the National Imagery and Mapping Agency (NIMA), is established. NIMA combines DOD and Central Intelligence Agency (CIA) personnel in order to better exploit and coordinate spatial intelligence. U.S. policy (in documents such as Presidential Decision Directive 23 on Remote Sensing) begins to plan for the increased use of commercial space services as a means to reinforce the services provided by government-owned satellites for national security purposes.
- Frustrated by continued duplication and slow progress in space programs, and prompted by an awareness of the increased importance of space for security, Congress uses the National Defense Authorization Act for Fiscal Year 2000 to

create the Commission to Assess United States National Security Space Management and Organization. In its final report, the Commission concludes that "we are now on the threshold of a new era of the space age, devoted to mastering operations in Space."[2] The United States leads all other nations in the use of space for national security, but problems in organization that date back to 1958 and the acquisition of new systems threaten to erode its advantage.

This brief summary reveals several crucial trends. The first is the interconnection between larger developments in warfighting and strategy and the use of space. The second is the diffusion of control and its implications for the pursuit of unity of effort, not only among the armed Services, but also between the military and the Intelligence Community. The third is the tendency to build spacecraft for a specific function or mission rather than as part of a larger military goal (like air superiority or sea control). Finally, the refinement and elaboration of space services allow the United States to refocus military space activities from a national/strategic to an operational/tactical level, creating new combat capabilities but also creating new tensions over who controls space assets and services: Washington or the combatant commander.These trends have shaped U.S. security efforts in space.

Although the benefits of space for national security are widely celebrated, the United States has struggled from the onset with the organizational and doctrinal changes required to make full use of space for military purposes. The Nation faces three difficult problems that grow directly out of the history of its military and intelligence programs: the lack of a coherent architecture for the many independent national security space systems; changes in the acquisitions process that slow new programs; and the challenge of articulating a theory of spacepower equal to sea- or airpower when satellite systems do not deliver force or firepower from space.

This summary also suggests that while it can be useful to consider the U.S. experience in developing sea- and airpower concepts, these can be imprecise guides for spacepower. In some ways, the naval experience, with its mix of commercial and military activities and the operations of fleets on the high seas, may be the best precedent. But if Alfred Thayer Mahan is the foundation for strategic thinking on seapower, he built upon centuries of experience with naval conflict and its relations to national power, and he looked explicitly at the 300 years of fleet operations amassed by the Royal Navy. The development of airpower offers a tempting set of precedents, but there are crucial differences between airpower and spacepower: spacecraft do not fly, they do not deliver weapons onto targets, and the legal regime for offensive space operations is both markedly different from air operations and untested.

The concept of a space architecture is crucial for understanding the development of national security space systems. Architecture defines structure, equipment, and operations and can be a roadmap for investment and development. Architecture is particularly important for space, given the physics of orbital operations, which dictate static patterns for movement and position. In this sense, architecture is somewhat comparable to the concept of order of battle.The most important point to bear in mind about a national security space architecture for the United States is that until the 1990s, there was none.

An Incremental Approach to Spacepower

In competition with the Soviet Union, the United States assembled an array of sensor-bearing, communications, and geonavigational satellites to support its ability to fight a global war.The triumvirate of spacepower—sensors, communications, and navigation—markedly increased U.S. security in the decades after Corona and ultimately provided the tools for a new approach to warfare, an approach that emphasized intangible advantage and information superiority. However, the United States undertook the construction of these space systems without a coherent vision for space and in an environment shaped by inter-Service rivalries. Services The United States built satellites because they offered a solution to a particular problem or a better way of carrying out an existing mission, not as part of some larger strategy for space operations.This fragmented approach formed the U.S. presence in space.

The absence of a larger vision meant that the development of spacepower was incremental. Satellites were useful tools or adjuncts, not the basis for an independent service. Nor was space a new arena for combat. Only after the number and kinds of satellites had reached critical mass, after U.S. organizational and strategic concepts had changed to emphasize intangible factors in military operations—coordination and information superiority—and after surprisingly quick success in a conflict against a powerful regional foe demonstrated the broader potential of space that the United States began to conceptualize the idea of spacepower.

This fragmentation is perhaps indicative of early attitudes about the military utility of space. Space was in some ways a microcosm of a larger problem. In the 1950s, when the national security space programs began, lines of responsibility and authority among the Secretary of Defense, the newly created Air Force, the other Services, and the CIA were unclear, and space projects were spread among the various agencies and Services.

The United States had learned the importance of joint operations from its experiences in World War II and had begun to reorganize military and intelligence functions to promote greater coordination.The vehicle for this reorganization was the 1947 National Security Act, which established the National Security Council, the Department of Defense, the Joint Chiefs of Staff, and the Central Intelligence Agency. The intent of Congress was to create "a comprehensive program . . . to provide for the establishment of integrated policies and procedures for the departments, agencies, and functions of the Government relating to the national security." The act envisioned "the integration of domestic, foreign, and military policies relating to the national security."It has taken years (some would say decades) to implement this vision. Military space activities began at the same moment the United States was wrestling with the larger question of how to integrate its military, intelligence, diplomatic, and economic power to achieve national security.

Yet while the Armed Forces and intelligence agencies were being subsumed within a larger integrated management structure, national security space was being fragmented. In part, this was due to the newness of the coordinating authorities of the Department of Defense.However, the fragmentation also suggests that the planners and strategists of the 1950s saw space and satellites as tools and accessories rather than as an independent military capability, somewhat akin to the way the Army saw aircraft before the First World War. An integrated vision of spacepower would advance no faster than the growth of an integrated approach to national security and military operations.

At least one service, the Navy, floated the idea of a separate command for space as early as 1958. Arleigh Burke, Chief of Naval Operations, proposed the new command, and one of his deputies, Admiral John Hayward, the Deputy Chief of Naval Operations for Development (and previously the Assistant Chief of Naval Operations for Research and Development), was "one of the strongest proponents of a unified national space program."[3] Navy's interest in space was driven by practical requirements for global communications and navigation, and the Service had begun to pursue space operations in the late 1940s.

Burke's proposal met with resistance from two quarters. The new Office of the Secretary of Defense argued that there were not enough space missions to justify an independent command.The Air Force took the position that it "should have primary responsibility for any military satellite vehicle, considering such activity to be essentially an extension of strategic air power." From the start, Air Force leaders had seen space as an extension of airpower and thus rightfully falling in their sphere of control. Efforts by the Air Force to assert dominance over space activities became one of the constants of the first 40 years of U.S. military space programs.

McNamara, as part of his larger effort to rationalize the Department of Defense and its budget processes, attempted in March 1961 to correct the fragmentation problem by making the Air Force the executive agent for military space (his decision was rescinded in 1970 and not reinstated until 2003).[4] McNamara's directive allowed the other military Services to conduct research and development but gave the Air Force oversight and lead for space. The other Services, particularly the Navy, were not overly constrained by this decision, and their independence may not have been a bad thing. The Navy initially gave a higher priority than the Air Force to developing satellite navigational aids, and its efforts led to global positioning systems (GPS) being deployed earlier than might have otherwise been the case.

The creation of NRO in 1961 was another attempt to overcome coordination problems.Eisenhower had assigned the Corona program to CIA rather than the Air Force during a time of struggle between the two agencies over control of strategic reconnaissance and over what became the U–2 and SR–71 reconnaissance aircraft. NRO was to provide a "more formalized and closer coordination" between DOD and CIA for space programs.[5] When the Eisenhower administration created NRO, vesting a secretive civilian agency with the primary responsibility for space programs made sense. There were few systems in operation, and they were highly classified. Over time, however, as the number of unclassified military space programs grew in number and importance, the distinction between "white" and "black" programs only perpetuated the U.S. tendency toward duplication and diffusion in space programs. Efforts to align NRO and Air Force programs more closely have continued to face the problem of melding the two different cultures that grew up around national security space since 1961.

The bifurcation of national security space—as an intelligence activity and as a military support activity—has been a source of tension almost from the start of national security space activities. Initially, this tension was an outgrowth of the original discomfort of the military Services with the creation of the CIA, a civilian intelligence agency that operated independent of military command. This tension over control was also reflected in the concerns of the different Services that their missions would always receive a lower priority if a single Service was vested with control of space missions.

Control over satellite acquisitions and tasking of space assets was also a problem. While the requirements of the military and the Intelligence Community overlap to a considerable degree, there are differences. A satellite built for the Intelligence Community may not meet the needs of the military, for example; each can have different requirements for remote sensing. Efforts in the 1990s to design satellites that met all possible requirements had the unintended consequence of slowing new acquisitions and making the planned satellites more costly. Tasking and mission priority also remain a potential, albeit decreasing, friction point. The United States has put in place management structures to resolve disputes over scarce space resources and decide when a military request takes precedence over an intelligence tasking, but the dual control over national security space continues to complicate development of a unified theory of spacepower.

Space as Strategic Support

Intelligence satellites are referred to as "national technical means" of collection, reflecting the early emphasis on space as a strategic and national resource. Space activities were closely tied to strategic interests: identifying targets for strategic weapons; detecting tests, launches, and possible attacks from the Soviet Union; and providing global and survivable communications. As a counter to its lack of human resources in the Soviet bloc, the United States developed an immense technical collection infrastructure that obtained intelligence from signals and imagery. The first contribution of space to intelligence lay in photoreconnaissance. Corona provided information on Soviet strategic programs that was otherwise unavailable. Over the next two decades, the Nation developed and deployed a range of satellite collection systems for intelligence.While aerial reconnaissance and collection by numerous ground facilities reinforced space-based collection, the use of space systems for collection became a hallmark of U.S. intelligence activities.

Aerial reconnaissance began as early as the Civil War, and it was easy to think of satellites as just an extension of aerial photography into space. In addition to imagery, the United States began in the 1960s to operate satellites to collect signals intelligence, to provide early warning of missile launches, and to monitor oceans for naval activity. Satellites obtained information that neither aircraft nor human agents could access. Over the next two decades, these satellites provided U.S. policymakers with a stream of information that few, if any, nations could match.

Gaining military and intelligence advantage from space assets depends on more than the possession of satellites. Countries seeking to use satellites for military purposes often overlook the expensive terrestrial element of spacepower. Effective use of satellite services requires the development of a support infrastructure of analysts and operators, and the ability to integrate satellite data and services into military plans and operation. The integration of space-based signals intelligence and imagery is a particularly complex task since it requires extensive changes to doctrine, expanded staffs, and increased communications capabilities. By the 1970s, the United States had developed a strong cadre of personnel, both civilian and military, who were capable of planning and carrying out operations in space to support national security objectives. Their efforts were supported by the development of new analytical tools, including software, that let them extract more value from space imagery and other data.

However, the military's struggle with jointness and integration was mirrored in the Intelligence Community. As the community grew in size, different cultures appeared in the agencies that managed each intelligence collection discipline and associated technologies. The disciplines did not integrate well with each other; the 9/11 Commission and others would later identify this failure to share intelligence as a key U.S. weakness. Only in the past few years, with the successful cooperation between the National Security Agency (NSA) and the National Geospatial-Intelligence Agency (NGA; formerly the National Imagery and Mapping Agency), have the collection disciplines undertaken a sustained effort at integration.

The prominent and foundational role of intelligence collection from space may have inadvertently hampered the development of spacepower concepts. The United States designed many of its space activities to support the highest levels of civilian and military command. In addition to this national focus and the narrow set of customers behind it, space programs were highly classified. The codeword classifications and compartmentalization covered not only the operational capabilities of the satellites, which clearly needed protection if they were not to be rendered ineffective, but also their very existence and, in many cases, the information they produced. The clandestine, compartmentalized, and restricted nature of the programs worked against unity of action or a single theory of spacepower.

The cost of access to space also hampered the development of spacepower concepts. Beyond the expense of building the satellite (and intelligence satellites were, as a rule, among the most expensive pieces of hardware the United States acquired), the cost of space launch was a serious obstacle to taking full advantage of space capabilities. The Jimmy Carter administration directed NASA to create a "National Space Transportation System" to reduce access costs by employing a reusable vehicle, the space shuttle. For the shuttle program to make economic sense, however, it would need to carry a high number of payloads. To attain this, Carter directed that all U.S. payloads, including national security payloads, would be launched on the shuttle and, more importantly, that existing expendable launch vehicles be retired.

Carter's decision was not without precedent. Sporadic and repeated efforts by Congress, the White House, or the Secretary of Defense to eliminate duplication are a hallmark of the U.S. national space effort. As early as November 1959, the Eisenhower administration had decided that a single agency should design and build a "super booster" for the "national space program" and that this agency should be NASA. The basis for the decision was that there was no clear military requirement for super boosters. The United States took the resources and personnel for this program from the Army and the other Services.[6]

If Carter's policy on launches had worked, it would have had serious implications for spacepower; it essentially would have meant that the military would no longer control its own access to space. However, the policy foundered after the 1986 *Challenger* explosion and the launch of national security payloads for the defense community returned to the more robust expendable launch vehicles. This solved the problems of access and reliability, but not of cost. The cost of reaching orbit essentially reflects technological and scientific limitations, but the expense of putting objects into space remains a major obstacle to the further development of spacepower.

The cost of access to space shaped military thinking about spacepower. In the 1950s, consistent with the view that space was simply an extension of the atmosphere, the United States began programs to create space planes such as the X–20 DynaSoar. This was an aircraft that would have been boosted into space by a Titan launch vehicle, where it could achieve orbital speed, attack terrestrial and space targets, and then glide back to land. Cost and doubts about the X–20's mission led to the cancellation of the project after $3.7 billion (in 2007 dollars) were spent and a prototype was completed.

The U.S. decisions not to pursue spacecraft like the X–20 or its follow-on program, the Manned Orbital Laboratory, channeled spacepower away from combat and the traditional application of force. Developments in long-range missiles made some of the DynaSoar's potential missions redundant. DOD also cancelled other manned military systems, such as an orbiting military space station, as it considered them too expensive when compared with terrestrial or unmanned systems. In some ways, the expense of building a presence in space turned out to have some advantages. Space systems were too expensive to deploy except in those cases where they alone could perform a crucial task. By default, this limitation forced an answer to the question of what it is that can be done in space that cannot be done somewhere else.

The contrast with airpower can help to illuminate the nature of military and intelligence activities in space. Airpower means that a nation's forces are unhindered in their use of the airspace; airpower can support their operations, enemy air forces cannot attack them or gain advantage from the air, but the enemy's forces and homeland could be attacked. Spacepower could provide all but one of these advantages. The inability to launch attacks from space hindered the development of spacepower theory. Sea- and airpower theorists can envision their fleets of ships or aircraft being the decisive instrument of victory. Few people imagined that for spacepower, and no one attempted to put it into practice.

The original theorists of airpower, Giulio Douhet, Hugh Trenchard, and Billy Mitchell, saw it as a new kind of conflict, one that would supplant and surpass previous forms of battle.Airpower offered the opportunity to break the stalemate of conventional warfare and defeat determined enemies without having to first vanquish their armies and fleets. Airpower could bypass trenches, fortifications, and ground forces and strike directly at an enemy's will and ability to wage war. These theories appeared in the decade after the infantry debacle of the First World War. In contrast, there were no great theorists of spacepower in the first decades of the military use of space. If the analogy holds, however, we would say that airpower theorists appeared in the decade after the first war to see the use of aircraft in combat, so if the 1990 Persian Gulf War was the first space war, we should not be surprised to see spacepower theories emerging in the 1990s.

Early proponents of spacepower saw it as an extension of airpower. This was an unworkable approach, given the difference between aircraft and spacecraft. The inability to "fly" manned weapons platforms in space closed off the easy route to the development of a theory of spacepower. Instead, the emergence of spacepower was linked to changing concepts for joint operations and the influence of intangible elements for military effectiveness and national power.

Space and New Approaches to Warfare

The military aspects of spacepower are an outgrowth of major changes in how the United States fights its wars. Defeat in Vietnam brought U.S. military forces to their nadir. From the wreckage of the mass mobilization army in the mid-1970s, new concepts of how America could apply force against its opponents emerged. The end of the draft meant the end of any serious effort to match the Soviet forces on a quantitative basis. As it contemplated how to fight outnumbered and win, the Nation would discover that space assets could provide a crucial advantage.

The new military would be smaller and professional. It would build on the scientific and technological strengths that became part of the American way of fighting in the 1940s.The incorporation of the scientific establishment into military activity during World War II provided U.S. forces with significant advantages in that conflict and the United States created a number of research institutions after the war (such as the Defense Advanced Research Projects Agency and the various Service Labs) to formalize the relationship between science and national security. The Cold War reinforced the importance of scientific research to bolster national security and provide technological solutions to military problems. The use of space and satellites was closely tied to this nexus of national security and science.

The Cold War, with its competition between two different political and economic systems, engendered a number of races to win prestige and international political support.

More importantly, as it became apparent that the United States would not be able to match the quantitative advantage the Soviet bloc had in the numbers of tanks, aircraft, missiles, and other weapons, American strategists turned to the idea of qualitative advantage as the key to defeating a conventional attack by the Soviets. The ability of the arsenal of democracy to out-manufacture the Axis powers had been one of the avenues to victory in World War II. The Soviet fixation on military production closed off this avenue by the 1970s.

Confronted by massive Soviet forces, American military thinking shifted in the 1980s to concepts where a high-tech force that obtained information and acted upon it faster than its opponents was more likely to win in combat. The emphasis on information superiority allows the most effective use of high-tech weapons, making American forces far more lethal today than their predecessors of 20 to 40 years ago and superior to any other conventional military force.

It was not until the 1980s, however, as the United States emphasized qualitative superiority in the face of unmatchable Soviet quantitative superiority, that the military began to realize that the benefits of the different space networks for collection, communications, and navigation were greater than the sum of the parts. The work of John Boyd, who emphasized the benefits of rapid decisionmaking and information superiority for military effectiveness, was influential in shaping the new approach. The elements of this new mode of warfare were information superiority, connectivity (among sensors, combatants, and commanders), and, ultimately, network-centric organization and operations.[7] The most important event for understanding this change was the first war against Iraq in the Persian Gulf. The outlines of a new mode of warfare emerged after the Gulf War. This revolution in military affairs emphasized the greater use and better communication of information among commanders, analysts, and combatants.

The Persian Gulf War, in which space-based resources played a central role in shaping both strategy and tactics for the first time, was a pivotal moment in the military use of satellites. The satellite network designed for use against the Soviet Union in a global war gave the United States a measurable advantage against a heavily armed regional competitor. Combined with airborne assets, this collection provided significant advantages to United States Central Command (USCENTCOM). Iraqi forces found it difficult to compete with an opponent well supplied with space services for navigation and remote sensing and possessing a superior communications network.

The war demonstrated the benefits for military operations of combining space-based communications, navigation, and sensor data. Remote sensing satellites provided data on the disposition and strength of Iraqi forces, supplied targeting information, and allowed coalition forces to assess battle damage. The specialized Defense Support Program (DSP) satellites were able to provide warning (albeit very little) of Iraqi Scud launches. The use of military communications satellites and rented transponders on commercial communications satellites allowed unparalleled coordination between deployed U.S. forces and Washington. Although receivers were in short supply for the campaign, GPS satellites allowed coalition forces to navigate with precision in the desert and in the air.

The combination reduced uncertainty for coalition commanders, allowing faster and more precise operations that less well-informed opponents could not match.

The most important aspect of the use of satellites in the Persian Gulf was the direction it suggested for future conventional warfare. First, the use of precision-guided weapons, combined with GPS and remote sensing data, made possible a new and more lethal method of attack. One of the early highlights of the Gulf War was General Charles Horner, the air component commander, showing the press a video of a precision-guided munition flying through an air vent into an Iraqi government building. The combination of air assets and space data required a much smaller number of aircraft, weapons, and sorties to destroy a target. Second, and perhaps more important, the integration of satellite services for communications and data collection suggested that the United States could develop an advantage in information use that would make its forces more effective in future conflicts. The integration of satellite services (communications, remote sensing, and navigation) with precision-guided munitions and command structures helped lay the groundwork for military transformation.

The successes of coordinated efforts in Operation *Desert Storm* stood in stark contrast to the operations in Grenada a decade earlier. Grenada highlighted coordination difficulties among air, naval, and ground forces that reduced the combined effectiveness of American forces. Mistakes and incompatibilities that the United States could overcome when opposed by a few hundred lightly armed Cuban soldiers might have proven fatal in any contest with Soviet forces in Central Europe. Grenada only reinforced the importance of coordination and coherence for military effectiveness.

The passage and implementation of the Goldwater-Nichols Department of Defense Reorganization Act of 1986 (PL 99–433) were crucial developments for military spacepower.Goldwater-Nichols made important improvements to the chain of command, but for space, its most important effect grew out of the new role of the combatant commanders and their new authorities over all branches of the armed Services. Goldwater-Nichols created a new set of customers—the combatant commanders—who were eager for information and impatient with the complex and slow procedures developed since the 1950s for passing information from "national" assets to the combatant.

The implications of Goldwater-Nichols for space were also significant. The new law and the Pentagon's efforts to implement it created a precedent for space operations. Instead of Army, Navy, Marine, and Air Force units or systems operating independently and reporting to different command authorities, the combatant commander had unified authority over all units and systems assigned to him. This unified, combatant-oriented approach would seep into the thinking about how to organize and use space assets.

However, Goldwater-Nichols did not extend far into space. A combatant commander exercised at best only partial control over the space assets he would use. While some assets belonged to DOD, others were controlled by the Intelligence Community. Satellites operated by civilian agencies and commercial satellites also fell outside the combatant commander's control.This diffusion of control over assets made control over information even more important.Immediate and direct access to the information and services generated by satellites could compensate for a complicated tasking process.

Timely access did not occur automatically. Grenada and the Gulf War exposed problems in the distribution of imagery and other satellite intelligence.[8] There were long delays in relaying information to the combatant commanders, although these delays became progressively shorter during the Gulf War (daily pressure from a vociferous USCENTCOM commander helped lead to this progressive shortening). Essentially, there was a lag, usually of many hours, in getting data collected by satellites to the combatant commander and his staff. In the competition with the Soviets, when the primary targets for satellite collection were strategic—fixed missile silos, weapons plants, or airfields—this lag had not been a problem. In combat operations, however, the lag contributed to the troubling uncertainty faced by commanders. The desire of commanders for timely and full access to satellite data and services helped to move the focus of military space activities from national assets used primarily for strategic purposes to assets providing information and services for operational and tactical purposes.

This change in focus for military space helped to drive a larger shift in U.S. intelligence priorities in the 1990s. Support for combatant commanders and for the warfighter became the central mission of intelligence, particularly as the collapse of the Soviet Union left the Intelligence Community without its traditional mission focused on a major state opponent. The increased priority placed on intelligence support for the military began with *Desert Storm* and peaked during operations in Kosovo, when a large proportion of all U.S. intelligence assets (including national technical means) were used to support U.S. forces.

The Gulf War showed the shortcomings of another strategic space system designed for the static environment of the Cold War. The DSP satellites used to detect Soviet missile launches performed well in detecting Iraqi Scud launches but were inadequate for determining the position of the mobile launchers; none were found during the war.The DSP launch notification fit well with a strategy of deterrence: the Soviet Union knew that the United States would detect any launch almost immediately and could quickly retaliate against preselected strategic targets. It did not work so well in the more fluid combat environment of the Gulf War.

The Gulf War also exposed a new set of risks for the United States. The availability of commercial space services gave smaller opponents the opportunity to mimic the space capabilities of the larger powers without the expense of building and launching a large satellite fleet. During the war, the combatant commander had to consider the possibility that the Iraqis would acquire commercial imagery from a French service provider or from the Soviets. This imagery might have allowed the Iraqis to divine his intention to swing the bulk of his forces in a hook to the west. In the case of France, the provision of such imagery was blocked, but the potential of Soviet imagery being provided to the Iraqis remained a nagging concern.

This concern has only increased as commercial space services in imagery and communication have become widespread. Commercial space assets fall under a different legal regime than national assets, and by the end of the 1990s, the United States faced (and continues to face) the potential problem of how to gain space control in a conflict where an opponent uses space services provided by a neutral third party. As with the Soviets during the Gulf War, cooperation cannot always be assumed. Blocking the service or attacking the satellite that delivers it puts the United States in the awkward position of widening its campaign. The growth in the availability of commercial space services since 1990 means that space is no longer a unique source of U.S. advantage.

That said, the United States still gains more from space than its potential opponents, not only because of the size of its space fleet, but also because of the effort it has made to incorporate space services into doctrine and planning. The best example of the effect of space technologies on military operations is GPS, which in some ways helps make the dreams of the airpower theorists a reality—instead of dozens of aircraft flying hundreds of sorties to destroy a target, a single aircraft and its weapons, guided by satellite data, could be sufficient.

More importantly, and in contrast to national-level space systems, GPS provides its data directly and immediately to the combatant. The alternative, during the Gulf War and earlier, was for satellite data to stream to a facility in the United States, undergo analysis, and then make its way to the combatant. If GPS operated like other satellite services, a tank commander or platoon leader would put in a request for positional data. The request would be queued. Once acted upon, Washington would process and relay the GPS data to the combatant command headquarters. It would then work its way back to the combatant, who would know his position only a day or two after asking for it. This is how space-based imagery and signals intelligence are supplied. By providing an alternate experience of immediate access to data, from space, GPS suggested an intuitive model for thinking about how to integrate space into air and ground operations: useable data should flow from satellites directly to the combatant.

Naval operations already had incorporated space into combat planning, albeit in a less direct form. Just as GPS allowed a ship to determine its position accurately, signals intelligence and radar imagery from satellites provided the ability to locate and target enemy ships or task forces. This targeting was an outgrowth of the use of signals intelligence in the World Wars (the British and Germans began to use radio intercepts in the First World War to locate opposing warships). The lesson for air, ground, and naval operations is that spacepower may mean getting precise information to combatants more rapidly than an opponent provides military advantage.

The insights about informational advantage helped to drive much of the thinking about the future of conflict in the 1990s, and this new thinking was in turn an incentive for spacepower theory. The storyline is that the United States assembled fleets of satellites for strategic purposes and then found that they could be applied for operational advantage. The revolution in military affairs that grew out of the Gulf War showed that there had been a change in the nature of warfare brought about by the use of new technologies, in particular space technologies. This led to changes in doctrine and organization that fundamentally alter the character and conduct of military operations.

It is no exaggeration to say that the revolution would not have been possible without satellites. Satellite communications provided new levels of coordination and the ability to transfer massive (for the time) amounts of information rapidly to commanders. Imagery and signals intelligence provided an unparalleled amount of knowledge about terrain, enemy forces, and the effect of U.S. strikes. GPS enabled precision navigation (and in later conflicts, precision-guided weapons) and helped to remove a chief cause of uncertainty from combat: the uncertainty of the location of one's own forces. Before GPS, the bulk of radio traffic in most battles revolved around the question, "Where are you?"

Uncertainty is the opposite of information superiority. Space assets provided tools and data that reduce uncertainty and allow strategists to operationalize John Boyd's ideas on how to use the decisionmaking cycle to attain superiority in combat. Space assets, in combination with new information technologies, were also an essential underpinning for jointness. Better communications, better locational data, and better intelligence increased the ability of the combatant commanders established by Goldwater-Nichols to meld the contributions of the disparate Services into a much more unified force than had been possible in previous conflicts.

The Pursuit of Coherence

Although the Gulf War showed that the United States had the most powerful conventional military in the world, the 1990s were a period of strategic confusion. The grand strategy that had guided national security since 1947 was no longer needed, but it was unclear what, if anything, should take its place, and both Republican and Democratic administrations undertook major efforts in the 1990s to define the new threats to U.S. security and formulate the appropriate response.

The effect of this strategic confusion on space programs was mixed. The United States had over 100 military or defense-related satellites in operation—roughly twice as many as all the military satellites operated by all other nations put together. These satellites provided communications, navigation, weather prediction, and intelligence and surveillance capabilities.Some programs, such as those that monitored the globe for nuclear detonations or for missile launches, remained important as nonproliferation became a new focus for strategy. Other programs seemed less relevant or were challenged by technological changes in communications, which damaged the ability to collect from space. The result was a deemphasis on spending for new space systems. The 1990s were, in many ways, a period of transition in military thinking but of stasis in space acquisitions.

The satellite network designed for use against the Soviet Union in a global war had given the United States a measurable advantage in a conflict against a heavily armed regional competitor, but the security problems these satellite networks were designed to address mapped imperfectly to the Nation's security problems once the Cold War was over. Both requirements and targets had changed. In both past and current configurations, the United States needed to sustain a global presence, but the rationale for that presence has changed significantly.

Telecommunications provides an example of a crucial change in commercial technologies that affected an important part of the national technical collection system. The adoption of fiber optic cable as the backbone of telecommunications networks in the 1990s ended the ability to collect telecom signals from space. Fiber optics carry the bulk of traffic and use pulses of light to transmit data. Satellites cannot collect against these networks. Radio transmissions could still be collected from space, but over the course of the decade, a very expensive U.S. investment lost some of its value.

The ad hoc space architecture that emerged during the Cold War depended on a small number of large systems. This architecture is more vulnerable than an alternative that depended on a larger number of smaller (and less expensive) systems, particularly if the use of the smaller satellites did not entail a degradation of capability. At the start of the military space competition between the United States and the Soviets, both sides developed antisatellite weapons, particularly after the Soviets threatened to deliver nuclear weapons from orbiting platforms. Despite these programs, there was an understanding that neither side would interfere with the other's satellites, an understanding made possible in the context of the larger strategic contest by the need for transparency to increase superpower stability.

This rationale no longer holds. During the Cold War, a peer competitor facing a strategic nuclear exchange would want to avoid misunderstanding. New competitors do not face the same constraints. Additionally, the Persian Gulf War demonstrated the value of space assets for U.S. military performance and the dependence of the Nation on its satellite fleet. Relatively cheap attacks against U.S. satellites could have a much greater payoff in reducing U.S. military effectiveness, particularly if the opponent did not have its own fleet and did not rely on space for its military capabilities—the lack of strategic parity meant that there was no mutual exchange of hostages in space.

In the 1990s, the only potential opponent who could consider an antisatellite effort was China. The Russians had the capabilities, but relations with the United States at that time made it unlikely that their programs would be a threat. China, on the other hand, began to explore the idea of attacks on U.S. space systems as early as the mid-1990s. There was a period of debate over whether China truly had antisatellite programs and whether these systems needed to be taken seriously—a debate largely ended by the unannounced Chinese satellite test of 2007—but even before this debate concluded, the United States realized that its space assets were targets. Space has never been a sanctuary—the first programs for antisatellite weapons appeared in 1959—but in the bipolar strategic environment, it had been remarkably safe. This safety has now disappeared.

One of the key developments of the 1990s was the emergence of post–Cold War competition in space. The competition, unlike the contest with the Soviets, was asymmetric; no one tried to match the United States satellite for satellite. However, many nations had seen the advantages space conferred on the United States in the Gulf War and have considered how to interfere with it; a handful tried to gain similar benefits from different (and smaller) space architectures.[9] One crucial difference was that these nations did not need to depend on dedicated military platforms. The emergence of a commercial space market in communications and remote imaging allowed nations to augment their military capabilities by buying commercial services. Commercial remote sensing and interpretive software provide a low-budget image intelligence capability accessible to most nations. These commercial systems do not yet provide a level of service equal to U.S. national technical means, but they offer non-spacefaring nations an immense expansion of capability for some military or intelligence tasks.

The 1990s also saw an accelerated integration of commercial space services into military operations. One reason for this was the decline in defense spending after the end of the Cold War. The United States could no longer sustain the satellite industrial base created during the Cold War at the lower levels of defense spending. This meant that some satellite manufacturers looked to take the skills and technologies they had developed for the military and commercialize them. It also meant that the military and intelligence communities would not be receiving the same flow of satellites into their inventories; this either encouraged or forced them to buy from commercial service providers.

Early debates in Congress and the executive branch in the 1960s led to the establishment of an independent military satellite communications system. This independent capability would meet national security needs, while the emerging commercial communications satellite industry would provide less sensitive services. In the mid-1970s, Congress directed DOD to increase its use of leased commercial satellite services, providing a precedent for thinking in the 1990s about commercial remote sensing.

In remote sensing, NRO encouraged some of its suppliers to undertake commercial operations. The cornerstone of the new approach, with its blending of commercial and national security activities, was the 1994 Presidential Decision Directive 23 (PDD 23). This directive was an effort by the Intelligence Community, the Defense Department, and the Department of State in 1991 to come to grips with the effect of the Persian Gulf War on demand for remote sensing and the end of Cold War expenditures for government satellite systems. The Gulf War excited foreign demand for space remote sensing capabilities at the same time that U.S. Government demand for remote sensing satellites was declining drastically. Congressional pressure to manage imagery requirements better and to support industry also shaped PDD 23 (the Land Remote Sensing Policy Act of 1992, for example, supported the development of private systems and authorized the Commerce Department to license private sector parties to operate private remote sensing space systems).

PDD 23 also provided a brief link between nonproliferation and national security space. One goal of the policy was to discourage other nations from "proliferating" dangerous remote sensing capabilities. The first Clinton administration attempted to develop a multilateral regime to control remote sensing capabilities along the lines of the Missile Technology Control Regime.Unsurprisingly, this effort was a failure; no nation was willing to deny itself the potential for access to space remote sensing. The 1990s were thus also the decade when the United States would have to consider in its military planning the effect of ubiquitous commercial space services available to all of its potential opponents.

PDD 23, reinforced by the 1996 National Space Policy (PDD 49), did have greater success, after a rough start, in encouraging the launch of U.S. commercial remote sensing service providers.While satellites operated by NRO were more capable than those of the commercial service providers, they were not omnipresent, and the services provided by commercial operators could provide expanded coverage, fill crucial gaps in collection, and be more easily shared with allies.

Several factors shaped security space efforts in the 1990s. The first was the reconceptualization of military operations that began after the Persian Gulf War. In connection with the experience of the Gulf War, the explosive growth of information technologies and networks provided new capabilities for the information provided by space assets and a net-centric way of thinking about how to organize and use those assets.The decline of the defense market and the diffusion of advanced technology into the commercial sector led to the creation of a robust commercial space presence that created, in communications and (at the end of the decade) in remote sensing, both opportunities and challenges for national security. Finally, reorienting the massive technical collection systems away from a single, static superpower opponent to a new range of problems involving smaller, informal targets initially created serious problems for intelligence operations in space. The reorganization of U.S. imagery analytical capabilities into the National Imagery and Mapping Agency (a merger of CIA and DOD assets) and the development of close relations between NGA and NSA helped to overcome this problem by taking advantage of the new tools for analysis and blending imagery with data from other national technical collection means. This combination of commercial and government data increased the value of imagery for military purposes.

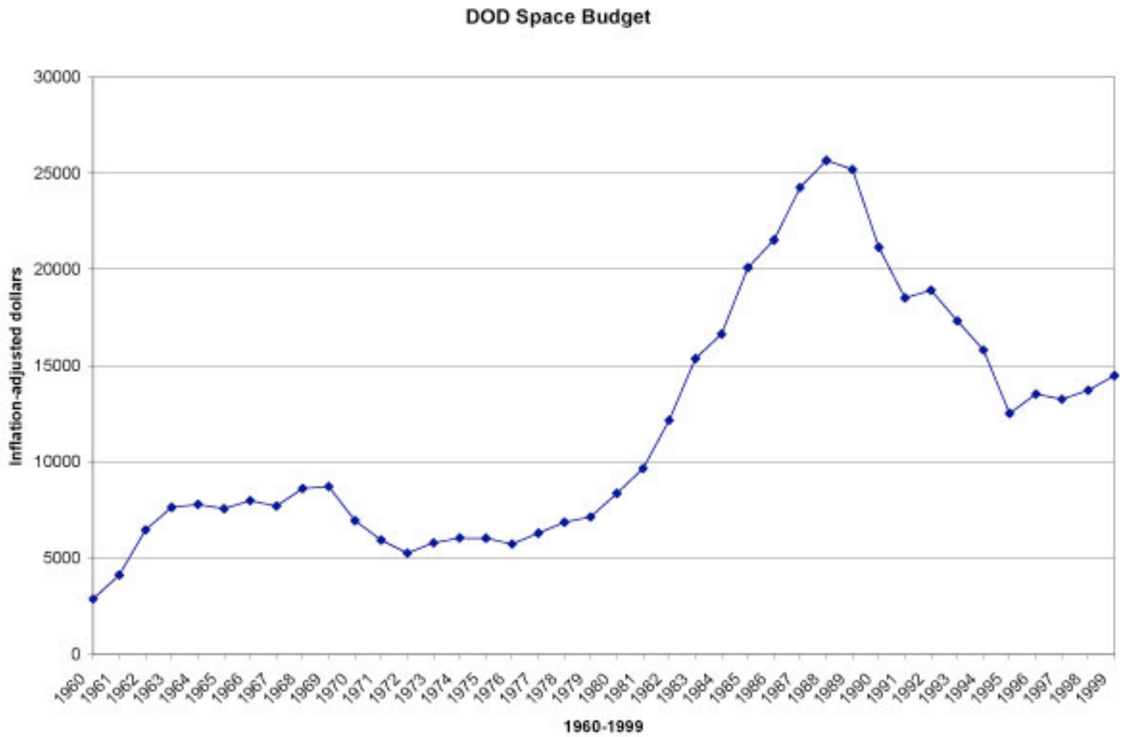
In communications, DOD would have been happier if it had its own communications satellites. However, the rapidly growing demand for data and communications engendered by the new style of warfare that began in the Persian Gulf, combined with smaller budgets, meant that DOD had no choice but to turn to commercial providers. Operations in Kosovo are reputed to have required 4 times as much communications capability as the first Persian Gulf War, and the Iraq war is reputed to require 10 times as much bandwidth. The combatant command's demand for data put immense strains on military communications and expanded the use of commercial communications satellites to support DOD.DOD purchases of satellite communications services were of considerable benefit to operators of commercial communications satellites and, in turn, gave DOD the data and communications capabilities it needed and also some flexibility in contracting for global communications services.

Another aspect of the new competition and the widespread awareness of U.S. capabilities in space was the routine adoption of countermeasures by a range of opponents. Adversary awareness was not new; the Soviets knew from the first that U.S. satellites were spying on them.The Internet provided even poor and unsophisticated opponents knowledge of when U.S. satellites would be overhead, since enthusiast Web sites provide tracking data for most satellites.Potential U.S. opponents informally shared information on countermeasures. The open discussion in the United States of satellite assets and, at times, of the classified results garnered by those assets encouraged these countermeasures. During Operation *Allied Force* in 1999, the Serbs successfully used a mixture of concealment, mobility, and deception to confound U.S. technical collection. Their success has encouraged others to explore ways to counter U.S. informational advantages. Jamming, spoofing, and kinetic attack will be part of any future conflict.

The Gulf War showed that more timely, precise satellite data are the key to greater effectiveness. This revelation led to requirements and plans in the 1990s to acquire more capable military communications satellites and new kinds of sensors, including a replacement for the venerable Defense Support Program satellites. However, in the absence of the incentives for spending and innovation provided by having a competitor, U.S. space programs entered a period of decline in the 1990s.

In part, this is explained by the decline in the U.S. investment in national security space. Spending on DOD space programs declined significantly, and while figures for intelligence programs remain classified, we can assume they followed a similar trend. If the 1990s was the decade when strategists, learning from the first space war in the Persian Gulf, began to reshape doctrine and tactics to give space a central role in military power, budget figures did not reflect this. The bulk of military space spending increases occurred in the 1960s and again in the 1980s, with the high point occurring in 1988 (see figure 14–1).[10] Spending fell drastically at the end of the Cold War, bottomed in 1995, and then remained flat until the end of the century. Overall, the United States spent 12 percent less on space in the 1990s than it did in the 1980s. This produced a $20 billion shortfall that, when combined with changes in the acquisitions process, slowed the increase in U.S. military space capabilities.[11]

Figure 14–1. DOD Space Budget, 1960–1999



Changes in acquisitions regulations to tighten control over program costs slowed the ability to introduce new systems. Additionally, changes in how NRO acquired satellites, "rigid requirements" negotiated among many agencies for new systems, and an increase in congressional oversight (since the 1980s, programs had been vetted by Intelligence Committee staffs) slowed innovation. This situation could be described as the triumph of accountants over engineers.Defenders of greater oversight for space acquisitions could say that the United States tried to do too much too fast in space in the 1990s; that its programs came too close to the edge of technical feasibility; and that there had not been enough consideration of the kinds of platforms needed or the alternatives to expensive space investments. Yet acceptance of risk, and of failure, is a crucial part of innovation. Could the United States ever again have a Corona program, with its 13 consecutive failures?[12]

Conclusion

The starting point for this history is a 1945 Army Air Force Report to the Secretary of War. The end point is the 2000 Report of the Commission to Assess United States National Security Space Management and Organization. Although separated by 55 years, both reports reached the same conclusion: that U.S. national security depended on a robust presence in space.Security operations in space, however, are not the same as spacepower.

Current discussions of spacepower come at a difficult moment for American strategic thinking. The United States is in a complex transition to adjust its policies, forces, and strategies to fit a new international security environment. This environment is not one of unalloyed peace that many had hoped for at the end of the Cold War, but a dangerous environment of uncooperative allies and asymmetric threats. Disappointment with the conflict in Iraq and disenchantment with muscular foreign policies have helped to reenergize interest in what some call *soft power*, which uses the tools of persuasion to advance national interests. Space programs are an element of soft power; they provide prestige and technological prowess that can be turned into influence and leadership on the international stage. When NASA manages to launch a shuttle, the world is reminded of America's technological prowess.

Soft power has serious limitations. It is inadequate to constrain a hostile and determined opponent. Realists might say that soft power can only be effective when it is backed by more traditional elements of power: a coherent strategy, a robust economy, a strong military, and efficient diplomatic and intelligence services—in other words, hard power. Spacepower is also a component of hard power. The information and services provided from space are a force multiplier, making for better informed strategies and more effective combatants.

In many other ways, space's unique contribution to U.S. national power is decreasing.The U.S. comparative advantage is shrinking. Commercial satellite services are readily available to anyone, anywhere, with a little money. The Mumbai terrorists used GPS and commercial imagery to plan their attacks, for example.The diffusion of technologies gives many nations an ability to build and operate satellites. More than 80 nations plan to acquire or build remote sensing satellites. Miniaturization of microelectronics, sensors, and satellites provides low-cost alternatives to U.S. behemoths. The sense that the United States spends more but gets less in civil space undercuts the history of achievements in the 1970s. Only in one area—the integrated use of national security space—does the Nation retain a comparative advantage so great that it can be termed asymmetric, an unequal lead against any potential opponent.

The basis of this predominance is the more than 100 U.S. satellites in orbit for remote collection of images and signals, communications, and navigation. The presence in space is matched by an extensive and experienced ground component to process, analyze, and disseminate information from space assets. It is reinforced by the U.S. lead in conceptualizing how best to use space assets and services for military advantage. The Cold War constellation of satellites proved invaluable in the recent wars with Iraq and the Taliban, and the U.S. lead in national security space is a core element for deterring potential opponents from challenging the United States in a conventional military conflict. Satellite services and the use of space are a critical component of U.S. national security.

The current U.S. military space system, while superior to any in the world, faces new demands and new missions for which it was not designed. For much of the preceding five decades, the space mission was targeted toward a single opponent whose threat came from large military and strategic forces. The current space mission is different; the Nation faces a range of opponents who are more diffuse, have lower profiles, and use different technologies. The requirement for timely, continuous information on these new opponents puts increasing stress on the national security space system. Problems of cost, technological limitations, and disorganization, which have been present since the 1950s, increase this tension.

Changes in the military use of space also challenge the assets and architectures built up over 50 years. Military planning, operations, and tactics have been transformed by the use of information, sensors, space assets, and information technologies. Future missions will place intensive requirements on space-based sensors and other sensor platforms to provide persistent, real-time surveillance, intelligence, and reconnaissance over areas of interest regardless of weather conditions. Providing information superiority at the tactical level may require accelerating flows of information from sensor to weapon to provide for "instantaneous attack" over widely dispersed and separate areas. Afghanistan and Iraq show the potential benefits to be gained from the tactical exploitation of national space capabilities, but they also show the need to accelerate the use of new technologies and architectures and speed integration of information and systems into military operations.

The differences between hard and soft power are suggestive for the concept of spacepower and for reviewing military and intelligence activities in space. Spacepower remains an ambiguous concept. This ambiguity, as yet unresolved, has complicated and shaped efforts since the 1950s to develop strategic concepts for military and intelligence operations in space.Space forces, as they are now, cannot destroy an opposing force, nor are they the instrument of victory in battle. If we agree with Clausewitz that "fighting is the central military act," can spacepower be anything but soft power and a support function for national security if it does not provide for the direct application of force? The history of military and intelligence activities in space, although well known and easily summarized, does not provide a clear answer to this question.

Notes

1. The 1982 National Security Decision Directive 42 on National Space Policy designated the shuttle as the primary launch vehicle for national security payloads and instructed the Department of Defense to discontinue the use of expendable launch vehicles once the shuttle could meet all of its needs.
2. Report of the Commission to Assess United States National Security Space Management and Organization, January 2001, 10.
3. "Call for Test Pilots," *Time*, April 13, 1959, available at <www.time.com/time/magazine/article/0,9171,810946,00.html>.
4. Directive 5160.32, "Development of Space Systems," March 28, 1961. The directive gave the Air Force authority for development, acquisition, and launch of military space systems.
5. Letter, Richard M. Bissell, Jr., to Allen Dulles, August 8, 1961, available at <www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB54/st13.pdf>.
6. See <www.eisenhower.archives.gov/dl/NASA/Binder19.pdf>.
7. See chapter 10, "The Revolution in Military Affairs and Joint Vision 2010," in the Annual Report to the President and Congress, Department of Defense, 1999 at <www.defenselink.mil/execsec/adr1999/>. There is an extensive literature discussing Boyd's

theories, which appeared in his "Discourse on Winning and Losing," an unpublished set of lectures delivered at the U.S. Air Force Air University. A partial bibliography of works on Boyd can be found at <www.au.af.mil/au/aul/school/ots/boyd.htm>.

8. Admiral Wesley McDonald, CINCLANT for the Grenada operation, said afterward: "We have designed and are continuing to design systems which collect intelligence in great volume and in near real time, but I am concerned as to whether we are designing into these systems the communications capability to get that data to the tactical commander in a useable fashion and timely manner. . . . What good is sophisticated satellite imagery sitting in Washington, DC, or Norfolk, Virginia, when the field commander who needs it is on the ground in Grenada, on a ship?" Quoted in Stephen E. Anno and William E. Einspahr, "Command and Control and Communications Lessons Learned: Iranian Rescue, Falklands Conflict, Grenada Invasion, Libya Raid," Air War College Research Report, Number AU–AWC–88–043, 36–63.
9. Commission to Assess the Ballistic Missile Threat to the United States, 1998:

   A number of nations are incorporating technical features of the RMA [revolution in military affairs] into their forces. These include space-based surveillance, reconnaissance and communications by way of both space and land-based fiber-optic networks (perhaps using civilian assets), guidance from the space-based global positioning system/global navigation satellite system (GPS/GLONASS) to increase the accuracy of missiles and the computational capabilities needed to plan, organize, and conduct operations.

10. Spending as a percentage of gross domestic product correlates closely with the dollar figures.
11. NASA, "Aeronautics and Space Report of the President, Fiscal Year 2004 Activities," appendix D–1B, "Space Activities of the U.S. Government," 120.
12. The National Commission for the Review of the National Reconnaissance Office, 2000; Dennis Fitzgerald, "Commentary on 'The Decline of the National Reconnaissance Office': NRO Leadership Replies," *Studies in Intelligence* 46, no. 2, available at <https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol46no2/article12.html>.

Chapter 15:

Theory Ascendant?
Spacepower and the Challenge of Strategic Theory

John B. Sheldon and Colin S. Gray

Some time ago, one of us asked, "Where is the theory of spacepower? Where is the Mahan for the final frontier?"[1] Over 10 years later, such an exhortation still has resonance as the realm of spacepower still lacks a "space focused strategic theory" and a "binding concept" that can "aid understanding of what it is all about."[2] This chapter seeks to provide an explanation, or at least plausible reasons, as to why such a theory of space-power has yet to transpire. First, we shall discuss the difficulties involved in creating a theory of spacepower that is able to endure the test of time and that has universal applicability. The chapter then examines recent attempts at theorizing on spacepower by James Oberg, Everett Dolman, and John Klein. Lastly, the chapter outlines what a theory of spacepower should look like, and just as importantly, what it should not look like, as a guide for future theorists.

It should be noted that an exhortation of an "Alfred Thayer Mahan for the final frontier" is not to be confused with an endorsement of a Mahanian style of theory. Such a style of strategic theory may yet suffice (for the present, at least) for the purposes of guidance for spacepower, but we do encourage all plausible methods of elucidating a theory of space-power, be it directly influenced by the thought and style of either Mahan or of any other strategic theorist. Instead, the call for a Mahan for space-power is in fact a call for a theory that can match the *stature* of Mahan's collected thoughts on seapower.

This chapter uses the word *strategy* in an unashamedly Clausewitzian sense, and for clarity of meaning we offer up a definition of strategy as well as spacepower. *Strategy* is defined here as the use that is made of force and the threat of force for the ends of policy.[3] This definition is preferred because it takes into account the instrumental character of strategy that uses a variety of means as well as its ubiquitous applicability in both peace and war. This definition is distinctly military in scope, but we do not dismiss the notion of spacepower serving diplomatic, economic, and cultural aspects of a state's wider grand strategy. B.H. Liddell Hart defined *grand strategy* as the process and ability "to co-ordinate and direct all the resources of a nation, or band of nations, towards the attainment of the political object of the war."[4] Most satellite systems are dual-use; military systems such as the U.S. global positioning system (GPS) navigation satellites have myriad civil and commercial applications, and commercial systems, such as high-resolution imaging satellites, have myriad military applications. *Spacepower* is defined here as "the ability in peace, crisis, and war to exert prompt and sustained influence in or from space."[5] This influence can be exerted by commercial, civil, or military satellites as appropriate, though it should be noted that a theory of spacepower should have little to say about the purely commercial and civil exploitation of space, just as air- and seapower theories have little to say about the purely commercial and civil exploitation of the sea and air. A theory of spacepower should not try to overreach its mandate and be all things to all agendas. Instead, a theory of spacepower is about the ability to exert prompt and sustained influence in or from space for the purposes and furtherance of *policy* in peace and war.

Impediments to a Theory of Spacepower

Why spacepower theory has yet to produce a notable theorist is the subject of speculation on numerous plausible and seemingly implausible factors. There is much to impede the creation and development of a sound theory for spacepower. Some of these impediments are unintentional and random incidents, phenomena and events that are the stuff of everyday defense planning and strategic decisionmaking. Other impediments are more insidious, the product of institutional prejudices and failings, or flaws in military and strategic culture. Spacepower theorists must try to remove themselves from these day-to-day impediments and institutional and cultural prejudices and failings in order to produce theory that is enduring and universally applicable.

Among the many impediments to the creation and development of spacepower theory, the following seem most pertinent for the purposes of our discussion.

Limited Spacepower History

At present, spacepower cannot draw upon any informative historical experience that can provide valuable lessons, as compared to the experience of land, air-, or seapower. Even the nuclear realm can draw upon historical experience, albeit a mercifully brief and limited one. Some might plausibly argue that spacepower has plenty of historical experience to draw upon from the Cold War and from military operations since Operation *Desert Storm* in 1991. The problem with the Cold War is that it was a unique moment in the history of international politics. Spacepower is a child of the Cold War but has also survived its erstwhile parent, which imposed a unique political context that dictated how spacepower was used. As the international system shifts from a unipolar to an eventual multipolar complexion, the political context in which spacepower operates shall also change and will likely resemble, in broad terms, previous multipolar experiences. This is not to say that the Cold War holds no lessons whatsoever for spacepower, but it does mean that it cannot be our sole data point.

Similarly, the exploitation of spacepower in the several wars of choice since the end of the Cold War from *Desert Storm* through to the present war on terror can be illustrative only to the extent that the largely unchallenged use of spacepower ever can be. In its numerous wars of choice since the early 1990s, the United States and its allies have become increasingly reliant upon spacepower for the threat and application of military force, yet real and potential adversaries have been relatively slow to counteract the strategic leverage derived from U.S. spacepower. This initially tardy response from those who have the most to fear from overwhelming U.S. military dominance, derived in large part from spacepower, is beginning to take greater urgency as more polities exploit space for their own security objectives as well as develop and obtain their own counterspace capabilities.[6]

Of course, it might be argued that adversaries of the United States and its allies have countered the overwhelming advantages that are derived from spacepower by fighting in a manner that renders space-derived combat power irrelevant, such as terrorism and other asymmetric tactics. This argument is plausible to a point but is rendered moot when one discovers that even these adversaries are the beneficiaries of spacepower in their own unique ways. For example, al Qaeda is known to have used satellite telephones for tactical command and control, and Hizballah uses its own satellite television station, Al-Manar TV, to disseminate its virulent propaganda. These examples aside, as the offense-defense competition of fielded space capability versus counterspace capability is liable to continue, so the theorist is likely to glean meaningful lessons as the U.S. and allied reliance upon spacepower is increasingly challenged.

Among the calls for a theory of spacepower, it is often forgotten that the use and practice of spacepower is quite young in comparison to land, air-, and seapower. Land power has been in existence for thousands of years and yet it was not until the 16th century that a concerted effort at theorymaking truly began,[7] and it was not until the 19th century that we saw the greatest exponents of land power, and strategic theory in general, in Jomini and Clausewitz.[8] The naval and maritime theories of Mahan, Julian Corbett, Raoul Castex, and Charles Edward Callwell only appeared after sea and maritime power had been practiced for several thousand years.[9] It is only with the arrival of airpower in the early 20th century that we have seen attempts to theorize about its exploitation in parallel with its continuing evolution. It cannot be denied, however, that airpower theory is the subject of considerable debate and even controversy. For some, the body of work created by the likes of Giulio Douhet, William Mitchell, J.C. Slessor, and John Warden[10] is far from conclusive, and in many cases should perhaps be regarded more as vision than as theory. As David MacIsaac points out, "Air power . . . has nonetheless yet to find a clearly defined or unchallenged place in the history of military or strategic theory. There has been no lack of theorists, but they have had only limited influence in a field where the effects of technology and the deeds of practitioners have from the beginning played greater roles than have ideas."[11] Harold R. Winton is even more explicit on this point when he writes that "there simply does not exist any body of codified, systematic thought that can purport to be called a comprehensive theory of air power."[12] Winton goes on to assert that one of the reasons why this is so is because airpower has a very thin historical base upon which to draw for the purposes of creating a comprehensive and universal theory.[13]

Attempts to craft a plausible theory of spacepower at this early juncture in spacepower history are indeed unique in the history of military thought, especially if the aim is (as it indeed should be) to develop a theory that avoids the worst excesses of airpower theory. We are far from convinced that it is too early in the history of spacepower to begin crafting a theory that can guide its action and relate it to all other forms of military and national power, but such a possibility cannot be entirely discounted.

Confusion over Definitions

This chapter is emphatic in what it means by *spacepower*, *strategy*, and a *theory of spacepower*. Unfortunately, many misunderstand, misconstrue, or are ignorant of such terms. Much of this confusion is innocent enough in intent but has and continues to cause much damage to the quest for a theory of spacepower. For example, at a symposium associated with the project resulting in this book, several delegates seemed to think that a theory of spacepower was essentially a theory for the unilateral domination of space by the United States. Such an interpretation is mistaken, though it should be noted that a plausible theory of spacepower should be able to lend itself to imperialist space ambitions *as well as* efforts to create a multilateral regime in space. For what purposes spacepower is used is entirely up to the policymakers of the day. All that a theory of spacepower should do is assist the policymaker in achieving those purposes, regardless of what they are. Nor is spacepower alone in this matter. Airpower too has had problems in pinning down a consensus on key and fundamental definitions.[14]

The exploitation and capabilities of spacepower in the United States and other states are, and have been, highly classified, thus preventing many would-be theorists from accessing any lessons learned from previous applications of spacepower and publicly promulgating any theory based on such access. There are many good reasons to keep certain aspects of spacepower classified, especially as it relates to intelligence gathering and the technical details of satellite capabilities, yet there is also a culture of secrecy that has evolved over the decades that has kept not only adversaries, but for a long while much of the U.S. military and government, in the dark about U.S. space capability. The classification of spacepower is not a uniquely American phenomenon, as the space powers of Russia, China, Israel, and several European countries attest, but the dissemination of space capabilities to developing countries may see, from a theorist's perspective, greater transparency in how spacepower is used as space increasingly becomes an arena for greater and more intense competition.

Tales of Derring-do

Over the decades, civil space programs, such as the first Soviet and U.S. manned space missions, the Apollo moon landings, and the International Space Station, have helped divert public and media attention away from military and intelligence space programs. In the United States, a high-profile civil space program, in the form of the National Aeronautics and Space Administration (NASA), was set up deliberately to distract attention from the overhead reconnaissance satellite capability as well as other military space programs in order to lend credence to the principle of peaceful uses of outer space in the longstanding U.S. national space policy. This is not to argue that the U.S. civil space program does not have any intrinsic value beyond that of providing useful political cover for more sensitive programs, but rather to point out that the focus on the scientific and civil aspects of spacepower has done little to encourage the development of a theory of spacepower.

Portrayal of Space in Popular Culture

The influence of popular science fiction programs and films, such as *Star Trek* and *Star Wars*, has helped generate a public perception and expectation of space that are far removed from reality. Among the media, science fiction has had a deleterious effect, creating a view of it as a place of grandiose yet broken dreams, little green men, and alien abductions. As a result, space, and therefore spacepower, is not taken as seriously as it should be.

Complexity

A theory of spacepower has to explain and translate action in space into strategic effect on Earth, and *vice versa*. It must take into account not only spacepower itself, but also the effect and influence of land, air-, and seapower, nuclear and information operations, as well as special operations upon each other and upon spacepower. A theory of spacepower also has to consider the roles and influence of science, technology, politics, law, diplomacy, society, and economics, among others. It is a daunting subject.[15]

Policy Distractions

Debates on nuclear deterrence and stability theory, ballistic missile defense, revolutions in military affairs, and, more recently, global insurgencies have all impeded the quest for a theory of spacepower. Elements of information-enabled warfare, such as precision strike and persistent battlespace surveillance, are all, to varying degrees, enabled by space systems. At present, spacepower is often thought about in these terms, yet there is a danger that a theory for spacepower is conflated with information-led warfare when, in fact, spacepower has the potential to be much more than an enabler. Space systems play a vital role in maintaining nuclear postures, any proposed missile defense system, and information-enabled operations. More recently, spacepower has been playing a critical but quiet role in the war on terror. Yet spacepower is not just the maintenance of nuclear postures, missile defense, precision strike, or supporting counterinsurgencies; it is all of these things and more.[16]

Perils of Linear Thinking

To say that spacepower is dependent on science, engineering, and technology risks insulting even the most theoretically challenged person. However, such a dependency may encourage spacepower practitioners and commanders to think of spacepower in a mechanistic and linear fashion. A theory of spacepower, or at least one worthy of the name, should respect the nonlinear, interactive, and paradoxical nature of strategy and its dimensions, which defy mechanistic analysis or mathematical equation.[17]

Technological Determinism

Similarly, because spacepower is so obviously dependent upon technology for strategic performance, there is a danger that theory is either blinded or sidelined by a culture that is technocentric. A theory of space-power simply cannot afford to ignore the role of technology, but it would not be a theory at all if this were the sole focus at the expense of the other dimensions of strategy.[18]

Understanding Orbitology

On a related issue, perhaps because spacepower *is* so dependent on science, engineering, and technology, strategic theorists (who normally have an educational background in the social sciences or history) have tended to avoid it. Any individual attempting to contribute to a theory of spacepower must have, at the very least, a working knowledge of orbitology and other principles of spaceflight.

Out of Sight, Out of Mind

Lastly, in many ways spacepower is discrete (even allowing for classification issues) and does not attract much attention in the way that armies, navies, and air forces do. Apart from the awesome sights and sounds of a space launch, one does not *see* spacepower. One does, however, *feel* spacepower, as its presence in the battlespace is ubiquitous. Indeed, spacepower can be likened to intelligence operations: one only hears of it when something goes wrong.

Small Steps: Building on Previous Spacepower Theory

Despite the importance the Department of Defense attaches to a theory of spacepower, there have been surprisingly few works on the subject within the body of spacepower literature that exists. The reasons for this may be ascribed to some of the impediments listed above, but perhaps the biggest reason is that developing and creating strategic theory, much like its practice, are very difficult to do. As Clausewitz pointed out, "Everything in war is very simple, but the simplest thing is difficult."[19] David Lonsdale is even more blunt: "Strategy is difficult; very difficult."[20] Discerning enduring and universal theory from scant (and often contradictory where it exists) evidence is "very difficult," despite the fact that many will not argue with the relatively simple proposition that a theory of spacepower is needed. Yet a number of thinkers have risen to the challenge in recent years and have attempted to fill the theoretical void. Among these are James Oberg (*Space Power Theory*), Everett Dolman (*Astropolitik*), and John Klein (*Space Warfare*).[21] Each deserves credit for placing himself above the parapet, and each in his own way has made unique contributions to the nascent body of theory. Can any of these authors lay claim to the mantle of being the Mahan of the space age? Alas, the answer must be a reluctant "no." Each has furthered our understanding of spacepower considerably, but none has offered a comprehensive theory of spacepower.

James Oberg

Oberg provides us with a comprehensive account of spacepower's role in everyday activities on Earth[22] but falls short in his effort to outline its nature, though his distillation of spacepower into Mahanian elements is a useful starting point for any analysis.[23] Oberg's writing is excellent for a description, in laymen's terms, of the physical workings and constraints of spacepower.[24] Oberg is also to be thanked for many of his axioms—or "Truths and Beliefs"[25]—that attempt to distill something enduring about spacepower. These axioms include the following:

- "The primary attribute of current space systems lies in their extensive view of the Earth."[26] Spacepower is able to provide global coverage with relatively few assets.
- "A corollary to this attribute is that a space vehicle is in sight of vast areas of Earth's surface."[27] Spacepower can be vulnerable due to a lack of natural cover in space, though sheer distance can afford some protection.
- "Space exists as a distinct medium."[28] At the tactical and operational levels of war, space is most certainly a distinct medium, though it should be noted that there is nothing about space that places it beyond strategy. The nature of spacepower is the use, or threatened use, of space systems for political purposes.
- "Space power, alone, is insufficient to control the outcome of terrestrial conflict or ensure the attainment of terrestrial political objectives."[29] The same is true of air- and seapower. The seat of political power for all polities resides on the land, where people live. Control of such power can only be ultimately won or lost by controlling land. Spacepower, along with air- and seapower, can help leverage—even critically—land power to achieve victory on land, but can never do so by itself. An exception to this may come about should human beings colonize other celestial bodies, such as the Moon or Mars. In that event, one might see spacepower take the lead role in delivering sovereign effects, with other forms of military power (especially land and airpower delivered by a preponderant spacepower) providing support.
- "Space power has developed, for the most part, without human presence in space, making it unique among other forms of national power."[30] Space-power is unique in that, for the time being at least, it is the only form of military power that generates strategic effect through robotic proxies. Whether this situation will change in the future with manned platforms performing the spacepower mission remains to be seen, and will be subject to myriad factors. However, the trend in the air and sea environments among the assorted militaries of the industrialized world is toward unmanned platforms.
- "Technological competence is required to become a space power, and conversely, technological benefits are derived from being a space power."[31] As space technologies disseminate throughout the world at a rapid pace, Oberg reminds us that true spacepower is that which can be organically sustained rather than purchased on the open market. It may prove critical to be able to develop, manufacture, launch, and operate one's own space-power without having to rely upon a third party for technological expertise. Technological competence in this area undoubtedly will have strategic benefits as well as economic ones.
- "As with the earth-bound media [land, sea, and air], the weaponization of space is inevitable, though the manner and timing are not at all predictable."[32] Because spacepower is not beyond strategy, so it is not beyond the fate that has befallen every other environment that humankind has exploited. We may debate the desirability of space weaponization as a policy option in the near and mid-term,

and, indeed, what that may or may not look like, but weaponization in one form or another will happen.

- "Situational awareness in space is a key to successful application of space power."[33] Space situational awareness at present is sketchy at best, and yet it is required in order to carry out many of the simplest and most mundane spacepower functions, as well as to be able to distinguish between natural hazards and intentional threats or interference.
- "Control of space is the linchpin upon which a nation's space power depends."[34] In fact, Oberg does not reach far enough here. Because terrestrially based armed forces have become so space-dependent, the control of space will become critically important for a nation's land, air-, and seapower, not just spacepower.

Oberg's *Space Power Theory* should be viewed as an initial foray into theory-making. It does not meet our Mahanian criteria in that it lacks a comprehensiveness that links spacepower to national power in a manner that elucidates the nature of spacepower, and perhaps overly focuses on the technological dimension at the expense of others. Given that Oberg courageously stepped into the breach at the last minute of a troubled project sponsored by the then–Unified U.S. Space Command, *Space Power Theory* has aged not too badly, and provides sturdy shoulders upon which others may climb.

Everett Dolman

Everett Dolman's *Astropolitik* has been the most controversial book to appear on spacepower in recent years and yet, in many respects, is perhaps the most rigorous intellectually. Dolman posits spacepower within a classical geopolitical model based on the works of geopolitical theorists such as Mahan, Halford Mackinder, and Nicholas Spykman, among others.[35] His analysis finds that certain points in space may prove strategically advantageous to those powers that would control them. These points include low Earth orbit (LEO), geostationary orbit, Hohmann orbital transfers, and the Libration points L4 and L5 between the Earth and the Moon.[36] Others, such as Dandridge Cole and Simon "Pete" Worden,[37] have made similar arguments in the past, but not with the intellectual power that Dolman has mustered.

Dolman's signal contribution to the field is his outstanding explanation of the geographical and geopolitical relationships between space-power and land, air-, and seapower. The assertion made by Dolman that the United States should seize LEO (unilaterally if necessary) in order to preserve a liberal global order is questionable in intent and implausible,[38] although a U.S.-led alliance might feasibly have a more legitimate claim to controlling LEO for more attainable and realistic goals. Similarly, Dolman may yet be proven right in his claim that the current outer space legal regime has stifled healthy competition in space that may have brought about more robust military and civil space capabilities, although blaming the failure of the space age to materialize solely on the space regime can come across as reductionism.[39]

Dolman has done the field a great service with *Astropolitik*. He fearlessly questions spacepower's sacred cows and throws down an intellectual gauntlet in the process. This said, Dolman's work cannot lay claim to be a comprehensive theory of spacepower, as its argument only resonates in the United States and lacks the universalism that marks all great works of strategic theory. Furthermore, *Astropolitik*'s durability may arise from its controversial assertions rather than from any overt attempt by Dolman to speak to the ages. Many of the policy concerns rightly raised by Dolman are unlikely to be of any broad interest to an audience seeking strategic guidance in the future.

John Klein

In Klein's *Space Warfare*, we see the first comprehensive attempt to apply a strategic analogy to spacepower. Klein takes Sir Julian Corbett's *Some Principles of Maritime Strategy* and applies it to spacepower, with mixed success. Corbett advocated a maritime approach to strategy that emphasized the interaction between land and seapower. Klein takes this a step further and advocates a spacepower version of maritime strategy that emphasizes the strategic interaction of spacepower with land, air-, and seapower.[40] The application, in broad terms, of Corbettian concepts of limited liability in war and the temporary nature of control to spacepower is useful, but when Klein seeks to apply the same framework to concepts such as offense, defense, concentration, and dispersal, the real limitations of the Corbettian strategic analogy are revealed.

The term *strategic analogy* is new, yet its theoretical roots can be found in the scholarship on historical analogies in statecraft and policymaking. An analogy "signifies an inference that if two or more things agree in one respect, then they might also agree in another."[41] Based on this definition, among others, a definition for the strategic analogy can be extrapolated. If two or more strategic environments separated, among other things, by time (though this is not a necessary criterion; strategic analogies may be used contemporaneously), geographical characteristics, doctrine, technology, culture, and political context agree in one respect, then they may also agree in another. Scholars, policymakers, military planners, and commanders use strategic analogies to provide a rational means for the comprehension and planning of novel strategic environments by retrieving information, principles, and past experiences from other, more established strategic environments and applying them to the new, unfamiliar strategic environment. In short, strategic analogies may provide a "shortcut to rationality"[42] in new and poorly understood strategic environments where there is little or no known strategic experience or established principles for effective operations. Strategic analogies are similar to historical analogies, except that the former use the strategic experiences and theories of other environments—such as the sea and the air—rather than the specific and particular historical events used in the latter. A strategic analogy may state that nascent spacepower is similar to seapower in several key respects, and then may infer that because of this it must be similar in other respects. A strategic analogy uses the body of theory and principles that has developed over the years, as well as the strategic history of the environment (land, sea, air) in question.

Klein's *Space Warfare* is an exercise in making strategic analogies and as a result reveals the limitations of this process. To be fair, Klein does state that "space is a unique environment, and any historically based strategic framework—whether naval, air, or maritime—cannot realistically be taken verbatim in its application to space strategy. Only the most fundamental concepts of maritime strategy, therefore, will and should be used to derive the strategic principles of space warfare."[43] Yet despite this acknowledgment, Klein at times seems to make the reality fit the theory, or at the very least, let the theory gloss over awkward facts. For example, Klein overreaches in his discussion of spacepower dispersal and concentration, where it is far from clear whether he is speaking about the dispersal and concentration of actual satellites (impossible, given the constraints of orbital dynamics) or the dispersal and concentration of effects generated by space-power (which is plausible).[44]

The use of strategic analogies is a necessary step on the road to creating and developing an enduring and universal theory of spacepower. Problems arise, however, when we become overreliant on strategic analogies at the expense of critical thinking. Strategic analogies should be nothing more than a cognitive crutch that allows us to ask the right questions of spacepower. We shall make progress in theorymaking when we kick away these crutches and engage our critical faculties to start the process of inductive reasoning.

Guide for the Future

The authors discussed above have all made valuable contributions to a theory of spacepower. Even their mistakes and omissions are useful, as they allow those of us who follow to climb on their shoulders and adjust the theoretical framework accordingly. We are forced to address and correct their mistakes and omissions, and future theorists will have to rectify ours. Truly, a Mahan for the space age may yet appear, but in lieu of such a person, it is perhaps prudent to assume that the continued development of a theory of spacepower will be a team effort that will build on the labors of others that have gone before. It may seem churlish to critique these works, but criticism is made with gratitude to those who have intellectually dared, and the theory of spacepower ultimately will be best served by constantly striving through honest debate.

With these sentiments in mind, we offer our own thoughts on a theory of spacepower for others to ruminate upon, critique, and, ultimately and hopefully, improve in their own turn. Many of the thoughts offered here have been asserted before by us but are worth repeating for their strategic value.

Space is a Place

The idea that space can redeem human sin still persists in many quarters. The reason for this persistence is as much about the perception of space as a place, and what that place purports to represent, as it is about the technologies required for its manned and unmanned exploration and use. This particular way of framing space can be described as *astrofuturism*, which "posits the space frontier as a site of renewal, a place where we can resolve the domestic and global battles that have paralyzed our progress on earth."[45] We believe that space as a place is no different from the land, sea, and air, and we reject the astrofuturist credo as a fallacy. Human beings and their robotic proxies operate and (in the case of the land) live every day in these environments, carrying out myriad functions from the spiritual and artistic to the martial (and these are by no means mutually exclusive).

Our entry into space must respect the human condition in its entirety, good and bad, and attempts to redeem human nature through the wonders of technology or hopes that the infinite expanse of space will offer the opportunity to unite humankind where our existence on Earth has failed are bound to disappoint. It is tragic but true that "short of a revolution in the heart of man and the nature of states, by what miracle could interplanetary space be preserved from military use?"[46]

Strategy, Eternal and Universal

In the quest for a theory of spacepower, it is perhaps wise to first state categorically what such a theory should *not* be. In particular, a theory of spacepower should not be at odds with the universal and eternal logic of strategy. Instead, it should be a theory of its use in the service of strategy. Edward N. Luttwak points out that to postulate such a thing as "nuclear strategy," "naval strategy," or, in this case, "space strategy" is to argue that each of these kinds of strategy is somehow fundamentally different from the strategy that governs them all. Luttwak writes, "If there were such a thing as naval strategy or air strategy or nuclear strategy in any sense other than a conflation of the technical, tactical, or operational levels of the same universal strategy, then each should have its own peculiar logic."[47] A theory of spacepower should not claim such a "peculiar logic," and the foundations for this theory should be cognizant and respectful of a superior and overarching logic of strategy.

Sir Julian Corbett wrote of the purpose of theory in strategy:

> It is a process by which we co-ordinate our ideas, define the meaning of the words we use, grasp the difference between essential and unessential factors, and fix and expose the fundamental data on which every one is agreed. In this way we prepare the apparatus of practical discussion; we secure the means of arranging the factors in manageable shape, and of deducing from them with precision and rapidity a practical course of action. Without such an apparatus no two men can even think on the same line; much less can they ever hope to detach the real point of difference that divides them and isolate it for quiet solution.[48]

Given the relative infancy of spacepower, it is important that sensible theoretical foundations be established. Spacepower has made itself ubiquitous in modern war and statecraft, yet discerning a strategic experience of spacepower has proved to be notoriously difficult. Over time, strategic experience will doubtless accumulate, and so eventually a comprehensive theory of spacepower will develop and evolve synergistically with its actual practice. Although spacepower is relatively new, the need for theory is not. As Corbett's thoughts suggest, a theory of spacepower should provide a common framework from which all can refer and a conceptual means by which spacepower is exploited to its full potential in order to attain policy objectives.

Pragmatism

That said, a theory of spacepower must guard against a creeping inflexibility and orthodoxy that stifle innovative thinking or constructive criticism. It will evolve along with its actual use, and it may be found that some tenets of spacepower thought are in fact wrong. A theory of space-power must also guard against flights of fancy and overactive imaginations that make theory useless as a guide to practice. Spacepower could be especially susceptible to such problems given that it is, conceptually, a blank canvas and is bound up for many people with science fiction. Spacepower is not science fiction, and its intellectual guardians, the theorists, much like the protagonists in the "widening gyre" of W.B. Yeats's "The Second Coming" who are either "lacking all conviction" or are "full of passionate intensity,"[49] must take care to protect it from the ignorance of some and the worst excesses of others. Theorists of spacepower, and practitioners who would read such theory, must always be mindful of the fact that strategy "is nothing if not pragmatic," and that "strategic theory is a theory for action."[50] A theory of spacepower that is disrespectful of the practicalities of spaceflight and orbitology, the limits of technology, and the eternal, universal workings of strategy could be worse than useless; it could be dangerous.

The Nature of Spacepower

To repeat, spacepower is not beyond the logic of strategy, nor can it be. Strategy is eternal in its nature and logic, and while the grammar and character of strategy evolve because of changes in their many dimensions such as society, politics, and technology, strategy's fundamental nature does not. Spacepower is subject to the nature of strategy and always will be. The nature of spacepower is simply the ability to use space for political purposes, and that too will never change. John G. Fox is only partially correct when he states, "The nature and character of space warfare 50 years from now may be wholly unrecognizable to those of us alive today."[51] Fox is probably correct in that the *character* of spacepower will change over the next 50 years, due perhaps to unforeseen technological developments. He is wrong, however, to state that the *nature* of spacepower is changeable; it is not. So long as humankind possesses the ability to exploit the space environment, then the nature of spacepower is immutable and impervious to societal, political, economic, technological, or any other kind of change.

Conclusion

This chapter has sought to elucidate the very real problems of creating and developing a theory of spacepower. The impediments are varied and tangible, but many of them apply equally to theorymaking for other military instruments. The crux of the matter is that strategy is difficult and so, therefore, is creating and developing a theory of spacepower. A true theory of spacepower will be able to account for its role in modern war and statecraft, as well as how it interacts with other instruments of power, and this chapter has sought to provide the would-be theorist with food for thought.

Notes

1. Colin S. Gray, "The Influence of Space Power upon History," *Comparative Strategy* 15, no. 4 (October–December 1996), 307.
2. Ibid., 304.
3. Colin S. Gray, *Modern Strategy* (Oxford: Oxford University Press, 1999), 17.
4. B.H. Liddell Hart, *Strategy*, 2^{d} rev. ed. (New York: Signet, 1974), 322.
5. Colin S. Gray and John B. Sheldon, "Spacepower and the Revolution in Military Affairs: A Glass Half-Full?" in *Spacepower for a New Millennium: Space and U.S. National Security*, ed. Peter L. Hays, James M. Smith, Alan R. Van Tassel, and Guy M. Walsh (New York: McGraw-Hill, 2000), 254.
6. A growing number of countries are realizing the benefits and challenges of spacepower. Among them are the People's Republic of China, India, Brazil, South Korea, Israel, France, Germany, Italy, Nigeria, and Iran. See the special issue of *Astropolitics* 4, no. 2 (Summer 2006), for essays on the implications of rising spacepowers.
7. With the exception of Sun Tzu, Thucydides, and Vegetius, of course. On the evolution of military theory in the modern period, see Azar Gat, *A History of Military Thought: From the Enlightenment to the Cold War* (Oxford: Oxford University Press, 2001).
8. See Baron Antoine Henri de Jomini, *The Art of War* (London: Greenhill Books, 1992); and Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1984).
9. See, among his other works, Alfred Thayer Mahan, *The Influence of Sea Power Upon History, 1660–1783* (Boston: Little, Brown, 1890); Julian S. Corbett, *Some Principles of Maritime Strategy*, introduction and notes by Eric J. Grove (Annapolis, MD: Naval Institute Press, 1988); C.E. Callwell, *Military Operations and Maritime Preponderance*, ed. and introduced by Colin S. Gray (Annapolis, MD: Naval Institute Press, 1996); and Raoul Castex, *Strategic Theories*, trans., ed., and introduced by Eugenia C. Kiesling (Annapolis, MD: Naval Institute Press, 1993).
10. See Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari (Washington, DC: Air Force History and Museums Program, 1998); William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power, Economic and Military* (Mineola, NY: Dover Publications, 1988); Wing Commander J.C. Slessor, RAF, *Air Power and Armies* (London: Oxford University Press, 1936); and Colonel John A. Warden III, USAF, *The Air Campaign: Planning for Combat* (Washington, DC: Brassey's, 1989).
11. David MacIsaac, "Voices from the Central Blue: The Air Power Theorists," in *Makers of Modern Strategy: From Machiavelli to the Nuclear Age*, ed. Peter Paret (Princeton: Princeton University Press, 1986), 624.
12. Harold R. Winton, "A Black Hole in the Wild Blue Yonder: The Need for a Comprehensive Theory of Air Power," *Air Power History* 39, no. 4 (Winter 1992), 32.
13. Ibid., 32–33.
14. MacIsaac, 625.
15. Gray, *Modern Strategy*, 205. See also David Jablonsky, "Why Is Strategy Difficult," in *The Search for Strategy: Politics and Strategic Vision*, ed. Gary L. Guertner (Westport, CT: Greenwood Press, 1993), 3–45; and David J. Lonsdale, "Strategy: The Challenge of Complexity," *Defence Studies* 7, no. 1 (March 2007), 42–64.
16. A point also made in Gray and Sheldon, "Spacepower and the Revolution in Military Affairs: A Glass Half Full?" 239–257.
17. See, for example, Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security* 17, no. 3 (Winter 1992/1993), 59–90.
18. See Colin S. Gray, *Weapons for Strategic Effect: How Important Is Technology?* Occasional Paper No. 21 (Maxwell Air Force Base, AL: Center for Strategy and Technology, Air War College, January 2001) for an exposition on the limits of technology.
19. Clausewitz, *On War*, 119.
20. Lonsdale, 42.

21. James Oberg, *Space Power Theory* (Washington, DC: U.S. Government Printing Office, 1999); Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London: Frank Cass, 2002); and John J. Klein, *Space Warfare: Strategy, Principles, and Policy* (New York: Routledge, 2006).
22. Oberg, 1–22.
23. Ibid., 43–66.
24. Ibid., 67–86, but also the very useful appendices.
25. Ibid., 124.
26. Ibid.
27. Ibid.
28. Ibid., 126.
29. Ibid., 127.
30. Ibid.
31. Ibid., 128.
32. Ibid., 129.
33. Ibid., 130.
34. Ibid.
35. See, in particular, Dolman, 12–59.
36. Ibid., especially 60–85.
37. See G. Harry Stine, *Confrontation in Space* (Englewood Cliffs, NJ: Prentice-Hall, 1981), for a discussion of Dandridge Cole's "Panama Canal" spacepower theory, and Simon P. Worden and Bruce J. Jackson, "Space, Power, and Strategy," *The National Interest*, no. 13 (Fall 1988), 43–52, for a similar "High Ground" view.
38. Dolman, 86–112.
39. Ibid., 113–144.
40. Klein, 44–50.
41. David Hackett Fischer, *Historian's Fallacies: Toward a Logic of Historical Thought* (New York: Harper and Row, 1970), 243.
42. Robert Jervis, *Perception and Misperception in International Politics* (Princeton: Princeton University Press, 1976), 220.
43. Klein, 20.
44. Ibid., 107–115.
45. De Witt Douglas Kilgore, *Astrofuturism: Science, Race and Visions of Utopia in Space* (Philadelphia: University of Pennsylvania Press, 2003), 2.
46. Raymond Aron, *Peace and War: A Theory of International Relations*, trans. Richard Howard and Annette Baker Fox (London: Weidenfeld and Nicolson, 1966), 664.
47. Edward N. Luttwak, *Strategy: The Logic of War and Peace* (Cambridge: The Belknap Press of Harvard University Press, 1995), 156.
48. Corbett, 7.
49. With our sincerest apologies to the Bard of Sligo, see W.B. Yeats, "The Second Coming," in *The Collected Poems of W.B. Yeats* (New York: The Macmillan Company, 1952), 184–185.
50. Bernard Brodie, *War and Politics* (New York: The Macmillan Company, 1973), 452.
51. John G. Fox, "Some Principles of Space Strategy (or 'Corbett in Orbit')," *Space Policy* 17, no. 1 (February 2001), 7–11.

Chapter 16:
Airpower, Spacepower, and Cyberpower

Benjamin S. Lambeth

When American airpower played such a central role in driving Iraq's occupying forces from Kuwait in early 1991, many doubters of its seemingly demonstrated capacity to shape the course and outcome of a major showdown independently of ground action tended to dismiss that remarkable performance as a one-of-a-kind force employment anomaly. It was, the doubters said, the clear and open desert environment, or the unusual vulnerability of Iraq's concentrated armored formations to precision air attacks, or any number of other unique geographic and operational circumstances that somehow made the Persian Gulf War an exception to the general rule that it takes "boots on the ground" in large numbers, and ultimately in head-to-head combat, to defeat well-endowed enemy forces in high-intensity warfare.

To many, that line of argument had a reasonable ring of plausibility when airpower's almost singular contribution to the defeat of Saddam Hussein's forces was an unprecedented historical achievement. During the 12 years that ensued in the wake of Operation *Desert Storm*, however, the world again saw American airpower prevail in broadly comparable fashion in four dissimilar subsequent cases, starting with the North Atlantic Treaty Organization's two air-centric contests over the Balkans in Operations *Deliberate Force* in 1995 and *Allied Force* in 1999 and followed soon thereafter by Operation *Enduring Freedom* against terrorist elements in Afghanistan in 2001–2002 and by the 3-week period of major combat in Operation *Iraqi Freedom* that ended Saddam Hussein's rule in 2003. Granted, in none of those five instances did the air weapon produce the ultimate outcome all by itself. However, one can fairly argue that in each case, successful aerial combat and support operations were the pivotal enablers of all else that followed in producing the sought-after results at a relatively low cost in friendly and noncombatant enemy lives lost.

In light of those collective achievements, what was demonstrated by American air assets between 1991 and 2003 was arguably *not* a succession of anomalies, but rather the bow wave of a fundamentally new American approach to force employment in which the air weapon consistently turned in a radically improved level of performance compared to what it had previously delivered to joint force commanders. Indeed, that newly emergent pattern has now become so pronounced and persistent as to suggest that American airpower has finally reached the brink of maturity and become the tool of first resort by combatant commanders, at least with respect to defeating large enemy force concentrations in high-intensity warfare. Yet in each of the five instances noted above, what figured so importantly in determining the course and outcome of events was not just *airpower* narrowly defined, but rather operations conducted in, through, and from the Earth's atmosphere backstopped and enabled, in some cases decisively, by the Nation's diverse additional assets in space and by operations conducted within cyberspace (that is, the electromagnetic spectrum).

Accordingly, any effort to understand the evolving essence of American *airpower* must take into account not only our aerial warfare assets, but also those vitally important space and cyberspace adjuncts that, taken together, have made possible the new American way of war. By the same token, any successful effort to build a theoretical framework for better charting the future direction and use of American air, space, and cyberspace warfare capability must first take due measure of the Nation's current state of advancement in each domain. Toward that end, the discussion that follows will offer a brief overview of where the United States stands today in each of the three operating mediums. It will then consider some pertinent lessons from the airpower experience that bear on the development of spacepower and cyberpower theory, along with the sorts of cross-domain synergies that should be pursued in the many areas where the air, space, and cyberspace arenas overlap. Finally, it will consider some essential steps that will need to be taken toward that end before a holistic theory of warfare in all three domains, let alone any separate and distinct theory of spacepower, can realistically be developed.

Recent Achievements in Airpower Application

By any measure, the role of airpower in shaping the course and outcome of the 1991 Persian Gulf War reflected a major breakthrough in the effectiveness of the Nation's air arm after a promising start in World War II and more than 3 years of misuse in the Rolling Thunder bombing campaign against North Vietnam from 1965 to 1968. At bottom, the *Desert Storm* experience confirmed that since Vietnam, American airpower had undergone a nonlinear growth in its ability to contribute to the outcome of joint campaigns at the operational and strategic levels thanks to a convergence of low observability to enemy sensors in the F–117 stealth attack aircraft, the ability to attack fixed targets consistently with high accuracy from relatively safe standoff distances using precision-guided munitions, and the expanded battlespace awareness that had been made possible by recent developments in command, control, communications, and computers, and intelligence, surveillance, and reconnaissance (ISR).[1]

As a result of those developments, American airpower had finally acquired the capabilities needed to fulfill the longstanding promise of its pioneers of being able to set the conditions for winning in joint warfare— yet *not* through the classic imposition of brute force, as had been the case throughout most of airpower's history, but rather through the *functional* effects that were now achievable by targeting an enemy's vulnerabilities and taking away his capacity for organized action. The combination of real-time surveillance and precision target–attack capability that was exercised to such telling effect by airpower against Iraq's fielded ground forces in particular heralded a new relationship between air- and surface-delivered firepower, in which friendly ground forces did the fixing and friendly airpower, now the predominant maneuver element, did the killing of enemy troops rather than the other way around.

During the years immediately after the 1991 Gulf War, further qualitative improvements rendered the Nation's air weapon even more capable than it had been. For one thing, almost every American combat aircraft now possessed the ability to deliver precision-guided weapons. For another, the advent of stealth, as was first demonstrated on a significant scale by the F–117 during the Gulf War, was further advanced by the subsequent deployment of the Air Force's second-generation B–2 stealth bomber that entered operational service in 1993. Finally, the advent of the satellite-aided GBU–31 Joint Direct Attack Munition (JDAM) gave joint force commanders the ability to conduct accurate target attacks with near impunity, around the clock and in any weather, against an opponent's core concentrations of power, whether they be deployed forces or infrastructure assets.

In the three subsequent major wars that saw American combat involvement (Operations *Allied Force*, *Enduring Freedom*, and the major combat phase of *Iraqi Freedom*), the dominant features of allied air operations were persistence of pressure on the enemy and rapidity of execution, thanks to the improved data fusion that had been enabled by linking the inputs of various air- and space-based sensor platforms around the clock. Greater communications connectivity and substantially increased available bandwidth enabled constant surveillance of enemy activity and contributed significantly to shortening the sensor-to-shooter data cycle time. Throughout each campaign, persistent ISR and growing use of precision munitions gave the United States the ability to deny the enemy a sanctuary. More important, they also reflected an ongoing paradigm shift in American combat style that now promises to be of greater moment than was the introduction of the tank at the beginning of the 20th century.[2]

Unlike the earlier joint campaigns that preceded it since *Desert Storm*, the second Gulf War involving the United States in 2003 was not mainly an air war, even though offensive air operations played a pivotal role in setting the conditions for its highly successful immediate outcome. Neither, however, was the campaign predominantly a *ground* combat affair, despite the fact that nearly all subsequent assessments of it have tended to misrepresent it in such a manner. That misrepresentation largely resulted from host-nation sensitivities that precluded correspondents from being embedded with forward-deployed allied flying units, and especially in the coalition's Combined Air Operations Center at Prince Sultan Air Base, Saudi Arabia, from which most of the air war was commanded and conducted. As a result, most of the journalists who provided first-hand reporting on the campaign were attached to allied ground formations.

Yet the ground offensive could not have been conducted with such speed and relatively small loss of friendly life (only 108 American military personnel lost to direct enemy action) without the indispensable contribution of the air component in establishing air supremacy over Iraq and then beating down enemy ground forces until they lost both the capacity and the will to continue fighting. By the same token, the rapid allied ground advance could not have progressed from Kuwait to Baghdad in just 3 weeks without the air component giving ground commanders the confidence that their exposed flanks were free of enemy threats on either side, thanks to the success of allied air attacks in keeping the enemy pinned down, exposed to relentless hammering from above, and unable to fight as a coherent entity. That omnipresent ISR eye over the war zone gave allied ground commanders not just the proverbial ability to "see over the next hill," but also a high-fidelity picture of the entire Iraqi battlespace.

In its execution of the major combat phase of *Iraqi Freedom*, U.S. Central Command (USCENTCOM) enjoyed air and information dominance essentially from the campaign's opening moments. Moreover, during the ensuing 3 weeks of joint and combined combat, allied air operations featured the application of mass precision as a matter of course. In the initial attack waves, every air-delivered weapon was precision-guided. Even well into the war's first week, 80 percent of USCENTCOM's air-delivered munitions had been either satellite-aided or laser-guided. In addition, the 3-week campaign featured a more closely linked joint and combined force than ever before. Persistent ISR coupled with a precision strike capability by all participating combat aircraft allowed the air component to deliver discriminant effects throughout the battlespace, essentially on demand. In contributing to the campaign, allied airpower did not just "support" allied land operations by "softening up" enemy forces. More often than not, it conducted wholesale destruction of Iraqi ground forces both prior to and independently of allied ground action. The intended net effect of allied air operations, which was ultimately achieved, was to facilitate the quickest possible capture of Baghdad without the occurrence of any major head-to-head land battles between allied and Iraqi ground forces.

As attested by its consistently effective performance from *Desert Storm* onward, American airpower has been steadily transformed since Vietnam to a point where it has finally become truly strategic in its potential effects. That was not the case before the advent of stealth, highly accurate target attack capability, and substantially improved information availability. Earlier air offensives were of limited effectiveness at the operational and strategic levels because it took too many aircraft and too high a loss rate to achieve too few results. Today, in contrast, American airpower can make its presence felt quickly and from the outset of combat and can impose effects on an enemy that can have a determining influence on the subsequent course and outcome of a joint campaign.

To begin with, thanks to the newly acquired capabilities of American airpower, there is no longer a need to mass force as there was even in the recent past. Today, improved battlespace awareness, heightened aircraft survivability, and increased weapons accuracy have made possible the *effects* of massing without an air component actually having to do so. As a result, airpower can now produce effects in major combat that were previously unattainable. The only question remaining, unlike in earlier eras, is *when* those effects will be registered, not *whether* they will be.

Of course, all force elements—land and maritime as well as air—have increasingly gained the opportunity in principle, at the theater commander's discretion, to achieve such effects by making the most of new technologies and concepts of operations.What is distinctive about contemporary fixed-wing airpower in all Services, however, is that it has pulled ahead of surface force elements in both the land and maritime arenas in its *relative* capacity to do this, thanks not only to its lately acquired advantages of stealth, precision, and information dominance, but also to its abiding characteristics of speed, range, and flexibility. Current and emerging air employment options now offer theater commanders the possibility of neutralizing an enemy's military forces from standoff ranges with virtual impunity, thus reducing the threat to U.S. troops who might otherwise have to engage undegraded enemy forces directly and risk sustaining high casualties as a result. They also offer the potential for achieving strategic effects from the earliest moments of a joint campaign through their ability to attack an enemy's core vulnerabilities with both shock and simultaneity.

In sum, a variety of distinctive features of American airpower have converged over the past two decades to make the Nation's air arm fairly describable as transformed in comparison to what it could offer joint force commanders throughout most of its previous history. Those distinctive features include such tangible and intangible equities as:

- intercontinental-range bombers and fighters with persistence
- a tanker force that can sustain global strike
- a sustainable global mobility capability
- surgeable carrier strike groups able to operate as a massed force[3]
- an increasingly digitized and interlinked force
- unsurpassed ISR and a common operating picture for all
- air operations centers as weapons systems in themselves
- operator competence and skill second to none.

These airpower equities have, in turn, enabled the following unique operational qualities and performance capabilities:

- freedom *from* attack and freedom *to* attack
- situation awareness dominance
- independence from shore basing for many theater strike requirements
- unobserved target approach and attack through stealth
- consistently accurate target attack day or night and in any weather
- the ability to maintain constant pressure on an enemy, perform
- time-sensitive targeting routinely, and avoid causing collateral damage routinely.

As borne out by their pivotal contributions to the Nation's five major combat experiences over the preceding decade and a half, these and related developments have made possible a new way of war for the United States, at least with respect to high-intensity operations against organized and concentrated enemy forces in land and maritime theaters. As has become increasingly clear since the successful conclusion of the 3-week major combat phase of *Iraqi Freedom* in April 2003, however, mastering the sorts of lower intensity counterinsurgency challenges that have dominated more recent headlines with regard to continuing combat operations in Iraq and Afghanistan remains another matter, and one that highlights modern airpower's limitations as well as strengths. Although today's instruments of air warfare have thoroughly transformed the Nation's ability to excel in conventional warfare, those instruments and their associated concepts of operations have not yet shown comparable potential in irregular warfare, since irregular opponents, given their composition and tactics, are less vulnerable to airpower as currently configured and employed. (On the other side of the coin, it should be noted in this regard that the recent rise of irregular warfare by the Nation's opponents has been substantially a result of airpower's proven effectiveness in conventional warfare, a fact that attests to modern airpower's unprecedented leverage at the same time that it illuminates the continuing challenges that airpower faces.)

Space Contributions and Near-term Priorities

Thus far in this discussion, the space medium and its associated mission areas have not been examined in any detail. Yet both have figured prominently and indispensably in the steady maturation of American air-power that has occurred since Vietnam. If there is a single fundamental and distinctive advantage that mature American airpower has conferred upon theater commanders in recent years, it has been an increasingly pronounced degree of freedom *from* attack and freedom *to* attack for all force elements, both in the air and on the ground, in major combat operations. The contributions of the Nation's space systems with respect to both ISR and precision attack have figured prominently in making those two force-employment virtues possible. Although still in its adolescence compared to our more mature air warfare posture, the Nation's ever-improving space capability has nonetheless become the enabler that has made possible the new strategy of precision engagement.

Despite that and other contributions from the multitude of military assets now on orbit, however, the Nation's air warfare repertoire still has a way to go before its post-Vietnam maturation can be considered complete. Advances in space-based capabilities on the ISR front will lie at the heart of the full and final transformation of American airpower. It is now almost a cliché to say that airpower can kill essentially anything it can see, identify, and engage. To note one of the few persistent and unrectified shortfalls in airpower's leverage, however, it can kill *only* what it can see, identify, and engage. Airpower and actionable real-time target intelligence are thus opposite sides of the same coin. If the latter is unavailing in circumstances in which having it is essential for mission success, the former will likely be unavailing also. For that reason, accurate, timely, and comprehensive information about an enemy and his military assets is not only a crucial enabler for airpower to produce pivotal results in joint warfare, it also is an indispensable precondition for ensuring such results. In this regard, it will be in substantial measure through near-term improvements in space-based capabilities that the Air Force's long-sought ability to find, fix, track, target, engage, and assess any target of interest on the face of the Earth will become an established reality rather than merely a catchy vision statement with great promise.[4]

The spectrum of military space missions starts with *space support*, which essentially entails the launching of satellites and the day-to-day management of on-orbit assets that underpin all military space operations. It next includes *force enhancement*, a broader category of operations involving all space-based activities aimed at increasing the effectiveness of terrestrial military operations. This second mission area embraces the range of space-related enabling services that the Nation's various on-orbit assets now provide to U.S. joint force commanders worldwide. Activities in this second area include missile attack warning and characterization, navigation, weather forecasting, communication, ISR, and around-the-clock global positioning system (GPS) operations. A particularly notable aspect of space force enhancement in recent years has been the growing use of space-based systems for directly enabling, rather than merely enhancing, terrestrial military operations, as attested by the increasing reliance by all four Services on GPS signals for accurate, all-weather delivery of satellite-aided JDAMs.

To date, the American defense establishment has largely limited its space operations to these two rather basic and purely enabling mission areas. Once the third mission area, *space control*, develops into a routine operational practice, it will involve the direct imposition of kinetic and nonkinetic effects both within and through space. Conceptually, space control is analogous to the familiar notions of sea and air control, both of which likewise involve ensuring friendly access and denying enemy access to those mediums. Viewed purely from a tactical and technical perspective, there is no difference in principle between defensive and offensive space control operations and similar operations conducted in any other medium of warfare. It is simply a matter of desirability, technical feasibility, and cost-effectiveness for the payoff being sought.

Unlike the related cases of sea and air control, however, serious investment in space control has been slow to take place in the United States, in part due to a persistent lack of governmental and public consensus as to whether actual combat, as opposed to merely passive surveillance and other terrestrial enabling functions, should be allowed to migrate into space and thus violate its presumed status as a weapons-free sanctuary. The delay also has had to do with the fact that the United States has not, at least until recently, faced direct threats to its on-orbit assets that have needed to be met by determined investment in active space control measures, all the more so in light of more immediate and pressing research and development and systems procurement priorities. For both reasons, the space control mission area remains almost completely undeveloped. About all the United States can do today to deny enemy access to the data stream from space is through electronic jamming or by physically destroying satellite uplinks and downlinks on the ground.

Finally, the *force application* mission, which thus far remains completely undeveloped due to both widespread international disapprobation and a general absence of political and popular domestic support, will eventually entail the direct defensive and offensive imposition of kinetic and nonkinetic measures from space in pursuit of joint terrestrial combat objectives. In its ultimate hardware manifestations, it could include the development, deployment, and use of space-based nonnuclear, hyperkinetic weapons against such terrestrial aim points as fixed high-value targets (hardened bunkers, munitions storage depots, underground command posts, and other heavily defended objectives), as well as against surface naval vessels, armored vehicles, and such other targets of interest as enemy leadership. How many years or decades into the future it may be before such capabilities are developed and fielded by the United States has been a topic of debate among military space professionals for many years. For the time being, it seems safe to conclude that any such developments will be heavily threat-determined and will not occur, if only from a cost-effectiveness viewpoint, as long as effective air-breathing or other terrestrial alternatives for performing the same missions are available.

Fortunately, as the Nation's defense community looks toward further developing these mission areas in an orderly sequence, it can claim the benefit of a substantial foundation on which to build. In February 2000, the Defense Science Board (DSB) concluded that the United States enjoyed undisputed space dominance, thanks in large part to what the Air Force had done in the space support and force enhancement mission areas over the preceding four decades to build a thriving military space infrastructure. Air Force contributions toward that end expressly cited by the DSB included a robust space launch and support infrastructure, an effective indications and warning and attack-assessment capability, a unique ground-based space surveillance capability, global near-real-time surveillance of denied areas, the ability to disseminate the products of that capability rapidly, and a strong command, control, and communications infrastructure for exploiting space systems.[5]

In looking to build on these existing capabilities with the goal of extracting greater leverage from the military promise of space, the Air Force now faces an urgent need to prioritize its investment alternatives in an orderly and manageable way. It cannot pursue every appealing investment opportunity concurrently, since some capability upgrade needs are more urgent than others. These appropriately rank-ordered priorities, moreover, must be embraced squarely and unsentimentally by the Nation's leadership. If the experience with the successful transformation of American *airpower* since Vietnam is ever to become a prologue to the next steps in the expansion of the Nation's military space repertoire, then it follows that the Air Force, as the lead service in space operations, will need to get its hierarchy of operational requirements in space right if near-Earth space is to be exploited for the greatest gains per cost in the service of theater commanders. Because an early working template for an overarching theory of spacepower might help impose a rational discipline on the determination of that hierarchy, perhaps the pursuit of such a focusing device should be undertaken as one of the first building blocks for such a theory.

Furthermore, a case can reasonably be made that the Nation's next moves with respect to military space exploitation should first seek to ensure the further integration of space with the needs of terrestrial warfighters, however much that might appear, at least for the near term, to shortchange the interests of those who are ready *now* to make space the fourth medium of warfare. More to the point, one can reasonably suggest that if the Nation's leadership deems a current space-based capability to be particularly important to the effective conduct of joint warfare and that it is either facing block obsolescence or otherwise at the threshold of failing, then it should be replaced as a first order of business before any other major space investment programs are pursued. Once those most pressing recapitalization needs are attended to, then all else by way of investment opportunities can be approached in appropriate sequence, including such space-based multispectral ISR assets as electro-optical, infrared, and signals intelligence satellites, followed by space-based radar once the requisite technology has proven itself ready for major resources to be committed to it.

Moreover, in considering an orderly transfer of such ISR functions from the atmosphere to space, planners should exercise special caution not to try to change too much too quickly. For example, such legacy air-breathing systems as the E–3 Airborne Warning and Control System (AWACS) and E–8 Joint Surveillance Target Attack Radar System (JSTARS), which have been acquired through billions of dollars of investment, cannot be summarily written off with substantial service life remaining, however well intended the various arguments for mission migration to space may be. Thus, it may make greater sense to think of space not as a venue within which to replace existing surveillance functions wholesale, but rather as a medium offering the potential for expanding the Nation's existing ISR capability by more fully exploiting both the air *and* space environments. It also may help to think in terms of windows of time in which to commence the migration of ISR missions to space. A challenge the Air Force faces now in this respect is to determine how to divest itself of existing legacy programs in a measured way so as to generate the funds needed for taking on tomorrow's challenges one manageable step at a time. That will require careful tradeoff assessments to determine the most appropriate technology and medium—air or space—toward which its resources should be vectored for any mission at any given time.

Finally, it will be essential that the survivability of any new ISR assets migrated to space be assured by appropriate protective measures that are developed and put into place first. American investment in appropriate first-generation space control measures has become increasingly essential in order for the Nation to remain secure in the space enabling game. Having been active in space operations for more than four decades, the United States is more heavily invested in space and more dependent on its on-orbit assets than ever before, and both real and potential adversaries are closing in on the ability to threaten our space-based assets by means ranging from harassment to neutralization to outright destruction, as attested by China's demonstration in January 2007 of a direct-ascent antisatellite kinetic kill capability against one of its own obsolete weather satellites 500 miles above the Earth's surface.[6] As the Nation places more satellites on orbit and comes to rely more on them for military applications, it is only a matter of time until our enemies become tempted to challenge our freedom of operations in space by attempting to undermine them.

In light of that fact, it would make no sense to migrate the JSTARS and AWACS functions to space should the resultant on-orbit assets prove to be any less survivable than JSTARS and AWACS are today. It follows that getting more serious about space control is not an issue apart from force-enhancement migration, but rather represents a sine qua non for such migration. Otherwise, in transferring our asymmetric technological advantages to space, we will also run the risk of burdening ourselves with new asymmetric vulnerabilities.

Exploiting the Cyberspace Arena

If the case for proceeding with timely initiatives to ensure the continued enabling functions of the Nation's space-based assets sounds reasonable enough in principle, then the argument for pursuing similar measures by way of vouchsafing our continued freedom of movement in cyberspace can be said to be downright compelling. The latter arena, far more than today's military space environment, is one in which the Nation faces clear and present threats that could be completely debilitating when it comes to conducting effective military operations. Not only that, opponents who would exploit opportunities in cyberspace with hostile intent have every possibility for adversely affecting the very livelihood of the Nation, since that arena has increasingly become not just the global connective tissue, but also the Nation's central nervous system and center of gravity.

Just a few generations ago, any American loss of unimpeded access to cyberspace would have been mainly an inconvenience. Today, however, given the Nation's ever-expanding dependence on that medium, the isolation, corruption, or elimination of electrical power supply, financial transactions,key communications links,and other essential Web-based functions could bring life as we know it to a halt. Furthermore, given the unprecedented reliance of the United States today on computers and the Internet, cyberspace has arguably become the Nation's center of gravity not just for military operations, but for *all* aspects of national activity, to include economic, financial, diplomatic, and other transactions. Our heightened vulnerability in this arena stems from the fact that we have moved beyond the era of physical information and financial exchanges through paper and hard currency and rely instead on the movement of digital representations of information and wealth. By one informed account, more than 90 percent of American business in all sectors, to say nothing of key institutions of governance and national defense, connects and conducts essential communications within the cyberspace arena.[7] Accordingly, that arena has become an American Achilles heel to a greater extent than any of our current opponents.

The term *cyberspace* derives from the Greek word *kubernetes*, or "steersman." Reduced to basics, it is the proverbial ether within and through which electromagnetic radiation is propagated in connection with the operation and control of mechanical and electronic transmission systems. Properly understood, cyberspace is not a "mission," but rather an operating domain just like the atmosphere and space, and it embraces all systems that incorporate software as a key element. It is a medium, moreover, in which information can be created and acted on at any time, anywhere, and by essentially anyone. It is qualitatively different from the land, sea, air, and space domains, yet it both overlaps and continuously operates within all four. It also is the only domain in which all instruments of national power (diplomatic, informational, military, and economic) can be concurrently exercised through the manipulation of data and gateways. Cyberspace can be thought of as a "digital commons" analogous to the more familiar maritime, aerial, and exoatmospheric commons. Moreover, just like the other three commons, it is one in which our continued uninhibited access can never be taken for granted as a natural and assured right. Yet uniquely among the other three, it is a domain in which the classic constraints of distance, space, time, and investment are reduced, in some cases dramatically, both for ourselves and for potential enemies.

There is nothing new in principle about cyberspace as a military operating domain. On the contrary, it has existed for as long as radio frequency emanations have been a routine part of military operations. As far back as the late 1970s, the commander in chief of the Soviet Navy, Admiral Sergei Gorshkov, declared famously that "the next war will be won by the country that is able to exploit the electromagnetic spectrum to the fullest."[8] Furthermore, the Soviets for decades expounded repeatedly, and with considerable sophistication and seriousness, on a mission area that they referred to as *REB* (for *radioelektronaya bor'ba*, or radio-electronic combat). However, only more recently has it been explicitly recognized as an operating arena on a par with the atmosphere and space and begun to be systematically explored as a medium of combat in and of itself.

At present, theorizing about airpower and its uses and limitations has the most deeply rooted tradition in the United States, with conceptualizing about military space occupying second place in that regard. In contrast, focused thinking about operations in cyberspace remains in its infancy. Yet cyberspace-related threats to American interests are currently at hand to a degree that potentially catastrophic air and space threats are not—at least yet. Accordingly, the U.S. defense establishment should have every incentive to get serious about this domain now, when new terrorist, fourth-generation warfare, and information operations challengers have increasingly moved to the forefront alongside traditional peer-adversary threats.[9]

In light of that emergent reality, it is essential to include cyberspace in any consideration of air and space capabilities. Like the air and space domains, cyberspace is part and parcel of the third dimension (the first two being the land and maritime environments). Also like those other two domains, it is a setting in which organized attacks on critical infrastructure and other targets of interest can be conducted from a distance, on a wide variety of "fronts," and on a global scale—except in this case, at the speed of light. Moreover, it is the principal domain in which the Nation's air services exercise their command, control, communications, and ISR capabilities that enable global mobility and rapid long-range strike.

In thinking about cyberspace as a military operating arena, a number of the medium's distinguishing characteristics are worth noting. First and foremost, control of cyberspace is a sine qua non for operating effectively in the other two domains. Were unimpeded access to the electromagnetic spectrum denied to us through hostile actions, satellite-aided munitions would become useless, command and control mechanisms would be disrupted, and the ensuing effects could be paralyzing. Accordingly, cyberspace has become an emergent theater of operations that will almost surely be contested in any future fight. Successful exploitation of this domain through network warfare operations can allow an opponent to dominate or hold at risk any or all of the global commons. For that reason, not only American superiority but also American dominance must be assured.

One reason for the imminent and broad-based nature of the cyberspace challenge is the low buy-in cost compared to the vastly more complex and expensive appurtenances of air and space warfare, along with the growing ability of present and prospective Lilliputian adversaries to generate what one expert called "catastrophic cascading effects" through asymmetric operations against the American Gulliver.[10] Because the price of entry is fairly minimal compared to the massive investments that would be required for any competitor to prevail in the air and space domains, the cyberspace warfare arena naturally favors the offense. It does so, moreover, not only for us, but also for any opponents who might use the medium for conducting organized attacks on critical nodes of the Nation's infrastructure. Such attacks can be conducted both instantaneously and from a safe haven anywhere in the world, with every possibility of achieving high impact and a low likelihood of attribution and, accordingly, of timely and effective U.S. retribution.

Indeed, America's vulnerabilities in cyberspace are open to the entire world and are accessible by anyone with the wherewithal and determination to exploit them. Without appropriate defensive firewalls and countermeasures in place, anything we might do to exploit cyberspace can be done to us as well, and relatively inexpensively. Worse yet, threat trends and possibilities in the cyberspace domain put in immediate jeopardy much, if not all, of what the Nation has accomplished in the other two domains in recent decades. Our continued prevalence in cyberspace can help ensure our prevalence in combat operations both within and beyond the atmosphere, which, in turn, will enable our prevalence in overall joint and combined battlespace. On the other side of the coin, any loss of cyberspace dominance on our part can negate our most cherished gains in air and space in virtually an instant. Technologies that can enable offensive cyberspace operations, moreover, are evolving not only within the most well-endowed military establishments around the world, but also even more so in the various innovative activities now under way in other government, private sector, and academic settings. The United States commands no natural advantage in this domain, and its leaders cannot assume that the next breakthrough will always be ours. All of this has rendered offensive cyberspace operations an attractive asymmetric option not only for mainstream opponents and other potential exploiters of the medium in ways inimical to the Nation's interests, but also for state and nonstate rogue actors with sufficient resources to cause us real harm.

Moreover, unlike the air and space environments, cyberspace is the *only* military operating area in which the United States already has peer competitors in place and hard at work. As for specific challengers, U.S. officials have recently suggested that the most sophisticated threat may come from China, which unquestionably is already a peer competitor with ample financial resources and technological expertise. There is more than tangential evidence to suggest that cyberwar specialists in China's People's Liberation Army have already focused hostile efforts against nonsecure U.S. transmissions.[11] Such evidence bears strong witness to the fact that state-sponsored cyberspace intrusion is now an established fact and that accurate and timely attack characterization has come to present a major challenge.

In light of its relative newness as a recognized and well-understood medium of combat, detailed and validated concepts of operations for offensive and defensive counter–cyber warfare and cyberspace interdiction have most likely yet to be worked out and formally incorporated into the Nation's combat repertoire. Interestingly, some of the most promising initial tactical insights toward that end may come from accessible sources in the nonmilitary domain, including from the business world, the intelligence world, the high-end amateur hacker world, and even perhaps segments of the underworld that have already pioneered the malicious exploitation of cyberspace. Ultimately, such efforts can help inform the development of a full-fledged theory of cyberspace power, which, at bottom, "is about dominating the electromagnetic spectrum—from wired and unwired networks to radio waves, microwaves, infrared, x-rays, and directed energy."[12]

With a full-court press of creative thought toward the development of new capabilities, the possibility of what a future cyberspace weapons array might include is almost limitless. Cyber weapons can be both surgical and mass-based in their intended effects, ranging from what one Air Force cyber warrior recently portrayed as "the ultimate precision weapon—the electron," all the way to measures aimed at causing mass disruption and full system breakdowns by means of both enabling and direct attacks.[13] The first and most important step toward dealing effectively with the cyberspace warfare challenge in both threat categories will be erecting impenetrable firewalls for ourselves and taking down those of the enemy. Of course, with respect to plausible techniques and procedures for tomorrow's cyberspace world, it will be essential never to lose sight of the timeless rule among airmen that a tactic tried twice is no longer a tactic but a procedure.

As the newly emerging cyberspace warfare community increasingly sets its sights on such goals, it would do well to consider taking a page from the recent experience of the military space community in charting next steps by way of organizational and implementation measures. For example, just as the military space community eventually emulated to good effect many conventions of the air warfare community, so might the cyberspace community usefully study the proven best practices of the space community in gaining increased relevance in the joint warfare world. Some possible first steps toward that end might include a systematic stocktaking of the Nation's cyberspace warfare posture, with a view toward identifying gaps, shortfalls, and redundancies in existing offensive and defensive capabilities.

Similarly, those now tasked with developing and validating cyberspace concepts of operations might find great value in reflecting on the many parallels between space and cyberspace as domains of offensive and defensive activity. For example, both domains, at least today, are principally about collecting and transmitting information. Both play pivotal roles in enabling and facilitating lethal combat operations by other force elements. Both, again at least today, have more to do with the pursuit of functional effects than with the physical destruction of enemy equities, even though both can materially aid in the accomplishment of the latter. Moreover, in both domains, operations are conducted remotely by warfighters sitting before consoles and keyboards, not only outside the medium itself, but also in almost every case out of harm's way. Both domains are global rather than regional in their breadth of coverage and operational impact. And both domains overlap—for example, the jamming of a GPS signal to a satellite-aided munition guiding to a target is both a counterspace and a cyberwar operation insofar as the desired effect is sought simultaneously in both combat arenas.[14] To that extent, it seems reasonable to suggest that at least some tactics, techniques, procedures, and rules of thumb that have been found useful by military space professionals might also offer promising points of departure from which to explore comparable ways of exploiting the cyberspace medium.

Finally, as cyberspace professionals become more conversant with the operational imperatives of joint warfighting, they also will have a collective obligation to rise above the fragmented subcultures that unfortunately still persist within their *own* community and become a more coherent and interconnected center of cyberspace excellence able to speak credibly about what the exploitation of that medium brings to joint force employment. Moreover, cyberspace warfare professionals will need to learn and accept as gospel that any "cyberspace culture" that may ultimately emerge from such efforts must not be isolated from mainstream combat forces in all Services, as the Air Force's space sector was when it was in the clutches of the systems and acquisition communities, but instead must be rooted from the start in an unerring focus on the art and conduct of war.

Toward a Cross-domain Synthesis

As long as military space activity remains limited to enabling rather than actually conducting combat operations, as will continue to be the case for at least the near-term future, it will arguably remain premature even to *think* of the notion of space "power," strictly speaking, let alone suggest that the time has come to begin crafting a self-standing theory of spacepower comparable in ambitiousness and scope to the competing (and still-evolving) theories of land-, sea-, and airpower that were developed over the course of the 20^{th} century. Only when desired operational effects can be achieved by means of imposition options exercised directly through and from space to space-based, air-breathing, and terrestrial targets of interest (or, more to the point, when we can directly inflict harm on our adversaries from space) will it become defensible to entertain thoughts about space "power" as a fact of life rather than as merely a prospective and desirable goal.

To be sure, it scarcely follows from this observation that today's space professionals have no choice but to wait patiently for the day when they become force appliers on a par with their air, land, and maritime power contemporaries before they can legitimately claim that they are true warfighters. On the contrary, the Nation's space capabilities have long since matured to a point where they have become just as important a contributor to the overall *national* power equation as has what one might call mobility power, information power, and all other such adjuncts of the Nation's military strength that are indispensable to joint force commanders for achieving desired effects at all levels of warfare. To that extent, insisting that it remains premature to speak of spacepower solely because our space assets cannot yet deliver such combat effects directly may, in the end, be little more than an exercise in word play when one considers what space already has done toward transforming the Nation's airpower into something vastly more capable than it ever was before U.S. on-orbit equities had attained their current breadth of enabling potential.

Until the day comes when military space activity is more than "merely" about enabling terrestrial combat operations, however, a more useful exercise in theory-building in the service of combat operators at all levels might be to move beyond the *air*-power theorizing that has taken place to date in pursuit of something akin to a working "unified field theory" that explicates the connections, interactions, and overlaps among the air, space, and cyberspace domains in quest of synergies between and among them in the interest of achieving a joint force commander's objectives more efficiently and effectively. A major pitfall to be avoided in this regard is the pursuit of separate theory sets for each medium. To borrow from Clausewitz on this point, space, like the earth's atmosphere and the electromagnetic spectrum, may have its own grammar, but it does not have its own logic. Each of the three environments explored in the preceding pages has distinctive physical features and operating rules that demand respect. By one characterization in this regard, "air permits freedom of movement not possible on land or sea. . . . Space yields an overarching capability to view globally and attack with precision from the orbital perspective. Cyberspace provides the capability to conduct combat on a global scale simultaneously on a virtually infinite number of 'fronts.'"[15] Yet while the air, space, and cyberspace mediums are all separate and unique physical environments, taken together, they present a common warfighting challenge in that operations in each are mutually supportive of those in the other two. For example, the pursuit of air supremacy does not simply entail combat operations in the atmosphere, but also hinges critically on ISR functions and on GPS targeting from both air-breathing and space-based platforms that transmit through cyberspace.

Another pitfall from the earliest days of airpower theorizing to be avoided is that of overreaching with respect to promises and expectations of what any ensuing theory should encompass and seek to make possible. Since airpower, spacepower, cyberpower, or any combination thereof can be everything from totally decisive to only marginally relevant to a commander's needs at any given moment, any insistence that these dimensions of military power be the centerpieces of overall national strategy will almost certainly fail to resonate and take lasting root in the joint arena. The single greatest failure of airpower's most revered founts of presumed insight and foresight, Generals Giulio Douhet and Billy Mitchell, was their passionate espousal not simply of a theory of *airpower*, but an overarching theory of *war* that hinged everything on the air weapon to the virtual exclusion of all other instruments of military power. As retired Air Vice Marshal Tony Mason of Great Britain's Royal Air Force insightfully noted in this regard, any truly effective theory of airpower (and, by the same token, of spacepower and cyberpower) must endeavor to emphasize not just the unique characteristics of the instrument, but also "the features it shares, to a greater or lesser degree, with other forms of warfare." Mason added that the preeminence of the instrument "will stand or fall not by promises and abstract theories, but, like any other kind of military power, by its relevance to, and ability to secure, political objectives at a cost acceptable to the government of the day."[16]

In light of the foregoing, the most immediate task for those seeking to build a better theory for leveraging capabilities in the third dimension may be to develop a point of departure for thinking systematically and holistically about synergies and best uses of the Nation's capabilities and prospects in all three domains, since all are key to the Nation's transforming joint strike warfare repertoire. Furthermore, it would be helpful to have a seamless body of applied and actionable theory that encompasses all three domains and that focuses more on functions and effects than on the physical locations of the instruments of power, with a view toward rank-ordering the many priorities in each and across all three, with the goal of charting a course for achieving cross-domain dominance. Another useful step toward managing the existing seams between and among the air, space, and cyberspace communities within the American defense establishment would be a perspective focused on *operational integration* accompanied by *organizational differentiation*. Through such a bifurcated approach, each medium can be harnessed to serve the needs of all components in the joint arena while, at the same time, being treated rightly as its own domain when it comes to program and infrastructure management, funding, cadre building, and career development.[17] Such organizational differentiation will be essential for the orderly growth of core competencies, discrete career fields, and mature professionalism in each medium. However, operational integration should be the abiding concern and goal for all three mediums, since it is only from synergies among the three that each can work to its best and highest use.

This is *not* a call for the Air Force, as the Nation's main repository of air, space, and cyberspace warfare capabilities today, to make the same mistake in a new guise that it made in 1959 when it conjured up the false artifice of "aerospace" to suggest that the air and space mediums were somehow undifferentiated just because they happened to be coextensive. Nothing could be further from the truth. It is, rather, to spotlight the unifying purpose of operations in all three mediums working in harmony, namely, to deliver desired combat effects in, through, and from the third dimension as quickly as possible and at the least possible cost in friendly lives lost and unintended damage incurred. Only after that crucial transitional stage of conceptualization has passed and when military space operations have come into their own as an independent producer, rather than just an enabler, of combat effects will it be possible to start giving serious thought to coming to grips with the prerequisites for a self-standing theory of spacepower.

Notes

1. For an overview of the Air Force's pivotal contribution to this transformation, see Benjamin S. Lambeth, "The Air Force Renaissance," in *The Air Force*, ed. General James P. McCarthy, USAF (Ret.), and Colonel Drue L. DeBerry, USAF (Ret.) (Andrews Air Force Base, MD: The Air Force Historical Foundation, 2002), 190–217. A fuller assessment of post-Vietnam developments in fixed-wing air warfare capability in all of the Services may be found in Benjamin S. Lambeth, *The Transformation of American Airpower* (Ithaca, NY: Cornell University Press, 2000).
2. These major air operations are examined in detail in Benjamin S. Lambeth, NATO's *Air War for Kosovo: A Strategic and Operational Assessment* (Santa Monica, CA: RAND Corporation, 2001); *Airpower Against Terror: America's Conduct of Operation Enduring Freedom* (Santa Monica, CA: RAND Corporation, 2005); and *The Unseen War: Airpower's Role in the Takedown of Saddam Hussein* (Santa Monica, CA: RAND Corporation, forthcoming).
3. For more on this point, see Benjamin S. Lambeth, *American Carrier Airpower at the Dawn of a New Century* (Santa Monica, CA: RAND Corporation, 2005).
4. Of course, space plays a larger role in the "fixing" of targets than just providing space-based ISR. Space-based communications and the Global Positioning System are both essential enablers of

unmanned aerial vehicle operations, which are also a critical contributor to the "fix, find, track, target, engage, assess" equation.

5. Cited in E.C. Aldridge, Jr., "Thoughts on the Management of National Security Space Activities of the Department of Defense," unpublished paper, July 6, 2000, 3.
6. For the essential known details of the test, see Craig Covault, "Space Control: Chinese Anti-satellite Weapon Test Will Intensify Funding and Global Policy Debate on the Military Uses of Space," *Aviation Week and Space Technology*, January 22, 2007, 24–25.
7. General James Cartwright, USMC, Commander, U.S. Strategic Command, remarks at the Air Force Association's Warfare Symposium, Orlando, Florida, February 8, 2007.
8. Admiral of the Fleet Sergei G. Gorshkov, *The Sea Power of the State* (Annapolis, MD: Naval Institute Press, 1979).
9. Among the classic articles in the airpower theory literature are Edward Warner, "Douhet, Mitchell, Seversky: Theories of Air Warfare," in *Makers of Modern Strategy*, ed. Edward Mead Earle (Princeton: Princeton University Press, 1943), and David MacIsaac, "Voices from the Central Blue: The Airpower Theorists," in *Makers of Modern Strategy: From Machiavelli to the Nuclear Age*, ed. Peter Paret (Princeton: Princeton University Press, 1986). See also the collection of essays in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell Air Force Base, AL: Air University Press, 1997). One of the better synopses of spacepower thinking to date is presented in Peter L. Hays et al., *Spacepower for a New Millennium: Space and U.S. National Security* (New York: McGraw Hill, 2000). For the most serious and thorough treatise thus far to have expounded about the cyberspace domain, its boundaries, and its potential, see George J. Rattray, *Strategic Warfare in Cyberspace* (Cambridge: MIT Press, 2001). The book is the doctoral dissertation of an Air Force lieutenant colonel who commanded the 23d Information Operations Squadron in the Air Force Information Warfare Center.
10. Colonel Glenn Zimmerman, USAF, "The United States Air Force and Cyberspace: Ultimate Warfighting Domain and the USAF's Destiny," unpublished paper.
11. See Carlo Munoz, "Air Force Official Sees China as Biggest U.S. Threat in Cyberspace," *Inside the Air Force*, November 17, 2006.
12. "Ten Propositions Regarding Cyber Power," Air Force Cyberspace Task Force, unpublished briefing chart, no date.
13. Zimmerman.
14. I am grateful to my RAND colleague Karl Mueller for suggesting these and other thought-provoking parallels between the two media.
15. Zimmerman.
16. Air Vice Marshal Tony Mason, RAF (Ret.), *Airpower: A Centennial Appraisal* (London: Brassey's, 1994), 273–274.
17. For an earlier development of this line of argument with respect to the Air Force's space community, see Benjamin S. Lambeth, *Mastering the Ultimate High Ground: Next Steps in the Military Uses of Space* (Santa Monica, CA: RAND Corporation, 2003). Part III: Civil, Commercial, and Economic Space Perspectives

Chapter 17:
Security and Spacepower

M.V. Smith

Spacepower provides different ways to manage security concerns. Because of its matchless ability to gain global access and achieve global presence while delivering nearly ubiquitous capabilities, spacepower is playing an increasing security role in war and peace around the globe on a perpetual basis. This chapter examines the opportunities spacepower provides to secure the peace and to fight wars.

Spacepower and War Prevention

Spacepower is ideally suited for war prevention—securing the peace—as a matter of day-to-day statecraft. To put this in clearer terms, "the primary value of spacepower is *not* support to warfighters, rather it is that space capabilities are the *primary* means of war prevention."[1] Spacepower can provide both indirect and direct methods to achieve war prevention. Indirect methods involve cooperative interstate behavior to reduce security concerns without the use or threat of force. Direct methods involve the use of force or threats of force. For now, spacepower lends itself more toward indirect methods such as providing global and cislunar transparency and expanding broad international partnerships. Direct methods are more hard-power–centric and include those capabilities that deliver assurance, dissuasive, and deterrent effects, matched with careful diplomacy, in a cost/benefit calculus. As space weapons proliferate, spacepower will offer effective direct methods of preventing war. Each indirect and direct method is discussed below.

Indirect Methods

Transparency. Space-based reconnaissance and surveillance platforms, because of their global nature, contribute directly to reducing security concerns by providing insight into observable human activities around the globe and in the cislunar region. Insight into human activity in space, manned or unmanned, is every bit as important as observations of terrestrial activities. When considered together, such insights can alleviate unfounded fears and prevent miscalculations, as well as deliver warnings and indications of activities of genuine concern. This was obvious right from the start of the space age during the Cold War when the first successful American reconnaissance satellite, called Corona XIV, returned more imagery of Soviet nuclear forces from deep inside the Soviet Union than did all of the prior U–2 missions combined.[2] This new satellite-derived information caused a sharp downward revision in the estimate of Soviet intercontinental ballistic missile launchers from 140–200 to between 10 and 25.[3] Later, only six of the sites were determined to be operational.[4] This application of spacepower helped reduce the American security concern and allowed the Eisenhower and subsequent administrations to right-size their nuclear deterrent force against a much smaller threat than suggested by estimates formulated without satellite data. Space was no longer merely a science project, but a real instrument of policy. True spacepower had arrived.

As the example above illustrates, spacepower provides transparency that reduces the *fog* during *peacetime*, increases the certainty of information, and allows contemplation of matters with a better approximation of the facts.[5] While this is entirely beneficial to the actor who possesses such information, the value of transparency has its limits. Some states feel increased security concerns if satellite-derived information about their observable affairs is distributed widely. China voiced this complaint shortly after the release of Google Earth, but accommodations were made to degrade the quality of images of areas sensitive to the Chinese government.[6] Such concerns must be addressed and dealt with directly, but accommodations can be made. Many states undoubtedly will change their conduct of military and other affairs to ways that are not observable by satellites. India, for example, avoided detection of its efforts to develop and test a nuclear device in 1998 by conducting activities when U.S. imagery satellites were not passing overhead and during times when sandstorms and intense heat could disrupt surveillance sensors.[7] Such nefarious workarounds can be eliminated by fielding a large constellation of several dozen reconnaissance and surveillance satellites owned and operated by suprastate or trans-state actors using multispectral technology. The point is that every inch of the Earth could be imaged several times a day using various techniques that can counter various many concealment efforts. Global transparency efforts are large and expensive and by their very nature will require a high degree of international partnering.

Partnering. Another opportunity that spacepower provides for managing security concerns is capitalizing on collaborative international security space arrangements to provide global transparency, space situational awareness, and space traffic management, to name just a few. Such partnerships need not be limited to security-related functions, but must cross into civil and commercial endeavors as well, such as space-based solar power, human missions to the Moon and Mars, space stations, space-based astronomy, and so forth. The goal is not only to accomplish something meaningful in space, but also to build mutual understanding and rapport among the participating states.

The American and Soviet joint venture on the Apollo-Soyuz mission in the mid-1970s is one such example. Although the tangible scientific benefits of the exercise are debatable, it demonstrated to both parties and to the international community that cooperation on a very challenging task is possible, even between the two Cold War antagonists with their widely divergent strategic cultures. This civil spacepower effort became a point of departure for other confidence-building gestures between the two and certainly eased tensions in the homelands and among the rest of the world as well, thereby reducing security concerns.

Partnering on spacefaring projects brings together more brilliant minds and resources to solve problems and to advance the art. It not only heightens the likelihood of success of those programs, but over time it also reduces the *friction* during *peacetime* between states, decreases the potential for cultural misunderstandings, increases the opportunities for alliance, integrates aspects of each state's economic and industrial base, and fosters working relationships between governments.[8]

Partnering is not always easy, as the members of the International Space Station or the mostly European states belonging to the Galileo Consortium will attest. In fact, it can be frustrating and even maddening. Disparate economic strengths, distribution of resources, and talent give each state a different value as a potential partner. States that are rich in some areas will be highly sought after as partners. Poorer states will not. However, from a partnership perspective, all are valuable as prospective partners as part of a collaborative international security arrangement.

The opportunities that spacepower offers spacefaring and non-spacefaring states alike in the forms of global transparency and international partnering in order to prevent wars are entirely different from opportunities provided by operations in any other media. The strategic cultures of most states—especially weaker or developing ones that are not yet spacefaring—will find the indirect methods highly attractive and engender soft power to the leaders of such efforts.[9] These approaches may be sufficient for most states' space-related security needs while reducing their security concerns inside the terrestrial confines.

Direct Methods

Many states will not feel comfortable having their security rest on such idealistic constructs as the indirect methods alone. Some states, especially those with more militaristic strategic cultures, will likely seek space weaponry (overtly or covertly) in the form of defensive systems to protect their space assets from attack and offensive systems to prevent foes from exploiting space to gain a military advantage.

The focus here is on hard power and space weapons—weapons that create their effects in space against the space segment, regardless of where the weapons themselves are based. We will not be looking at spacepower's longstanding support to terrestrial forces that are continuously engaged in dissuasion and deterrence strategies. This is particularly the case with nuclear forces but is increasingly so with conventional forces as well.

Many factors contribute to space-related security concerns faced by states and directly correlate to their likely drive for space weaponry. Each state will perform its own threat-risk calculus and respond accordingly. There are some elements of the threat-risk calculus that must be kept in mind. For example, more advanced spacefaring states have the most at risk in space and therefore have greater incentives to field defensive weaponry. Less advanced states may build offensive weapons as an asymmetric means of countering the power of a space-reliant potential adversary. The proliferation of space weapons will drive the need for greater space defenses. The lack of sufficient space situational awareness for threat and damage assessment and attribution increases the sense of risk by all. Finally, every state, whether it is directly spacefaring or not, is a user of space services, and therefore all states are space actors and must consider their space threat-risk calculus.

Acquiring weapons is not a sufficient precursor to war, as the peaceful conclusion of the Cold War illustrates. In fact, the possession of hard power capabilities managed in a responsible and constrained manner enables the war preventive strategies of *assurance*, *dissuasion,* and *deterrence*, as were used to avert hostilities during the Cold War and beyond. There is an important point that must be made here. States can only practice assurance, dissuasion, and deterrence if they *openly* possess a credible force of space weapons.[10] There is no war prevention benefit gained by keeping space weapons a secret, other than avoiding a space arms race. A potential adversary must clearly perceive a credible space weapons capability for these strategies to work. There are no agreed definitions for these terms, so care will be given to explain exactly what is meant.

Assurances. The concept of assurances is borrowed directly from nuclear-related literature. It involves stronger and weaker states making guarantees (assurances) for the purpose of preventing proliferation of weapons of mass destruction and war. There are negative and positive security assurances. These concepts can be related to space weapons and warfare. Negative assurances would be guarantees by space weapons states not to use or threaten the use of such weapons against states that have formally renounced space weapons. Positive assurances would be the agreement between a space weapons state and a non–space weapons state that the latter would receive assistance if it is attacked or threatened by a state that uses space weapons against them.[11]

Presently, there are no known assurances between space weapons states and non–space weapons states in the international community beyond those in the Outer Space Treaty. This is a wide open area waiting for diplomatic engagement. Presumably, the threat posed by space weapons has not yet raised the level of security concerns among the international community to stimulate assurance-making among states.

As we have seen in the nuclear community, some states will give public assurances not to proliferate, only to work to acquire weapons covertly. There is always the risk of being hoodwinked, which highlights the need for greater transparency and other soft power–related means of securing the aims of policy. In addition, no state has yet come forward and declared itself a "space weapons state," even though we see evidence of testing and actual employment of such weapons with increasing frequency. The utility of space weapons–related assurances are questionable until it is clear who has space weapons and who does not.

Dissuasion. Dissuasion, like soft power, rests on the ability to shape the preferences of others so they behave in a certain desired manner.[12] But unlike soft power, where others choose a course of action you would like them to pursue simply because they find it attractive, dissuasion is really about *persuading* them *not* to do something that you would not like them to do. Dissuasion is a negotiation of sorts, where one party "talks" the other out of doing something by demonstrating to them that the costs outweigh the benefits, because the competition is so far ahead that it becomes either impossible or simply impractical to catch up.

Dissuasion is a method attempted by powerful, long-established nuclear states to persuade nonnuclear states from proliferating. They approach states before they proliferate and directly or tacitly attempt to dissuade them from proceeding with their program by convincing them that the cost of competing with the powerful established proliferator in the nuclear arena is just too great. The hope is for the state to decide on its own that joining in the nuclear competition is not in its interest.

As applied to spacepower, a state that demonstrates a robust defensive and offensive capability may tacitly dissuade others from attempting to compete against that state in space.[13] Conversely, if a state's overall power, especially military power, appears directly tied to its space-based assets—a center of gravity—but it has no visible means for defending them or denying other states from exploiting space for military gain, it almost baits potential adversaries into fielding space weaponry.

The evidence shows mixed results with dissuasion with regard to nuclear proliferation. Since the mid-1990s, India, Pakistan, and North Korea have acquired nuclear devices, and Iran may be well on its way. Libya may be a success story. Its leadership seems to have made a cost-benefit analysis that resulted in the shutdown of its nuclear program. Other states may have been dissuaded, but the evidence is not clear.

There is an important note to add regarding spacepower. A state that has overwhelming spacepower may successfully dissuade another actor from competing militarily in the space arena, but that actor might choose to pursue asymmetric and potentially more violent means of achieving its aims as a result.

Deterrence. When soft power, assurances, and dissuasion fail, spacepower plays a central role in deterrent strategies that may prevent wars. Deterrence is the prevention of war based on coercion by threat of damage.[14] It must be a credible threat of inflicting unacceptable damage on an opponent. This was the case during the Cold War standoff between the United States and Soviet Union.

During the arms race of the Cold War, U.S. and Soviet space systems became thoroughly integrated into their states' nuclear attack warning, command and control, assessment, targeting, planning, and most every aspect of finding, targeting, and potentially destroying each other. The end of the Cold War and the commensurate reduction of security concerns that followed allowed the focus of space systems to evolve rapidly away from purely support to nuclear forces toward support to all warfighting activities, conventional, covert, and otherwise. It remains clear, however, that spacepower assets, as deeply integrated as they are in all aspects of military operations among advanced spacefaring states, will continue to be the interconnecting glue making terrestrial deterrence more effective.

It may be possible to deter an advanced spacefaring adversary who is heavily reliant on space systems but who has taken few or no precautions to defend them. In this case, possessing a credible set of offensive space weapons may threaten the adversary into avoiding confrontation. Sensing this, the adversary may initiate a crash program to acquire defensive capabilities or space weapons of its own.

Unfortunately, deterrence is based on an abstraction where there is no limit to the extreme of violence that can be threatened in retaliation. As Clausewitz noted, "Each side, therefore, compels its opponent to follow suit; a reciprocal action is started which must lead, in theory, to extremes."[15] This tendency can easily lead to arms racing.

Assurances are faith-based at best. Meanwhile, dissuasion and deterrence come with very real risks. Both presuppose that both sides of a potential confrontation are equally rational, have equal understanding of the stakes, and are using the same rational calculus to establish policy in an interactive fashion.[16] Given the differences in the strategic cultures of the players involved, these presumptions can never be the case in reality. As a result, there are margins of error associated with every calculation. A state that overtly builds offensive space weapons for the purpose of enabling dissuasive and deterrent strategies for war prevention may be misunderstood as having hostile intentions that trigger security concerns across the globe. The same is true for a state that may build what it considers to be a defensive system but that has an apparent dual application as an offensive system. China's test of a direct ascent antisatellite weapon in January 2007 may be a case in point.[17] A state may do its best to tailor its forces to support dissuasive and deterrent strategies and focus them at whatever it suspects the enemy holds dear, only to discover that the enemy reacts quite differently than expected. There are no guarantees.[18] A way to reduce the margins of error and the risk associated with direct hard power war prevention strategies is to include them within the policy-driven context of both indirect strategies suggested above: within the framework of global transparency and within broad international partnerships.

Spacepower and Warfare

We have arrived at what will undoubtedly be the most controversial part of this chapter, wherein we discuss spacepower and its nexus with warfare. It is controversial only because space has yet to be overtly weaponized or generally recognized as an arena of open combat. Many, if not most, want to keep it a weapons-free peaceful sanctuary, particularly the suprastate actors. Just because all other media are weaponized and used as arenas of combat does *not* mean that space will automatically follow suit.[19] Perhaps this generation will figure out how to keep the beast of war in chains short enough to prevent it from going to space. But the next (and each succeeding) generation must also keep the chains short. Unfortunately, the constant march of technology is making space more important to states at the same time it is making it easier to build space weapons.

In anticipating the future of spacepower for theoretical discussion, we can do little more than extract a roadmap from the history of human activity and extrapolate forward. The preponderance of evidence suggests that space will be no different than air, land, and sea regarding warfare. In the words of Colin Gray:

> It is a rule in strategy, one derived empirically from the evidence of two and a half millennia, that anything of great strategic importance to one belligerent, for that reason has to be worth attacking by others. And the greater the importance, the greater has to be the incentive to damage, disable, capture, or destroy it. In the bluntest of statements: space warfare is a certainty in the future because the use of space in war has become vital. . . . Regardless of public sentimental or environmentally shaped attitudes towards space as the pristine final frontier, space warfare is coming.[20]

The strategic value of space to states is not in question. Advanced spacefaring states are already reliant—and moving toward dependence—on space-derived services for activities across every sector of their societies. Spacepower is becoming critical to their styles of warfighting. Likewise, the injury that can be caused to such states by menacing their space systems can be considerable. Given these incentives, the beast of war will either break its chains all at once or stretch them slowly over time.[21]

Like war itself, space warfare, the decision to build space weapons, and whether or not to weaponize space are all matters of policy, not theory.[22] It is the job of theory to anticipate such developments given the template that history suggests. Land, air-, and seapower lend imperfect analogies to spacepower, but they are applicable enough to see that spacepower may have its own grammar, but not its own logic.[23] The logic of statecraft and warfare laid out in Sun Tzu's *The Art of War* and in Carl von Clausewitz' *On War* applies to spacepower as well as any other element of military power. A student of spacepower must become thoroughly familiar with both of these works.[24] War is a political activity and therefore a human activity with a long history that serves as a guide path. Spacepower is already part of the warfighting mix in the political and strategic unity of war, and this trend will continue.[25] Some predict that spacepower will make the greatest contributions to combat effectiveness in wars of the 21st century.[26]

War Extended to Space

War is an instrument of policy, and spacepower, as an element of the military instrument of power, is part of the policy mix that makes war, whatever form it may take.[27] Space generally has been treated as a sanctuary since the Eisenhower administration, and the use of space systems in warfare is limited to supporting terrestrial forces. This is not likely to change if the security concerns of states remain low. However, if states are confronted with intense security concerns, such as their survival, the weaponization of space and its use as an arena of conflict becomes far more likely.

Spacepower is a player at every point along the spectrum of conflict.[28] Covert operations often use space services with the same degree of reliance as the large joint military forces of advanced spacefaring states engaged in a conflict. In addition, space systems often support multiple military operations with varying intensities in different parts of the world simultaneously.

Spacefaring prowess is a common attribute of the dominant powers in the world today. Special attention must be paid to so-called rogue states that have access to space-related technology and may even be spacefaring but do not have the conventional forces to achieve their policy aims. Those aims tend to be very intense, and these players may seek space weapons as an asymmetric hedge against spacefaring adversaries who may try to coerce them.

The dominant military powers in the world, some of whom are potential adversaries, also tend to be the dominant spacefaring states. Because of the economic benefits and exponential enhancements that spacepower delivers to terrestrial warfighting, those states are under increasing pressure to defend their space systems and to counter those of their potential adversaries. This may lead to a space weapons race and an immediate escalation of hostilities to "wipe the skies" of enemy satellites should war break out between two or more dominant military space powers.[29]

When assessing the interplay between the spectrum of conflict and the spectrum of belligerents, it may be the case that war between two weak actors will not likely extend into space. However, if the power is perceived to be disparate, a weak actor is far more likely to use space weapons against a powerful state as an asymmetric defensive move.[30] A powerful state may counter the space systems in use by a weaker adversary, but it is likely to do so by placing diplomatic pressure on commercial vendors, or executing attacks on their ground stations, or launching highly selective covert attacks on the satellites they use by employing temporary and reversible means.

Should two dominant spacefaring powers go directly to war with each other with intense motives, both will find it critical to preserve their space systems and will consider it a dangerous liability to allow their enemy to exploit theirs. Given the ability of spacepower to cut the fog and friction of war while connecting military forces at the tactical, operational, and strategic level, it is likely that space systems will be primary targets that will be negated in the opening moves of war. The fight for space is likely to be intense and brief. Temporary means of negation will likely switch to permanent methods of destruction to remove doubt in the minds of commanders.

Offense and Defense

Twenty-six centuries ago, Sun Tzu pointed out, "Invincibility lies in the defense; the possibility of victory in the attack. One defends when his strength is inadequate; he attacks when it is abundant."[31] All warfare depends on interplay between the offense and the defense. They are "neither mutually exclusive nor clearly distinct. . . . each includes elements of the other."[32] Defense generally implies a negative aim of protection and of preserving the status quo in the face of an attack. Conversely, offense generally pursues a positive aim by inflicting damage on the adversary to coerce him into accepting terms. However, consider that there are defensive aspects resident in every attack. Warriors of old carried their shields into battle when they attacked with their swords to protect them from the thrusts of the defenders. The offense is also resident in every defense.

Remember that the Royal Air Force won the great defensive Battle of Britain by attacking the invading German bombers.

The general goal of offense is to inflict such damage on the adversary that they are *defensively culminated*, meaning they can no longer resist the attack and must either accept terms or be annihilated. Conversely, the goal of defense is to resist the attack and inflict such costs on the adversary that they are *offensively culminated*, meaning they can no longer attack and can only defend themselves. These concepts will come into play when we discuss space control and space denial.

It is often said that defense is the stronger form of warfare.[33] This is not true in space—today. Defending satellites and their data links is a difficult proposition at best. Satellites are delicate, fragile devices that can easily fall prey to any number of space weapons that currently exist, such as lasers, radio frequency jamming, brute force weapons, and surface-to-space missiles with kinetic kill vehicles—many of which are relatively small, mobile systems. While satellites in low Earth orbit are the most vulnerable to lasers and lofted kinetic kill vehicles, satellites all the way out in the geostationary belt and in highly elliptical orbits share a universal vulnerability to radio frequency jamming and electromagnetic brute force attacks. Satellites do not need to be physically destroyed to be rendered ineffective. Satellites are commanded (as applicable) and provide their services to ground stations and users via the electromagnetic spectrum. Hence, there is a rule: no spectrum means no spacepower. The rapid proliferation of jammers and electronic intrusion devices around the world in recent years occurred upon recognition of this rule.

Defenses to date are paltry at best.An adversary with robust space denial weapons may be able to negate all friendly space systems in a matter of hours; therefore, it is imperative for space powers to acquire the ability to find, fix, track, target, and destroy an adversary's space weapons very quickly. Such systems may reside on land, at sea, in the air, or in space. It will require close coordination with terrestrial forces to engage them against space weapons at the behest of the space commander.

In essence, today's space defense rests on the assurances in the Outer Space Treaty, which imperfectly implies that space is a peaceful sanctuary, although it only bans the basing of weapons of mass destruction in space. Does this mean all lesser threats are allowed? This is a hotly debated point. No one contests language in article 51 of the United Nations charter that gives states the inherent right of self-defense. Presumably, this includes self-defense from space weapons and space-based weapons. It can be argued that space weapons are a matter of the inherent right of self-defense. The slope to space warfare is slippery indeed.

Although offense is the dominant form of war in space today, this will not always be the case. Defense is possible. Three principles will likely guide the development of future space defenses.

First, *if you can't see it, you can't hit it*. Satellites are already getting smaller—too small for most space surveillance networks to detect and track. This trend will likely continue not only as a matter of cost savings, but also as a matter of stealthy defense. Avoiding detection includes maneuvering satellites to undisclosed wartime orbits.

Second, *all warfare is based on deception*.[34] Potential adversaries collect intelligence on each other's space systems and make their estimates based on their intelligence assessments. Action must be taken to deceive potential adversaries into underestimating the value of critical systems and overestimating the value of inconsequential systems. In addition, the use of wartime-only modes of operation, frequencies, and other unanticipated behaviors will further complicate an adversary's problems.

Third, *there is strength in numbers*. *The age of the capital satellites is over*. Employing only one or two large, very expensive satellites to fulfill a critical mission area, such as reconnaissance, is foolish. Future space systems must be large constellations of smaller, cheaper, and, in many cases, lower-fidelity systems swarming in various orbits that exploit ground processing to derive high-fidelity solutions. In addition, swarms improve global access and presence.

The best defense for a space system in the 21st century may be the dual-use system that is owned, operated, and used by broad international partners. A hostile foe may be deterred from attacking a satellite if doing so comes with the likelihood of expanding the war against their cause. This is also dependent on the hostile foe's policy aim. If it is intense, such as national survival or radical ideology, they may attack anyway.

The term *attack* is practically synonymous with *offense*, but it must be understood in a much more nuanced way regarding spacepower than is generally ascribed among those who hype the threat of direct kinetic kill antisatellite weapons that may smash satellites to bits. It must be remembered that space systems are comprised of space, ground, and user segments integrated through data links. Any of these segments or links can be targeted by an attack to gain the desired effect. A specific target within a space system is selected and a weapon is chosen to attack that target in a certain way to achieve the desired *level of negation*. The first includes temporary and reversible effects such as deception, disruption, and denial. The second includes permanent physical effects such as degradation and destruction. They can be described this way:

- *Deception* employs manipulation, distortion, or falsification of information to induce adversaries to react in a manner contrary to their interests.
- *Disruption* is the temporary impairment of some or all of a space system's capability to produce effects, usually without physical damage.
- *Denial* is the temporary elimination of some or all of a space system's capability to produce effects, usually without physical damage.
- *Degradation* is the permanent impairment of some or all of a space system's capability to produce effects, usually with physical damage.

- *Destruction* is the permanent elimination of all of a space system's capabilities to produce effects, usually with physical damage (called *hard kill* or, without physical damage, *soft kill*).[35]

Ultimately, the level of negation is chosen to achieve the desired effect that serves the objectives given to space forces in support of the overall strategy and operational plans of the war. A very low-intensity war is likely to involve covert use of the temporary and reversible levels of negation. Conversely, more intense wars will probably tend toward the permanent levels.

There is a drawback to temporary levels of negation. It is exceptionally difficult to determine if the application of the weapon is achieving the desired effect. Permanent levels of negation may deliver more easily observable confirmation of effects. This is somewhat analogous to the problems determining a tank kill in Operation *Desert Storm*. Some commanders considered a tank killed if its unit was attacked and the tank was no longer moving. Others did not agree with this. But all agreed that it was a kill if the tank had its turret blown off.

It must be kept in mind that a small number of powerful directed energy space weapons can quickly cause permanent levels of negation to dozens of satellites. On the other hand, it would take several dozen space weapons such as jammers that only cause temporary effects to negate the constellations of the larger spacefaring states. Since noise jammers are only effective when broadcasting, and broadcasting jammers are relatively easy to find and target, there are incentives to develop space weapons that cause permanent effects.

Spacepower in Warfare

The purpose of security spacepower is to provide capabilities to assist in achieving political and military objectives. It is an independent form of power that can be used alone or in concert with other forms of power to achieve desired ends. Space is a place where humans live and place uninhabited systems that help resolve problems. It begins above the Earth's surface at the lowest altitude where a satellite can sustain a circular orbit, albeit briefly, at approximately 93 miles and extends outward to infinity—excluding heavenly bodies.[36] Eventually, humanity will extend its interests fully across cislunar space and beyond, especially for economic development. Security spacepower will protect those interests, just as navies protect passage and commerce on the seas. Someday in the future, populations and their political entities will likely migrate into space as well. For now, however, humans live on the surface of the Earth, and contemporary spacepower in this context refers to the struggles occurring there, but this will evolve over time to include the cislunar region and the Moon.

The reason for going to near-Earth space for security purposes is to gain access to regions of the Earth where terrestrial forces either cannot go or cannot loiter as economically as some satellites. A relatively small number of similar satellites spread out in orbital space can survey the entire Earth's surface, which gives space-based constellations the ability to perform missions on a global scale. States perform many missions in space. In the opening years of the 21st century, these missions are primarily informational—that is, providing command, control, communications, and computer (C^4) support; positioning, navigation, and timing; intelligence, surveillance, and reconnaissance (ISR); and weather support to terrestrial forces, among others. Air, land, and sea forces also perform missions like these, but only space systems (and some terrestrial cyber networks) perform them continuously on a global scale. These space networks create a global infrastructure that links together expeditionary forces deployed anywhere in the world and connects these forces with each other in all media, and with their leadership.

When War Prevention Fails

Five terms are presented below that may seem familiar to anyone who has read U.S. Air Force doctrine regarding space: *space control, space support, space denial, space logistics*, and *space attack*. However, these terms are used differently here, because the driving concepts are pulled apart and analyzed more closely to reveal greater nuances that have much further-reaching strategic implications than the relatively simple and coarse definitions offered in current doctrine.

Space control.The primary mission of space forces at all times is assuring relative space control, which means *securing the space medium to provide freedom of access to space and freedom of action in space for all lawful and nonhostile spacefaring activities*.Space control is that which provides security when freedom of access or action in space is contested.

Space control is not only for military purposes. It allows civil, commercial, and other space activities to continue uninterrupted around the globe. It provides the benign environment that is a necessary precondition for most spacefaring activities. The importance of ensuring uninterrupted space commerce cannot be overstated. All states are increasingly reliant on space systems for all matters critical to their economic well being.

Space control efforts must minimize disruptions to the flow of the global economy. During war, every effort should be made to limit the effects only to the belligerents. This minimizes the risk of a war expanding by drawing in other states seeking to protect their interests by force. Space control also requires preventing the creation of space debris, which becomes a hazard to spacefaring activities and denies freedom of action in space to all actors in the vicinity of debris fields. Such is the negative aim.

Achieving the negative aim of space control requires passively or actively defending space systems under attack. This may require attacks to suppress or destroy the adversary's offensive space weapons, which may be based in the air, on land, at sea, or in space. It may be necessary to drive a hostile foe all the way to offensive culmination in space to arrive at the security required to assure free passage of commerce and other activities. The policy, strategy, and situation will dictate the degree of offensive space control that is used. Factors to consider will be the time and place where space control must be gained, how rapidly it is needed, what parts of the adversary space system(s) are vulnerable, the possibility of collateral damage, how long space control must be sustained, and the desired level of negation (for example, destruction, degradation, denial, disruption, deception). Space control does not need to be total in order to be effective. In fact, attempting to exact total space control over an adversary, to include dominating all decisive points and the equatorial chokepoint, would be counterproductive as preparations to do so would drain the budget and be highly wasteful.[37]

Space control also has a positive aim, which is to sustain the requisite degree of freedom of action to enable friendly space forces to continue or expand the missions of *space support* to friendly forces, *space denial* of adversary space capabilities (if required), and *space logistics* to sustain friendly operations on orbit, and it someday may include the mission of *space attack* of striking adversary targets from space. Each of these missions will have a priority dictated by the policy and strategy they support.

Space situational awareness is a most vital component of space control. Freedom of access to space and freedom of action in space require timely and reliable information about what is actually happening on orbit. It includes what could be called space traffic management and debris avoidance, in addition to characterization of threats and anomaly detection and attribution, as well as attack assessment. The ability to accurately characterize what is happening in space becomes more critical as the world becomes more space reliant, as the number and frequency of spacefaring activities increase, and as space weapons proliferate.

Competition for space control is not limited to warfare. Such competition also occurs during peacetime negotiations for treaties, laws, and rules of the road that in any way curtail the freedom of access to space or freedom of action in space. This is why some countries, such as the United States, are very cautious about entering into such negotiations. The long-term implications of various forms of agreements are difficult to anticipate. There is little doubt, however, that additional treaties, laws, and rules of the road are warranted to codify the appropriate and inappropriate behaviors of spacefaring actors. This will soon be critical to accommodate the rapidly increasing number of satellites on orbit, space tourism, space hotels, and lunar and asteroid resource development.

Space support. This includes all of the space force enhancements and information services that modern militaries have become accustomed to. The negative aim of space support includes providing all of the space services associated with the *surveillance strike complex*, which includes all those space sensors, communications links, and other space capabilities that allow terrestrial forces to defend friendly interests. It encompasses such things as warnings, tip-offs, indications, cueing, and assessments of attack by air, land, sea, or space forces. It includes all of those space systems used in any way to integrate passive and active defensive measures. An example is the missile warning network, which detects missile launches by satellite, routes the data into the fire control system of missile defense batteries, and sends it to commanders via communications satellites.

The positive aim of space support includes providing all the space services associated with the *reconnaissance strike complex*. The reconnaissance strike complex encompasses all those space sensors, communications links, and other space capabilities that allow terrestrial forces to attack the enemy. It includes the entire space-enabled ability to find, fix, track, target, engage, negate, and assess enemy targets. An example is a reconnaissance satellite finding an enemy tank, routing this data to a strike aircraft via communications satellite, and guiding the aircraft's munition to target via the global positioning system, while observing battle damage indications and other assessments from space.

The surveillance and reconnaissance strike complexes of most actors have many space-related elements in common. The global positioning system, for example, provides data that is typically critical to both complexes. Of particular note is the blending of commercial assets, such as communications satellite services, into the strike complexes of states and nonstate actors. Commercial space systems used by the enemy to advance its war effort, including the satellites on orbit, are valid military targets. Their likelihood of being attacked is directly related to the intensity of the war aims of the belligerents and their ability to strike the relevant commercial systems.

Here a moral dilemma arises. Is it better to attack a ground station with a high probability of killing human beings, or is it better to attack a satellite with no possibility of human death? No answer can be given here, for the answer is entirely dependent on the policy and strategy, both formed in the unique context of the situation.

Space denial. Denial of adversary space forces is as important as space control. Its essence is the use of space weapons to negate adversary space systems. Its negative aim is to defend friendly interests by negating the enemy's space systems associated with their reconnaissance strike complex, thereby increasing the fog and friction inherent to the enemy's offensive efforts to hasten its offensive culmination.

Space denial can be used for two positive aims. The first includes space denial attacks against adversary space systems associated with their surveillance strike complex to facilitate other attacks against them and to hasten their defensive culmination.

The second positive aim of space denial has received little attention. It involves negating adversary space systems simply to raise their costs in the war effort, in an attempt to coerce them into accepting terms. This can be done as part of an overall punishment strategy or risk strategy of imposing costs on the enemy with the promise of imposing even greater costs in the future.An interesting twist to this strategy might be limiting strikes only to satellites in orbit. Nobody dies, but there are tangible costs imposed. It might be possible to coerce a state that is heavily reliant on space services into accepting modest terms by negating only their satellites in orbit. Such prospects heighten the need for effective space defenses for highly reliant states. States that do not find themselves as dependent on space have far less of a need for space defenses and may become concerned when others merely discuss defensive systems, since the line between offense and defense is so easily blurred.

It is important to remember that an adversary's satellites are global assets. It may be politically untenable for a number of reasons to permanently damage an adversary's satellite. For example, while an imagery satellite may threaten to disclose friendly troop movements in one region, that same satellite might perform treaty verification on the opposite side of the globe or other missions that there is a friendly interest in preserving. In many scenarios, space denial might best be limited to very localized and temporary effects.

The best way to deny an adversary *access* to space is to destroy their space launch facilities, but we must also be aware that the adversary may contract their spacelift with other countries where they may have satellites in storage. The best way to deny space support to an adversary is to directly negate the satellites they use. While some satellite systems may be particularly susceptible to the destruction of their ground stations, this may have only limited effect on other satellite systems that may degrade gracefully in the absence of ground control. It is also likely that an adversary will employ mobile ground stations for tactically important space systems that require frequent ground contact. This not only makes targeting ground stations more difficult, but it also highlights the need to negate an adversary's satellites on orbit. It is also possible to attack the users of space support by jamming their receivers through a variety of techniques. This has the benefit of localized and temporary effects. In many scenarios, it is likely that a combination of attacks on all three segments of a space system (ground stations, satellites on orbit, and user equipment), as well as their linkages, will be required to achieve the desired effect.

Space control and space denial efforts will be complicated if an adversary is using third-party launch facilities, satellites, or ground control systems provided by commercial vendors, international consortia, or an ally. Diplomatic efforts will likely be required to eliminate third-party support to adversaries, but if the political will exists, friendly forces must be ready to expand the conflict by striking wherever adversaries receive space support. If diplomatic efforts fail and policy does not allow expansion of the conflict to strike third-party targets, then the adversary has a sanctuary they will likely exploit.

Space logistics. Space logistics are those activities to sustain satellites and their capabilities on orbit. It includes launching satellites to orbit, on-orbit check-out, maintenance, refueling, repair, and the like. With regard to wartime space logistics, it is imperative for spacefaring states to repair or replace lost satellite capabilities on orbit. The goal is to rapidly restore capabilities before they affect political, economic, and combat operations. Activating on-orbit spares, leasing commercial satellite services, launching new satellites to replace those lost through attrition, or gaining access to an ally's satellite services may do this. It is also essential to repair or replace lost satellite ground control systems. Methods for doing this may include transferring ground control responsibility to another location (fixed or mobile), leasing commercial support, or obtaining ground support from an allied state.

A word of caution is warranted regarding the launch of new satellites to replace those lost to enemy attack. Unless there is complete certainty that the adversary is offensively culminated and *all* adversary space weapons have been accounted for and successfully negated, launching a satellite of the same design into the same orbit will be like throwing skeet in front of a shooter. In practice, there is no way to be absolutely certain that the threat is completely removed.

Space attack. It is possible that someone will put weapons on orbit that can attack terrestrial targets. Space attack could have a negative aim of striking an adversary's advancing forces or offensive systems as a matter of defending friendly interests and hastening the enemy's offensive culmination. Space attack could also have two positive aims. The first could be striking adversary forces or their defensive systems to expedite their defensive culmination. The next could be attacking their centers of gravity directly as part of the war-winning effort.

There are many good reasons for not putting weapons in space for the purpose of space attack. Among them are the enormous expenses of putting them in space and their vulnerability once there if they are left undefended. But there is a paradoxical logic to warfare that increases the likelihood of someone actually doing it: Because there are many good reasons not to put weapons in space, putting weapons in space makes little sense; no one is expecting weapons in space; therefore, an actor achieves the element of surprise by putting weapons in space!

Situational awareness has always been critical in diplomacy and warfare, but in the new era of precision targeting, situational awareness must be equally precise—a bomb is only as accurate as the coordinates used by the planner, the warfighter, and the munition itself. Precision targeting is well understood, but the need for precision surveillance and reconnaissance is not.

Multitudes of ISR sensors in all media characterize the modern battlespace. Some collect signals intelligence, while others collect photoreconnaissance data. Still others collect radar information. These sensors and their operators not only attempt to identify targets, but also try to determine each target's precise coordinates. The ability of different sensors to determine the precise coordinates of targets varies, but in general, terrestrial sensors are much better at this than space-based sensors for several reasons. First, space systems are typically much farther away from the targets. Second, satellites in the lowest orbits are moving very fast in relation to targets and have relatively short dwell times on targets compared to terrestrial systems, and satellites in higher orbits are much more distant and are generally less able to refine target coordinates as precisely. Third, satellite sensors degrade over time, and there currently is no effort under way to perform physical maintenance on them to keep them in prime condition. Finally, given the relatively few ISR satellites in low Earth orbit, continuous coverage of areas of interest from space with the most precise space-based sensors is currently impossible.

In sum, aircraft have several distinct advantages over spacecraft in regard to *theater* ISR collection, but space-derived surveillance and reconnaissance information is critical to diplomatic and military operations because it provides a "first look" into denied areas and at the battlespace and assists planners in finding and coarsely geolocating many targets before terrestrial forces move into the region. As a rule of thumb, today's space-derived surveillance and reconnaissance is useful in finding 80 percent of the targets and is able to determine their location to roughly 80 percent of the accuracy required to conduct precision strikes. In some cases, space systems do better than 80 percent in finding and fixing targets, and in other cases, they do worse. What is important is the tremendous advantage space systems provide politicians and commanders by giving them a high-quality first look into the situation they face. With this information, they are able to make decisions about how to employ their limited terrestrial surveillance and reconnaissance assets (aircraft, ships, submarines, reconnaissance ground forces, etc.) more efficiently to refine the surveillance and reconnaissance picture to the quality they desire for the operations they are considering. In some cases, the first look from space may suffice, but usually terrestrial surveillance and reconnaissance assets are required. During combat operations, space-based surveillance and reconnaissance sensors continue to provide data, filling gaps in coverage by theater assets. Space-based surveillance and reconnaissance sensors also frequently cue terrestrially based sensors, as was the case during the Gulf War with missile warning satellites cueing Patriot batteries to intercept Iraq's inbound Scud missiles.

Perhaps most important of all, day in and day out, during war and peace, spacepower provides the 80 percent first look on a *global* scale. It allows analysts to watch the world and report tip-offs, warnings, and indications that give political and military leaders the freedom to employ their terrestrial forces more expeditiously and with greater confidence that another threat is not more pressing. Spacepower literally watches the backs of terrestrial forces to make sure no threat is sneaking up behind them. This allows greater concentration of terrestrial forces in theaters of combat operations because space-based surveillance and reconnaissance assets are sufficient to act as a kind of global sentry. This sort of mission is ideally suited to space systems because they have unimpeded access around the globe and relatively few assets are required to sustain surveillance and reconnaissance missions on a global scale.

Much more is possible. By increasing the number of low Earth orbiting sensors, continuously improving the quality of the sensors, and developing the means to service and repair them (either on orbit or by recovery and relaunch), the 80 percent rule of thumb will creep closer toward the 100 percent solution, despite the warfighter's demand for ever-increasing precision. As space systems becomes more capable, is it likely that they will replace terrestrial forms of surveillance and reconnaissance collection? No. Aerial reconnaissance did not eliminate the need for land and sea forces to conduct reconnaissance of their own. There is no reason to believe that space-based reconnaissance will replace any other form of reconnaissance either.

Spacepower does not usurp missions from other forces. Spacepower assets give a state new core competencies for its military order of battle. The ability to do anything continuously on a global scale is a new contribution to warfare made possible by spacepower. The various C^4ISR capabilities, including weather observation, missile warning, and navigation and timing broadcasts, give space-enabled forces a distinct asymmetric advantage over adversaries in the opening days of the 21st century. This advantage will evaporate over time as other actors on the world stage develop, lease, or borrow similar capabilities.

Space forces do not compete with terrestrial forces for roles and missions. Airpower, land power, seapower, spacepower, and now cyberpower bring different capabilities to modern warfare. The armed forces of many nations train their warfighters in highly specialized ways with the objective of being able to dominate operations within their respective media. Operations in each media require centralized control by practitioners of that form of power, in close coordination with the other warfighters, to ensure the optimum management of resources and integration of efforts to achieve the objectives of strategy.

A great fallacy resulting from the prevalent budget-driven integration mindset is the oft-cited statement that "missions will migrate to space when it becomes reasonable to do so." This presumes that commanders in forward areas are willing to trade highly flexible organic terrestrial assets for less flexible (and often less capable) space systems that another commander will likely manage as global assets. Economic considerations may force such a compromise, but a more prudent approach is to develop robust space capabilities in addition to airpower, land power, seapower, and cyberpower assets. Remember, the difference between space systems and terrestrial systems is that space systems provide global access and global presence during both war and peace.

When space forces eventually obtain systems that can create physical effects at any location on the surface of the Earth (for example, conventional bombing), this will not replace the standing requirement for aircraft and missiles to be able to do the same thing, just as the bomber did not replace artillery. Space operations are expensive, and economic considerations may require air delivery of munitions. Exceptions include times when cost is not a consideration, such as combat in areas where aircraft are denied access, when aircraft cannot respond to a time-critical situation as quickly as spacecraft, when only a specialized weapon delivered from space will have the desired probability of killing a target, and when surprise is of the utmost importance.

There is unquestionably some overlap between the capabilities of spacepower and other forms of power, but this is a source of strength, not waste. Just as the triad of bombers, submarines, and missiles during the Cold War prevented either adversary from gaining a significant advantage should their opponent successfully counter one set of capabilities, today's redundancy prevents an adversary from gaining a significant advantage should they successfully counter space-based systems or other terrestrial forces. There will be some adjustments in force structures as space capabilities become more robust, but *no* mission in *any* service should *ever* move *entirely* to space. Under *no* circumstances should *all* of the eggs *ever* be placed in the space basket. Instead, there should be an integrated combined arms approach.

During time of peace, spacepower assets monitor the globe, helping to identify and characterize potential threats. When a threat emerges, political and military leaders may opt to send terrestrially based surveillance and reconnaissance sensors into the area of interest to get a closer look. Should hostilities break out, space forces will gain whatever degree of space control is required and will contribute whatever they can to help friendly forces in theater in terms of space support to the surveillance and reconnaissance strike complexes, but they still must watch the rest of the world, in every other theater, looking for tip-offs, warnings, and indications of other threats.

Space attack will take many different forms, but it seems likely that space-based weapons will fill specific niches, ideal for only a handful of missions during certain phases of operations. No claim is made that spacepower by itself can be decisive in general conventional warfare, but in certain circumstances, it may help set the conditions for victory by friendly forces. Conversely, if space forces are defeated, this may turn the tide of the war against friendly forces and contribute to defeat. There may be certain forms of limited warfare where the coercive application of space systems may achieve the political and military aims of an operation. If this defines decision, then so be it.

Conclusion

The primary value of spacepower is war prevention, not support to warfighters. It does this by providing transparency into observable human activities around the globe and into space that removes uncertainties and security concerns or allows them to be addressed with a better approximation of the facts. Space also provides opportunities for cooperative ventures on spacefaring activities across all sectors. These ventures can become the framework of better international relationships and confidence-building maneuvers between potential adversaries. Powerful spacefaring states may be able to use martial space strength in traditional ways, such as providing assurances and using dissuasive and deterrent strategies, to prevent wars.

If history serves as a template for the future in space, then space will become a warfighting medium. It is already heavily militarized, with powerful spacefaring states using the medium to enable their surveillance and reconnaissance strike complexes in ways that accelerate the scale, timing, and tempo of combat operations exponentially beyond non-spacefaring actors' ability to cope. Weak actors are likely to employ space weapons in an attempt to counter the advantage space confers on powerful states. The most dangerous situation, however, occurs if two powerful spacefaring states go to war with each other. If the motives are intense, it is likely that they will be forced to counter each other's space systems in the very early stages. At present, there are inadequate defenses for space systems, but defense is possible. Space denial strategies of warfare are likely to evolve, wherein a belligerent merely attacks an adversary's space systems to inflict costs or to induce strategic paralysis on the enemy before offering terms. Finally, space is very much part of the military mix of all actors, state and nonstate, and it must be recognized that spacepower is not a replacement for terrestrial forces, but an additional set of tools that delivers unique capabilities.

Notes

1. The claim that the proper primary mission for spacepower is war prevention was first made to the author of this chapter by Brigadier General S. Pete Worden, USAF (Ret.), in the fall of 2005. He expands this to claim that spacepower is the primary means that states can use to prevent wars. See also chapter 30 in this volume by Worden, "Future Strategy and Professional Development: A Roadmap."
2. The security concern of facing the threat of a Soviet missile attack faced was so great that the Eisenhower administration tolerated 12 successive failures of Corona systems before the 13th actually delivered usable imagery. Described in William E. Burrows, *The New Ocean* (New York: Modern Library, 1999), 232–233.
3. A National Intelligence Estimate released in February 1960 assessed the Soviets as having as many as 140–200 ICBMs on launchers by mid-1961. Dwayne A. Day et al., *Eye in the Sky: The Story of the Corona Spy Satellite* (Washington, DC: Smithsonian Institution, 1998), 216–217.
4. Ibid., 217.
5. Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1984), 140. In describing what he calls the "uncertainty of all information," Clausewitz describes the quality of information in war as affected by a kind of *fog*, which he claims "tends to make things seem grotesque and larger than they really are."
6. Google Earth is an Internet-based imagery database set in an easy-to-use imagery manipulation program that is expanding to show relatively high-quality images of the entire Earth.
7. Tara Shankar Sahay, "Pakistan Feels Let Down by U.S. Spy Satellites," *Rediff on the Net*, May 13, 1998, available at <www.rediff.com/news/1998/may/13spy.htm>; and Krishnan Gurswamy, "India Tricks U.S. Satellites," Associated Press, May 19, 1998, available at <http://abcnews.go.com/sections/world/DailyNews/India980519_nukes.html>.
8. Clausewitz, 119–121. Clausewitz, who limited his discussion only to war, described *friction* in this way: "Everything in war is very simple, but the simplest thing is difficult." This is also true of large organizations and partnerships. But like a machine, the more frequently the partners work together, the easier it becomes, as if the process has a way of lubricating itself. In this way, partnering may be difficult as first but will become easier with time; hence, it will reduce the friction.
9. Soft power defined by Joseph S. Nye, Jr., *Soft Power: The Means to Success in World Politics* (New York: Public Affairs, 2004), 5.
10. One may wonder if the successful Chinese antisatellite test conducted in January 2007 is an example of a state attempting to establish its dissuasive and deterrent powers against the leading spacefaring state at that time, the United States.
11. "Positive and Negative Security Assurances," available at <www.reachingcriticalwill.org/legal/NSA.htm>.
12. Derived from the definition of soft power found in Nye, 5.
13. This is part of the central thesis found in Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London: Frank Cass Publishers, 2002).
14. Thomas C. Schelling, *Arms and Influence* (New Haven: Yale University Press, 1966), 3.
15. Clausewitz, 77.
16. Author interview with Michael Krepon, May 10, 2007.
17. Earlier ASAT tests by the United States and the Soviet Union from the early 1960s through the 1980s may also be examples of this phenomenon. It is by no means limited to the Chinese. See description of U.S. and Soviet ASAT tests in Clayton S. Chung, *Defending Space: U.S. Anti-Satellite Warfare and Space Weaponry* (New York: Osprey Publishing, 2006), 32–37.
18. Author interview with Jeffrey Lewis, May 27, 2007.
19. Karl Mueller, "Totem and Taboo," *Astropolitics* I, no. 1 (September 2003), 26–28.
20. Colin S. Gray, *Another Bloody Century: Future Warfare* (London: Phoenix, 2006), 307.
21. It has been postulated that the weaponization of space will occur in one of two ways, based on either a single trigger event or a slippery slope. See Barry D. Watts, *The Military Uses of Space: A*

Diagnostic Assessment (Washington, DC: Center for Strategic and Budgetary Assessments, February 2001), 98.

22. Clausewitz, 87. Clausewitz' famous dictum that "war, therefore, is an act of policy," serves as a central proposition for *On War*.
23. Extrapolated from Clausewitz, 605.
24. Sun Tzu, *The Art of War*, trans. Ralph D. Sawyer (Boulder, CO: Westview Press, 1994); Clausewitz, previously cited.
25. Clausewitz, 605–607.
26. Colin S. Gray, *Modern Strategy* (Oxford: Oxford University Press, 1999), 256–257.
27. Clausewitz, 87.
28. Brian E. Fredriksson, "Space Power in Joint Operations: Evolving Concepts," *Air and Space Power Journal* (Summer 2004), available at <www.airpower.maxwell.af.mil/airchronicles/apj/apj04/sum04/fredriksson.html>.
29. The urgency felt by powerful spacefaring states to "wipe the skies" is the thesis of a book by William B. Scott et al., *Space Wars: The First Six Hours of World War III* (New York: Forge, 2007), 7–16.
30. Ibid.
31. Sun Tzu, *The Art of War*, trans S.B. Griffith (New York: Oxford University Press, 1982), 85.
32. *Warfighting: The Marine Corps Book of Strategy* (New York: Currency-Doubleday, 1994), 30.
33. Clausewitz, 84; *Warfighting*, 30.
34. Sun Tzu, *The Art of War*, ed. James Clavell, trans. Lionel Giles (New York: Delacort Press, 1983), 11.
35. Air Force Doctrine Document 2–2, *Space Operations,* November 27, 2001, 13.
36. There is no universally agreed definition of where space begins and ends, but for this discussion, the author is only talking about space in terms of in Earth orbit and beyond. For a fuller discussion of debate of where space begins and ends, see M.V. Smith, *Ten Propositions Regarding Spacepower* (Maxwell Air Force Base, AL: Air University Press) 4, 38.
37. This point was brought out by Mahan with regard to command of the sea; total control is not necessary. This point is developed in relation to spacefaring activities in Dolman, 34.

Chapter 18:

U.S. Military Spacepower: Conceptual Underpinnings and Practices

John M. Collins

Congressional legislation designates the fundamental roles of the U.S. Army, Navy, Air Force, Marine Corps, Coast Guard, and U.S. Special Operations Command (USSOCOM). The Department of Defense (DOD) assigns implementing functions. Resultant responsibilities strongly influence the characteristics and respective budgetary shares of those building blocks, while military space forces remain on the outside looking in. That is where they will stay as long as present trends persist, because few movers and shakers on Capitol Hill and in the Pentagon understand that the word *aerospace* is an oxymoron. This chapter tells why and recommends corrective actions.

Aerospace is an Oxymoron

The "wild blue yonder" is pitch black above Earth's atmosphere. Hard-to-alter orbital patterns preclude loop-the-loops, barrel rolls, and other flamboyant maneuvers that fighter pilots favor. Astronauts cannot go down in flames where oxygen is nonexistent, and their vehicles cannot roar in the soundless vacuum that permeates space.

Geographic contexts indeed differentiate space from land, sea, and air more clearly than any other factors.[1] Air, water, weather, climate, and vegetation are confined to Earth, which—along with other planets, our Moon, and asteroids—contains the only land forms and natural resources. Cosmic radiation, solar winds, micrometeorites, and greatly attenuated gravity are unique properties of space, which has no shape or known extent. Shock waves are nonexistent. Visibility is far better than the best obtainable on Earth. Maneuver room is virtually limitless, except on our Moon and other orbs. Day-night cycles vary with altitude. Astronauts in low Earth orbits, for example, may race from light to dark to light every 90 minutes or so, while luminary transitions in deep space proceed imperceptibly.

Orbital distances are meaningful mainly in terms of time, except for communications, which proceed at the speed of light (186,000 miles per second). Space has no north, east, south, or west to designate locations and directions. Declination, the astronomical analog of latitude, is the angular distance north or south of the celestial Equator. Right ascension is the counterpart of longitude, and the dimly lit constellation Aries, against which spectators on Earth see the Sun when it crosses our Equator in springtime, defines the prime meridian. Navigators determine positions from that celestial equivalent of the Greenwich Observatory.

That distinctive medium demands a distinctive military spacepower school of thought, plus roles, functions, and concepts designed to assist the development of policies, strategies, tactics, plans, and programs for precisely the same reasons that armies, navies, and air forces demand different modus operandi.Cavernous voids currently exist in most respects, because neither Congress nor DOD facilitates such developments.

Military Spacepower Theories

Spacepower theories presumably provide the focus for this forum, but theories by definition expand knowledge bases with no particular purposes in mind. Albert Einstein, for example, never imagined that his Special Theory of Relativity with $E=MC^2$at its core would spawn nuclear weapons. Nobody predicted that the tiny rocket Robert Goddard launched from a cabbage patch in 1926 would become the great-granddaddy of all ballistic missiles and space boosters. This survey consequently concentrates on schools of thought, officially assigned U.S. military spacepower responsibilities, and concepts designed to solve offensive, defensive, and deterrent problems.

Customary Schools of Military Thought

Schools of thought are basic beliefs accepted as authoritative by subscribers who share common characteristics, outlooks, opinions, and values. Continental, maritime, aeronautical, and special operations schools currently dominate the mindsets of U.S. military concept formulators. The capsulated descriptions below deliberately oversimplify salient characteristics to emphasize peculiarities. The first three lean heavily on J.C. Wylie's exposition of the special operations school, *Military Strategy: A General Theory of Power Control*.[2]

Continental school. Adherents of the continental school, who are direct descendents of German strategist Carl von Clausewitz,[3] tend to compartmentalize Planet Earth into theaters of operation, regional areas of responsibility, and local zones of action. They contend that the defeat of enemy armed forces, mainly by manpower-intensive armies, is the ultimate object of war. Navies and air forces exist primarily to transport troops to scenes of action and support them after arrival. Only land power can conclude conflicts decisively and thereafter occupy hostile territory if necessary.

Maritime school. Members of the maritime school, blessed by a global reach, favor the teachings of venerated U.S. Navy Captain Alfred Thayer Mahan and British naval historian Sir Julian S. Corbett, who preached that control of high seas and littorals determines decisions ashore. The basic objective is to dominate critical sealanes and chokepoints that channel naval formations and commercial traffic afloat. Surface ships, submarines, and amphibious forces then can master land masses by blockades or the selective projection of power inland.[4]

Aeronautical school. The aeronautical school took shape in 1921, when Italian Brigadier General Giulio Douhet postulated that airpower unaided can be decisive; that given free rein, airpower could make protracted combat obsolete; and that control of the air and destruction of enemy warmaking potential, primarily population centers and industrial bases, constitute the central aim. Airpower proponents practiced what they preached with carpet bombing campaigns during World War II. Douhet's disciple Curtis E. LeMay later advocated bombing Vietnam "back to the Stone Age." [5]

Special Operations school. Flamboyant Army Major General William "Wild Bill" Donovan, who founded and led the Office of Strategic Services during World War II,[6] fathered the U.S. Special Operations school. He promoted small land, sea, and air teams prepared to perform overt, covert, and clandestine missions that orthodox armed forces could not accomplish as well, if at all. Adherents of this school, which mingles force with fraud and finesse, offer decisionmakers scalpels rather than sledgehammers for deterrent and warfighting purposes.

Astronautical school. There is no military spacepower school of thought, no Beacon on the Hill that beams to true believers. Whosoever devises a spacepower school of thought to complement land, sea, air, and special operations schools deserves top billing in the mythical Military Spacepower Hall of Fame.

Characteristics of a Military Spacepower Champion

Military spacepower's champion must be a tenacious, brainy visionary who also is a super salesperson. Charismatic Wernher von Braun, who had a grandiose dream that he pursued relentlessly, might make a hard-to-beat role model. He thought big after reading science fiction novels authored by Jules Verne and H.G. Wells plus the theoretical writings of Hermann Oberth, whose 1923 opus entitled *Die Rakete zu den Planetenräumen* (*By Rocket to Space*) was inspirational. Von Braun championed rocket development and space exploration between the 1930s and the 1970s and, in that process, opened up whole new worlds.[7]

Mining the Minds of Old Masters

Land, sea, and air schools of thought disregard or downplay interdependencies and benefits obtainable only from well-orchestrated joint and combined operations. Only the special operations school addresses the complete conflict spectrum, including complex problems that al Qaeda and other franchises generate during the global war against terrorism, which could persist for generations.

Military spacepower architects consequently would be well advised to retain the best and reject the rest. They might best begin by cherry-picking the minds of land power, seapower, airpower, and special operations masters whose legacies include numerous intellectual jewels. Carl von Clausewitz, for example, reminds readers that armed forces primarily serve political purposes.[8] British visionary Basil H. Liddell Hart's writings could help theorists fit military spacepower into U.S. grand strategies that meld force and threats of force with diplomacy, economic pressures, psychological operations, subterfuge, and other imaginative means to achieve national security objectives under all conditions.[9] Alfred Thayer Mahan's contention that enemies "must be kept not only out of our ports, but far away from our coasts" because the welfare of the whole country depends on trade and commerce perhaps applies equally well to circumterrestrial space.[10]

U.S. Military Spacepower Responsibilities

Congress, using Title 10, United States Code (USC) as a vehicle, *assigns broad, enduring roles to our Army, Navy, and Air Force*. That document enjoins each to prepare for prompt and sustained combat operations on land, at sea, or in the air, respectively. Primary responsibilities of the Marine Corps, within the Department of the Navy, feature the seizure or defense of advanced naval bases, amphibious operations, and combat ashore to promote naval campaigns. Title 10 additionally prescribes 10 "activities" (roles) for U.S. Special Operations Command, which possesses responsibilities similar to those of a military service. Title 14, USC specifies Coast Guard tasks. No comparable instructions establish *a* U.S. Space Force.

The President of the United States and Secretary of Defense assign space-related functions that supplement statutory roles. DOD Directive 5100.1,the pertinent document, directs the *Army, Navy, and Air Force* respectively to organize, equip, train, and provide service-peculiar space forces; develop service-peculiar space tactics, techniques, and equipment; conduct service-peculiar individual and unit space training; and participate in joint space operations, training, and exercises (see table 18–1).

Table 18–1. Typical Military Functions

	Land Forces	Naval Forces	Air Forces	Space Forces
Combat Functions				
Offensive Combat	x	x	x	
Air Defense	x	x	x	
Missile Defense	x	x	x	x
Airborne Operations	x		x	
Amphibious Operations		x		
Antisubmarine Warfare		x		
Unconventional Warfare	x	x	x	
Counterinsurgency	x	x	x	
Counterterrorism	x	x		
Coastal Security		x		
Internal Security	x			
Combat Support Functions				
Intelligence	x	x	x	x
Communications	x	x	x	x
Psychological Operations	x		x	
Electronic Warfare	x	x	x	
Inflight Refueling			x	
Search and Rescue		x	x	
Service Support Functions				
Airlift (Long Haul)			x	
Sealift (Long Haul)		x		
Spacecraft Launch/Recovery				x
Logistics	x	x	x	
Civil Affairs	x			
Meteorological		x	x	x
Navigation		x	x	x
Nonmilitary Functions				
Humanitarian Assistance	x		x	
Disaster Relief	x		x	
Civic Works	x			

Sketchy responsibilities listed in Title 10 and DOD Directive 5100.1 afford flimsy starting points for comprehensive, integrated military spacepower concepts, but corrective actions remain remote. Intellectual trendsetters who specialize in space therefore must generate a good deal of guidance on their own initiative.

Military Spacepower Concepts

H.G. Wells' imaginative *War of the Worlds*, George Lucas's "Star Wars" trilogy, and G. Harry Stine's *Confrontation in Space*[11] stimulate surprisingly few enthusiasts for military spacepower. Conceptual progress thus remains glacially slow 50 years after tiny *Sputnik*, the first manmade space satellite, flew in 1957. Creative thinkers who also are crack salesmen accordingly should accelerate activities and broaden their visions to embrace armed combat as well as assorted support activities, which currently predominate. There are at least two strong incentives for doing so at an accelerated pace.

Shortly before its demise, the Soviet Union put low-altitude U.S. satellites in potential peril with the world's first operational antisatellite (ASAT) system, a ground-based orbital platform armed with pellets. According to DOD, "Several interceptors could be launched each day from each of [two] pads. . . . engagement during the first orbit [would leave] little time for a target satellite to take evasive action."[12] Russia, whose relations with the United States currently are dicey, could easily perfect and deploy improved models able to penetrate much deeper space.

The People's Republic of China electrified the world on January 11, 2007, when it destroyed its obsolescent Fengyun-1 weather satellite with a test-fired direct-ascent ASAT, an action that fits neatly into Beijing's cosmopolitan space strategy. One commentator recently speculated that "a cycle of Chinese challenge and American response could come to dominate the bilateral relationship."[13]

Hoping for the best while preparing for the worst makes practical sense in those situations. President George Washington, in his first annual message to Congress on January 8, 1790, in fact advised that "to be prepared for war is one of the most effectual means of preserving peace."

Relevant Interests and Objectives

A clear and sustained sense of purpose in the White House, the Department of Defense, and the Department of State is imperative. National security interests such as survival, security, peace, prosperity, and freedom of action typify compelling wants and needs. Implementing objectives indicate what space forces must do to attain those ends under worst-case circumstances. Goals that feature nonprovocation might foster peace, whereas those that strive to control circumterrestrial space would mesh better with interests in military power. Most importantly, objectives on Earth and in space must be complementary to prevent perilous gaps and incompatibilities. Determination to protect Earth-bound command, control, communications, and intelligence (C^3I) chains, for example, but not the fragile space satellites upon which they depend, would dangerously weaken the entire apparatus.

Operational Priorities

The principle of war called *mass* contains an important message for creative thinkers who strive to create superlative concepts for U.S. space forces: concentrate strengths on vital objectives. Airpower proponents, who grasped the full significance of that notion, long ago assigned top priority to air superiority, because strategic bombing, battlefield interdiction, close air support, reconnaissance, transportation, and C^3I missions are unlikely or infeasible if rivals rule the air.

U.S. space forces currently depend on a few immobile Earth-based installations that launch, recover, control the activities of, and receive output from most spacecraft. All are vulnerable to missile attacks and sabotage. The survival of U.S. communications, intelligence collection, weather, and navigation satellites are now or soon could be similarly at stake if Russia, China, or both deploy sizable ASAT systems, which are technologically feasible in each case. "Soft kill" effects from electromagnetic pulse attendant to nuclear blasts in space and enhanced charged particle flux could be just as deadly as physically damaging weapons.[14] Top-level U.S. decisionmakers consequently should soon ascertain whether protection for supersensitive targets should become the priority mission before, rather than after, the first crisis occurs.

Space-related Arms Control

Quantitative and qualitative arms races not only deplete resources, talents, and energies, but also guarantee ever-greater violence if armed conflicts erupt. Proficient arms controllers therefore advance assorted alternatives designed to discourage military one-upmanship without undermining required capabilities.

Arms Control Aims

Spacepower arms controllers, like those whose efforts focus on Earth and its atmospheric envelope, aim to verifiably limit numbers, types, technological characteristics, locations, and uses of armaments and stockpiled munitions. Successes foster the following strategic objectives:

- military imbalances
- enhance defensive capabilities
- or alleviate international tensions
- improve threat predictions
- forestall accidental conflicts
- reduce risk of surprise attacks
- minimize damage and casualties if deterrence fails
- or contain costly escalation
- preserve selected environments.

Altruistic Treaties

Political cooperation, the most widely professed interest in space, conforms with the United Nations Charter, which seeks "peaceful and friendly" international relations everywhere. Article II of the Outer Space Treaty of 1967, in conformance with the spirit and letter of that prescription, disapproves of sovereignty anywhere in space. The 1979 Moon Treaty more specifically states that "neither the surface nor the subsurface of the moon [or other celestial bodies within the solar system] . . . shall become the property" of any person, state, or other organization.[15]

Cautionary Notes

Prudent strategists should treat both of the foregoing pacts cautiously, because they could become invalid when (not if) economic competition permeates space. Gullible U.S. arms controllers who inked "agreements in principle" and failed to read fine print in the past have been bushwhacked more than once since the Soviets unilaterally abrogated the nuclear test moratorium of 1958 with a spectacular series of atmospheric explosions in 1961.[16] On June 13, 2002, 6 months after giving required notice of intent, the United States withdrew from the 1972 U.S.-Soviet Anti-Ballistic Missile (ABM) treaty,[17] which was incompatible with threats that developed first in hostile North Korea, then in Iran.

Some spacepower specialists, ever mindful of such developments, believe that no arms control is better than bad arms control. The flip side of that coin, of course, is that good arms control is infinitely preferable to none. U.S. negotiators who hope to avoid predecessors' mistakes consequently should insist that treaty texts precisely define the meaning of every significant word, phrase, and punctuation mark before they sign on dotted lines.[18]

Assumptions

J.C. Wylie sought a comprehensive theory that could glue all military schools of thought together into a whole that would equal more than the sum of its parts. Four assumptions, which even crusty critic General LeMay deemed "unassailable,"[19] steered his search:

- despite all efforts to prevent it, there may be war
- the aim of war is some measure of control over the enemy
- nobody can invariably predict the time, place, scope, intensity, course, and general tenor of any war
- the ultimate determinant in war is a man on the scene with a gun.

That catalog could have included as a fifth assumption Wylie's contention that "planning for certitude is the greatest of all military mistakes." He admitted that no general military theory could "guarantee successful strategy any more than a good political theory can guarantee successful government," but it could "provide a stable and orderly point of departure from which we might proceed . . . in devising, in carrying out, and in later criticizing a strategy for a particular purpose."[20]

Military space planners currently must rely more heavily on assumptions than their land, sea, and air counterparts. The following five assumptions are merely illustrative; the positions the planner takes will drive the ultimate strategy:

- The purposes, scope, and number of powerful participants competing militarily in space will (not) soon multiply and intensify.
- Comprehensive military superiority in space would (not) confer indispensable, perhaps decisive, advantages on Earth.
- Space colonies and competition for lunar resources will (not) cause armed conflict within the foreseeable future.
- U.S. military spacepower will (not) indefinitely depend upon vulnerable, crucially important Earth-based facilities.
- Resources and the will to employ them will (not) foster U.S. military space forces with a wide range of capabilities within the next 25 to 50 years.

Deterrent Concepts

Deterrence has utility across the conflict spectrum on land, at sea, in the air, and in space. Deterrent dynamics, unlike those of passive avoidance, feature threats, promises, or acts, not necessarily military in nature, that pledge punishment if deterees perform forbidden deeds and perhaps offer rewards if they abstain. Spacepower strategists require answers to three key questions:

- Who deters whom from making what impermissible moves by what means, with what motivations, at what times and places, in what situations?
- What countermoves will deterees most likely make?
- What counter-countermoves seem advisable?[21]

Concepts crafted to discourage onslaughts succeed most consistently when sound principles guide production. There are no firm rules like Bernoullian numbers and Boyle's Law of Gases, but preparedness and nonprovocation are just two among a dozen commendable principles of deterrence that savvy strategists could apply in space.[22]

Preparedness

Perpetual preparedness, whose constituent parts are readiness and sustainability, improves prospects for peace wherever and whenever virulent threats exist, because nothing tempts opportunists more than opponents with their guards down. Creative thinkers who craft military space concepts must answer the question: "Prepare to perform what tasks in which specific circumstances at what levels of effort?"

Robust defenses and preemptive/retaliatory capabilities normally give trigger-happy aggressors reasons to relax. Preparation to surge space deployments could strengthen deterrence by demonstrating resolve, provided sufficient assets in reserve are ready to respond on short notice. Concepts might concurrently call for deployed combat forces to adopt more favorable orbits. Decisions to do so would demand carefully considered judgment calls, because sudden military buildups and repositionings in space might prompt foes to preempt if they feared that they were about to be attacked.

Readiness to reciprocate in kind is another deterrent notion: you assault my spacecraft, I assault yours. Antisatellite capabilities pose powerful disincentives according to that concept, provided adversaries rely heavily on vulnerable space satellites, cannot replenish losses quickly at acceptable costs, and want to preserve their own forces more than they want to repress those of rivals.[23]

Nonprovocation

Military postures that rivals consider dangerously provocative can cause deterrence to collapse just as surely as unpreparedness can. Sound concepts therefore should shun "use or lose" space forces that must strike first or risk ruin. Deterrent strategies must dampen enemy proclivities to preempt, but that is a dubious proposition because dividing lines between deterrence and destabilization can be indistinct. Impervious space-based defenses able to neutralize enemy ballistic missiles in flight, for example, could camouflage a first-strike strategy. Even a few nuclear weapons in such circumstances might permit the possessor to win without fighting (the "acme of skill" according to Sun Tzu circa 500 BCE[24]), then direct losers to disarm. Poorly shielded foes would face two unattractive alternatives: surrender or suicide.[25]

Risk reduction measures, much like those fashioned to forestall nuclear conflict on Earth, might promote deterrence equally well in space. Routine discussions between adversaries, high-level hotline consultations, and on-site inspections of launch sites, satellites, space stations, and lunar installations typify potentially helpful confidence-building techniques. Participants in those processes nevertheless would be well advised to guard against enemy deception and disinformation.

Offensive Concepts

U.S. offensive spacepower concepts pioneered by Wernher von Braun and Bernard Schriever thus far have been confined mainly to ballistic missiles that *transit* space.[26] Nations that lack strong offensive or counteroffensive capabilities *in* space eventually will forfeit freedom of action, perhaps when least expected, and find it difficult to deter armed aggression against their interests anywhere. The desirability of attacking any target set depends on variables that include objectives, perceived threats to their accomplishment, degrees of difficulty, escalation prospects, other unwelcome side effects, and budgetary costs. Troublesome tradeoffs inevitably arise when key considerations collide.

Principles of War

Military strategists, practitioners of operational art, and tacticians tacitly paid homage to principles of war many centuries before Clausewitz compiled the first formal list in an 1812 memorandum for Prussia's Crown Prince Friedrich Wilhelm. Armies, sea services, and air forces in nearly every nation possess some compendium. U.S. catalogues contain 10 that could serve space forces as well as Earth-bound colleagues: objective, offensive, mass, economy of force, maneuver, unity of command, security, surprise, simplicity, and morale.[27]

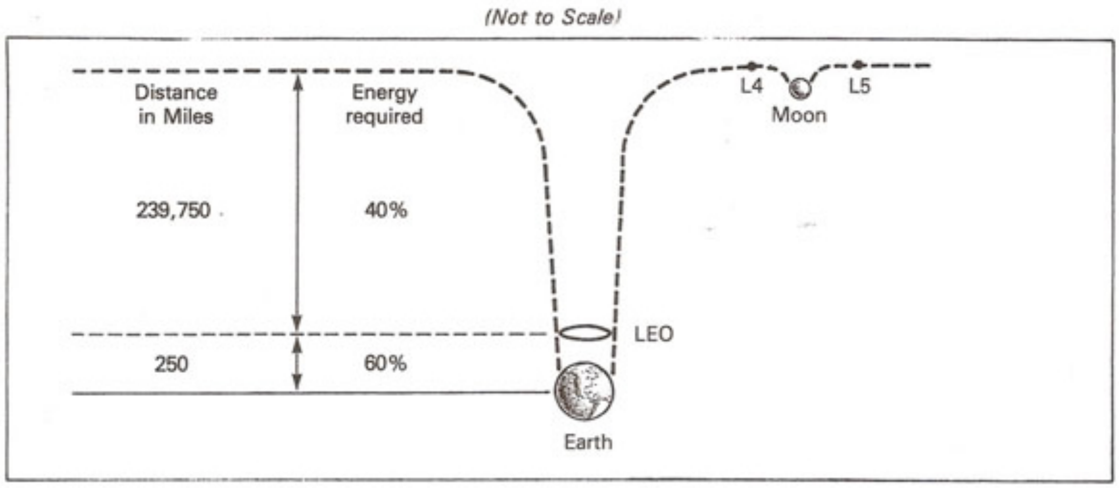
Not all of the foregoing principles are invariably relevant. Mass and economy of force, for example, compete for attention. Values vary with situations—offensive operations characteristically benefit from surprise, while defenders bank more on security. Some critics contend that principles of war possess little or no practical utility,[28] and all are subject to interpretations, but most professionals believe that they comprise convenient checklists with which to appraise concepts, policies, plans, and operations. Spacepower specialists accordingly should modify existing lists if necessary, interpret each entry from their peculiar perspectives, then use the lot to evaluate risks and estimate costs before they knowingly violate any of them. Historical records reveal that winners by and large took heed of principles, whereas losers, discounting those who were clearly out of their league, generally did not.

Strategic Leverage Available in Space

Armed forces on our Moon theoretically would possess great strategic leverage, because spacecraft at the bottom of Earth's "gravity well" need tremendous energy to leave launch pads and climb quickly into space. Gravitational pull on our Moon is merely one-sixth as strong as that around Earth, so launch problems are minuscule in comparison. Occupants of military positions analogous to "high ground" consequently enjoy much greater maneuver room and freedom of action. Put simply, it is easier to drop objects down a well than to throw them out (see figure 18–1).[29]

Figure 18–1. Earth and Moon Gravity Wells

> Low earth orbits, near the bottom of Earth's gravity well in terms of distance (60-250 miles), are more than half way up in terms of energy required to reach that altitude. Spacecraft velocity must be about 4.5 miles per second (mps) to attain LEO. A mere 2.4 mps more is enough to reach the top, nearly 240,000 miles higher.



Strategic Centers of Gravity

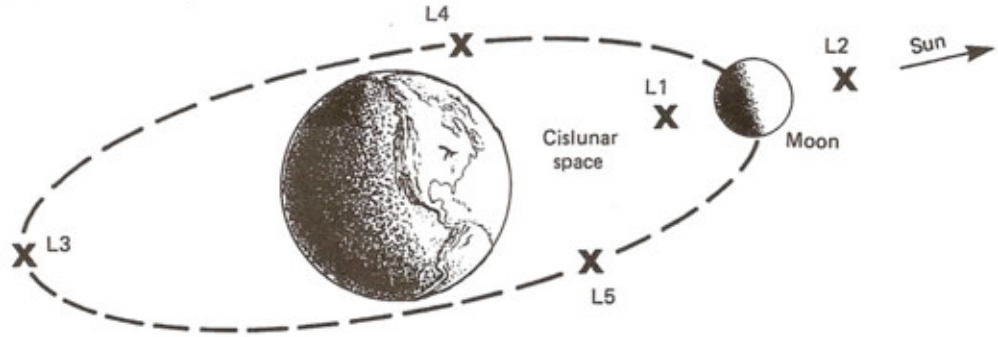
Clausewitz defined the term *strategic center of gravity* as "the hub of all power and movement, on which everything depends. That is the point against which all energies should be directed."[30] The Earth-Moon system contains at least two candidates. One has intrinsic value. The other is important solely because of position.

On Earth. Elaborate facilities that launch, control, support, and recover space vehicles from Earth almost certainly will constitute strategic centers of gravity far into the future. They are scarce, vulnerable, indispensable, and cannot be reconstituted expeditiously, and thus qualify as key terrain, the seizure, destruction, retention, or control of which would confer a decisive advantage.

In space. Five lunar libration points may constitute strategic centers of gravity in space (see figure 18–2). They actually are not points at all, but three-dimensional shapes, perhaps configured like 10,000-mile-long kidney beans. Mathematical models and computer simulations indicate that spacecraft within their respective spheres could remain there for long periods without expending precious fuel, because gravitational fields of Earth and Moon are in balance. Vehicles near L4 and L5, which are least disturbed by the pull of our Sun and other planets, probably could loiter almost indefinitely, if preliminary calculations are even close to correct.[31]

Figure 18–2. Map. Lunar Liberation Points

Three-Dimensional Perspective



DISTANCES IN MILES

From Earth	Lunar Orbit	240,000
From Moon	L-1	45,000
	L-2	42,000
	L-3	480,000
	L-4	60° ahead of moon
	L-5	60° behind moon

The U.S. National Commission on Space in 1986 envisioned that astronauts could fit L1 with military facilities as well as a "motel, gas station, warehouse, restaurant, and garage." L2 is a potentially important clandestine assembly area, since cislunar- and Earth-based sentinels could not see it. L3 seems suitable as a semistable staging base for military operations directed against Earth or spacecraft in orbit around it. Nature, however, hypothetically reserves the greatest advantage for libration points L4 and L5, which constitute presumably stable positions 60 degrees ahead of and behind our Moon in its orbit. Armed forces at either or both locations theoretically could dominate the entire Earth-Moon system, because they look down both gravity wells. Moreover, L4 and L5 are so large that forces lurking therein might be difficult to target. No other location is potentially as commanding.[32] Military space strategists could modify Halford J. Mackinders's original Heartland Theory[33] as follows, if the aforementioned postulations prove true: Who controls circumterrestrial space could dominate Planet Earth; who controls our Moon could dominate circumterrestrial space; who controls L4 and L5 could dominate the Earth-Moon system.

Maneuvering in Space

Most military space concepts concentrate on attack techniques that spacecraft might employ and disregard strike forces on our Moon that, perhaps sooner than shortsighted observers anticipate, could choose from the full range of offensive maneuvers in vogue on Earth. Envelopments from above or against flanks, turning movements that bypass forward defenses, and clandestine infiltrations might be most popular.

Assaults in free space conversely need innovative concepts, because the ideas of *front*, *flanks*, *top*, *bottom*, and *rear* would depend primarily on the direction that orbiting sensors and weapons systems face. Complex enemy space formations called constellations may make axes of advance immaterial, since widely separated satellites point sensors and weapons omnidirectionally. Orbital mechanics and human ingenuity limit maneuvering spacecraft. Counterrotation ASAT systems that attack almost head-on, for example, would have to follow slightly different tracks than their targets, or else they would collide. Relationships between point A and point B remain constant on Earth, whereas all weapons (save those that function at the speed of light) would require long leads and superlative homing devices in space—enemy spacecraft 1,800 miles away, for example, would move 100 to 200 miles or more in the 0.02 second it would take to bounce a reflection off that target and for a laser beam to return.[34]

Surprise and Deception

Speed (typified by directed energy weapons that strike without warning) and audacity can contribute to surprise. Earth-to-geosynchronous ASATs rarely will surprise opponents, because trips will take hours until technological breakthroughs radically reduce flight times, but weapons already in space could attack high-value targets without warning, if burn times were brief.[35]

Sun Tzu, the first well-known military strategist, professed that all warfare is based on deception,[36] which might abet surprise in space, even though sensors can spot potential enemies at great distances in every direction. Vacuum makes it hard to discriminate between missile warheads and lightweight decoys, because the latter flutter in telltale fashion only after they enter Earth's atmosphere, where objects with low mass-to-area ratios lag behind heavier objects. Spoofers in space, like those on this planet, would find it easy to flood rival receivers with bogus messages, so recipients would be hard pressed to separate bona fide communications from bogus traffic.

Civilian "fronts" for military space activities likely will become more common. Prewar proof of fraudulence will be elusive, in much the same way that nuclear reactors sometimes fool seasoned inspectors whose mission is to confirm or deny peaceful purposes as opposed to weapons production. Fakers might deploy widely separated weapons components in space and then assemble them unexpectedly.

Defensive Concepts

What, where, and how to defend are fundamental policy decisions. Previously identified strategic centers of gravity on Earth and in space clearly demand the least porous protection obtainable. Values, vulnerabilities, likelihoods of attack, implications of loss, and replacement problems determine what other spacepower assets deserve safeguards:

- Missions and financial costs determine relative values.
- Estimated enemy capabilities determine relative vulnerabilities.
- Estimated enemy intentions determine likelihoods of attack.
- Strategic, operational, and tactical plans determine implications of loss.
- Ready reserves and production capacities determine reconstitution times.

Savvy space defenders could use those five factors to prioritize problems and devise strategic and tactical schemes to reduce detection by enemy sensors, defeat attacks, and reduce damage.

Ballistic Missile Defense

Soviet leader Nikita Khrushchev on August 26, 1957, boasted about the successful launch of a "super-long-distance intercontinental multistage ballistic missile . . . [which] flew at a very high, unprecedented altitude . . . [and] landed in the target area."[37] That test accelerated previously lackadaisical U.S. ballistic missile defense (BMD) efforts, although the first Soviet intercontinental ballistic missiles did not enter active service until 1960. U.S. brainstormers first conceived Project Defender, which envisioned space-based interceptors long before implementing technologies became available.Progress peaked with Sentinel and Safeguard programs, and then languished after the Senate ratified the ABM Treaty in August 1972. The sole U.S. operational site at Grand Forks, North Dakota, shut down in 1975, but President Reagan's so-called Star Wars speech on March 23, 1983, revived efforts to make strategic nuclear missiles "impotent and obsolete."[38] Belligerent North Korean president Kim Jong Il currently keeps BMD on U.S. front burners.

Land, sea, and air components have long played prominent BMD roles, but space-based contributions remain confined to early warning and communications. Fifty years after Khrushchev's announcement, the best available U.S. ballistic missile interceptors still leave a lot to be desired, even against mediocre opposition. Room for improvement thus remains immense.[39]

Active Defense in Space

Defensive problems on our Moon parallel those that defenders must solve on Earth, whereas the stealthiest craft in free space will remain somewhat easier to track than aircraft until advanced technologies not yet on drawing boards become available. Most, moreover, must fly predictable orbits at predictable speeds. The amount of thrust needed to change orientations significantly demands large expenditures of strictly limited onboard fuel.

Limit. Thin-skinned space vehicles, their optics, and their electronics are vulnerable to directed energy weapons (lasers, particle beams), kinetic energy weapons (Brilliant Pebbles, railguns, smart rocks), induced nuclear effects, and assorted other explosives. Hardening is possible, but only at the expense of mass, which causes costs to skyrocket. Even slight wiggling could diffuse particle beams that, unlike laser burns, easily penetrate the hardest shells. Survivability nevertheless will be poor until technologists and tacticians devise damage limitation measures much better than those now available.

The outlook for abilities to defend against electronic attacks is somewhat better. Encryption and deception could be a cost-effective way to limit enemy attempts to spoof. Extremely high frequencies (EHF) could reduce nuclear scintillation and absorption from minutes to seconds. Enemy jammers have to remain in the line of sight between transmitters and receivers, because EHF transmission beams are narrow. Outlays for high-tech defensive hardware acquired for such purposes, however, would be large. High price tags also would accompany programs to cope with electromagnetic pulse that nuclear detonations in space would induce. The acquisition, installation, operation, and maintenance of Faraday cages, filters, surge arresters, waveguide cutoffs, fiber optic links, and other sophisticated devices would merely scratch the surface.[40]

Limit consequences. Enemy assaults are sure to damage or destroy some crucially important targets, because perfect defenses are infeasible. Therefore, steps to limit consequences are essential. One way is to reduce target values. Many simple, single-mission, relatively inexpensive unmanned spacecraft, for example, would be preferable to a few supersophisticated but highly vulnerable budget-busters that serve similar purposes. Largely autonomous space vehicles able to perform most functions well without external instructions or support would make command and control centers on Earth and the Moon less lucrative targets. Redundant deployments and reconstitution capabilities could reduce the value of individual targets. The former would furnish immediately available backup. The latter would facilitate short-notice surges and simplify expeditious replacements.[41]

Impediments to Military Spacepower

U.S. military space forces currently perform unique reconnaissance, surveillance, target acquisition, tracking, communications, navigational, meteorological, missile warning, and verification missions. Additional offensive and defensive contributions are currently feasible or conceivable, but military spacepower capabilities unfortunately will improve and expand at a snail's pace as long as technological complexities, astronomical costs, and impotent constituencies impede imperative progress.

Technological Complexities

Technological complexities associated with space operations currently dwarf those that plague the Defense Department's most complicated land, sea-, and airpower programs. Three cases nevertheless confirm that a competent whip-cracker, given high Presidential priorities, congressional support, and approval by the American people, could quickly and cost-effectively cut technological Gordian knots by welding individualistic innovators into a team and focusing their efforts until the mission is complete.

Manhattan Project. The Manhattan Project produced the world's first nuclear weapons less than 3 years after Brigadier General Leslie Groves, USA, took charge in 1942. Despite the mind-boggling needs to split atoms, develop critical masses, and create controlled chain reactions, scientists devised Little Boy, a uranium gun-type bomb, and Fat Man, a more complicated and powerful plutonium implosion weapon, and then linked those huge munitions with suitable delivery vehicles. A 19-kiloton Trinity test atop a tower near Alamogordo, New Mexico, ushered in the nuclear age shortly after daybreak on July 16, 1945. Little Boy and the untested Fat Man obliterated Hiroshima and Nagasaki respectively on August 6 and 9.[42] Japan almost immediately capitulated.

Polaris submarines. The U.S. Navy, with Rear Admiral William F. Raborn as program manager, expeditiously designed, developed, and tested Polaris submarines and submarine-launched ballistic missiles (SLBMs) 20 years after the Manhattan Project. That task involved at least five technological breakthroughs in breathtaking time: a nuclear propulsion system; an innovative navigation system; small nuclear warheads; solid fuel missile propellant; and an inertial guidance system suitable for SLBMs. Participants then deployed 41 boats within one decade (1957–1967)[43] that clearly were the world's best and remained so for several years.

Mercury, Gemini, and Apollo. Cosmonaut Yuri Gagarin, the first human being in space, circled this planet aboard *Vostok I* on April 12, 1961. U.S. astronauts thereafter left Soviet competitors in the lurch with astonishing speed beginning the very next month, when a Redstone rocket boosted Mercury capsule *Freedom Seven* 116 statute miles above Earth on a 15-minute, 28-second suborbital flight with Alan Shepard aboard. He barely had time to crow, "What a beautiful view!" before splashdown. Three weeks later, on May 25, 1961, President John F. Kennedy told Congress, "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth."[44]

NASA's team successfully completed 5 more Mercury, 10 Gemini, and 10 Apollo flights, then put not one but two men on the Moon. Meanwhile, a third loitered above after stacking a command module, service module, and lunar excursion module atop a Saturn V launch vehicle, the most powerful any nation ever built before or since (*Energiya*, a Soviet rocket that flew only twice, came closest in 1987–1988). Two prime movers kept progress on track: George Low, NASA Chief of Manned Space Flight, and NASA Administrator James E. Webb.[45]

Space exploration became a backwater soon thereafter, victimized by official disinterest and shrinking budgets that forced NASA to disband much of its marvelous team, which could have set the stage for military space capabilities. Infrequent shuttle flights and activities aboard a small international space station have been the only manned missions since Skylab's three-man crews briefly orbited Earth in the 1970s. Outposts on the Moon and other predicted spectacular outcomes remain conspicuously absent.

Astronomical Costs

Research, development, procurement, operational, and maintenance funds sufficient to deploy full-spectrum military space capabilities currently would strain DOD's budget to the breaking point, even if U.S. Armed Forces withdrew from Iraq today, rogue nations like North Korea and Iran no longer threatened U.S. national security interests, and the global war on terror ceased. Exploiting natural resources and manufacturing bulky items on the Moon rather than boosting heavy cargoes into space would cut costs by orders of magnitude, but those options apparently remain far in the future.[46] Meanwhile, most gaps between military spacepower concepts and reality will remain unbridgeable until affordable hardware and bases make pipe dreams come true.

Impotent Constituency

The U.S. Army Signal Corps activated an aeronautical division with three men and one reconnaissance aircraft in 1907, soon after the first powered flight at Kitty Hawk, North Carolina, on December 17, 1903. Five redesignations, many mission adjustments, and two world wars preceded decisions to form a separate Air Force four decades later, because operations aloft were distinctively different from those on land and at sea.[47]

U.S. military space forces remain orphaned 47 years after the first military satellites began to orbit Earth. The U.S. Army, Navy, and Air Force will continue to grant space responsibilities lower priorities than they deserve until Congress creates a separate service with coequal status on a land-sea-air-space team and assigns fundamental roles, and DOD fills in blank spots with functions that cover the complete conflict spectrum from normal peacetime competition through the most violent conceivable combat.

Future of U.S. Military Spacepower

President John Fitzgerald Kennedy assigned a compelling spacepower mission in 1961 when he told NASA to put a man on the Moon and return him safely during that decade. The Nation cheered when three heroes accomplished that daunting task in record-breaking time, but the White House and Congress put manned space exploration on back burners soon after Kennedy's one-shot mission was complete and have kept it there ever since.

President George W. Bush in August 2006 promulgated a new National Space Policy that declares that "United States national security is critically dependent upon space capabilities, and this dependence will grow." It enjoins the Secretary of Defense and the Director of National Intelligence, in consultation with the Secretary of State and other departments/agencies, to "employ appropriate planning, programming, and budgeting activities, organizational arrangements, and strategies that result in an operational force structure and optimized space capabilities that support the national and homeland security."[48] That document "talks the talk" but most likely will not "walk the walk," because it assigns no inspirational mission that appeals to resource providers and the American people. Accelerated development of comprehensive military space capabilities therefore awaits the issuance of a Presidentially motivated mission calculated to generate comprehensive and *sustained* support, as opposed to scintillating flashes in the pan like a few Moon landings.

Conclusion

The Soviet Union, a military superpower and sworn enemy of the United States, was the first nation to exploit space. We quickly caught up with and then surpassed that worthy opponent scientifically and technologically but, 50 years later, there is no U.S. military spacepower school of thought, despite probabilities that future surprises could dwarf Sputnik's strategic significance. U.S. military spacepower concepts are still confined to reconnaissance, surveillance, communications, and other support activities plus ballistic missile defense.

Admiral J.C. Wylie's *Military Strategy: A General Theory of Power Control* contains repeated pleas for "a full bag of strategic concepts that will always provide . . . a strategy applicable to a particular situation assumed for the future or existing at any given moment."[49] That thin volume additionally recommends readily available alternatives for employment whenever required, but venerated British strategist Basil H. Liddell Hart explained why resistance to a fully-fledged U.S. Space Force remains stubbornly strong when he wrote that "the only thing harder than getting a new idea into the military mind is to get an old one out."[50]

U.S. policymakers accordingly must massively alter existing mindsets, create a much better mix of offensive, defensive, and deterrent capabilities, cease excessive reliance on a few elaborate Earth-bound facilities that launch, control, support, and recover spacecraft, and replace supersensitive, costly vehicles with reliable, cost-effective collections. Failure to do so risks games of catch-up that may not be winnable if they delay imperative improvements too long. The most admirable military space concepts and plans, in short, would be marginally useful unless implementing personnel, materiel, and infrastructure are much improved.

Recommendations for Congress

- Enact legislation that creates a separate U.S. Space Force within the Department of Defense.
- Assign fundamental responsibilities (roles) analogous to those of our Army, Navy, Air Force, Coast Guard, and U.S. Special Operations Command.
- Designate an Assistant Secretary of Defense (ASD) for Spacepower, with responsibilities analogous to those of the ASD for Special Operations and Low-Intensity Conflict.

Recommendations for DOD

- Assign U.S. Space Force functions analogous to those of our Army, Navy, Air Force, Coast Guard, and U.S. Special Operations Command.
- Designate the Joint Staff's Director of Strategic Plans and Policy to oversee the development of creative military spacepower theories and concepts and to develop implementing policies and plans.
- Designate National Defense University (NDU) as the focal point for the development of creative military spacepower theories and concepts.
- Direct NDU to establish outreach programs designed to tap top-quality talent and an intellectual clearinghouse designed to integrate the best obtainable ideas.
- Designate an impartial Inspector General to inform the President of progress or lack thereof regarding U.S. military spacepower theories, concepts, policies, and plans.
- Expeditiously commence manned military space missions to break the inertia.

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Chapter 19:

Increasing the Military Uses of Space

Everett C. Dolman and Henry F. Cooper, Jr.

America's reliance on space is so extensive that a widespread loss of space capabilities would prove disastrous for both its military security and its civilian welfare. The Armed Forces would be obliged to hunker down in a defensive crouch awaiting withdrawal from dozens of no-longer-tenable foreign deployments. America's economy, and along with it the rest of the world's, would collapse.

For these reasons, the Air Force is charged with protecting space capabilities from harm and ensuring reliable space operations for the foreseeable future. As a martial organization, the Air Force looks to military means to achieve these assigned ends—as well it should. The military means it seeks include the ability to apply force in, through, and from space, as well as enabling and enhancing terrestrially based forces. Is this not self-evident?

Consider for a moment that the Navy has a similar charge: to ensure freedom of access to international waters and, when directed in times of conflict, to ensure that other states cannot operate there. Now imagine how the Navy might achieve these objectives if it were denied the use of weapons, to include shore-based weapons or those owned by other Services. What if it were further denied the capacity or legal power to research, develop, or test weapons? How effective could it be? Such restrictions would be absurd, of course. And yet this scenario is almost perfectly parallel with the conundrum facing the Air Force in space.

In this chapter, we make the case that opposition to increasing the militarization and weaponization of space is a misapplied legacy of the Cold War and that dramatic policy shifts are necessary to free the scientific, academic, and military communities to develop and deploy an optimum array of space capabilities, including weapons in space, eventually under the control of a U.S. Space Force.

Creating the Myth of Space Sanctuary

During World War II—before the advent of the atomic bomb or intercontinental ballistic missiles (ICBMs)—the Chief of the U.S. Army Air Corps, General "Hap" Arnold, had a prescient view of the future:

> Someday, not too distant; there can come streaking out of somewhere (we won't be able to hear it, it will come so fast) some kind of gadget with an explosive so powerful that one projectile will be able to wipe out completely this city of Washington. . . . I think we will meet the attack

> alright [sic] and, of course, in the air. But I'll tell you one thing, there won't be a goddam pilot in the sky! That attack will be met by machines guided not by human brains, but by devices conjured up by human brains.[1]

Within about 15 years of Arnold's comments, Soviet ICBMs armed with nuclear warheads did indeed have the ability to threaten Washington, but over 40 years later, America's ability to reliably defend itself from ICBMs remains minimal—due not to technology limitations but to long-standing policy and political constraints.

To understand the passion of the current opposition to space weapons, one must look into the fundamental issue of the Cold War: nuclear weapons deployed at a scale to threaten the existence of all life on the planet. The specter of potential nuclear devastation was so horrendous that a neo-ideal of a world without war became a political imperative. Longstanding realist preference for peace through strength was stymied by the invulnerability of ballistic missiles traveling at suborbital velocities. Thus, America accepted a policy of *assured* and *mutual* destruction to deter its opponents in a horrible (if effective) balance of terror. This meant it became politically infeasible even to contemplate shooting down missiles aimed at America or its allies— especially from machines in space that might prove so efficient as to *force* an opponent to strike while it could, before such a system became operational.

With the coupling of space capabilities, including the extremely important roles of force monitoring and treaty verification, to nuclear policy, the unique characteristics of nuclear weapons and warfare became interconnected with military space. This is perhaps understandable, if fundamentally in error, but not only did space weapons become anathema for missile defense, but also weapons in space for the protection of interests there became a forbidden topic.

Ironically, elements of the elite scientific community in the 1950s and 1960s created the conditions that frustrated the second half of Arnold's vision, which called upon America's edge in technology to provide for the Nation's defense—because they believed reaching that objective was not achievable and that seeking to achieve it was not desirable. Perhaps because they were motivated by guilt for their complicity in bringing the nuclear bomb to fruition, these individuals preferred to rely solely on diplomacy and arms control and argued against exploiting technology, which they believed would only provoke an arms race. They advocated this point of view at the highest political levels—and they were very successful in meeting their objectives.

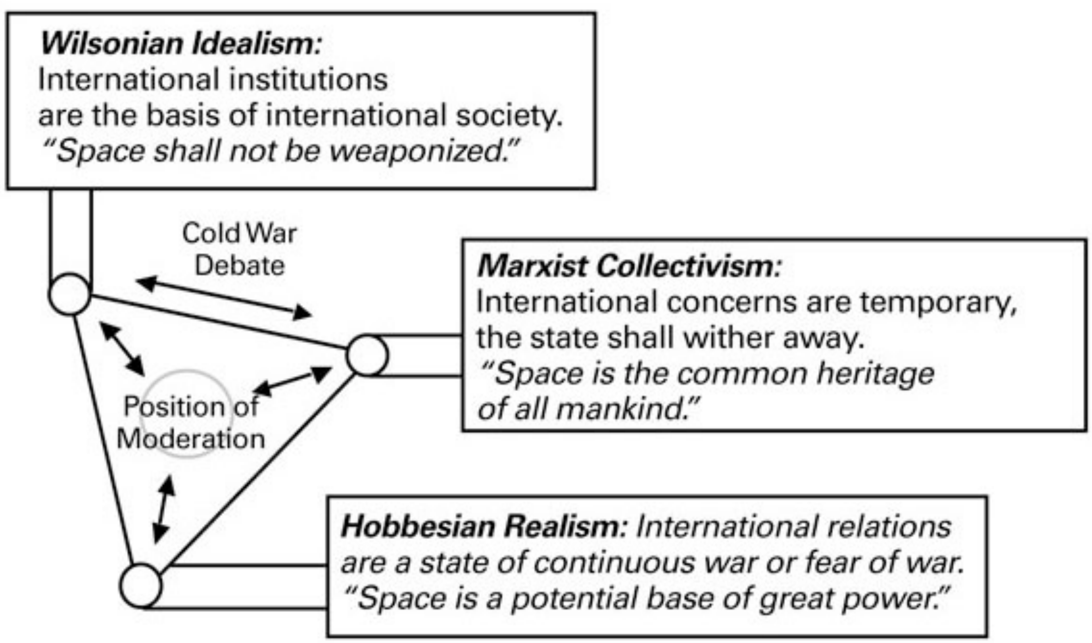
Whether by design or chance, the civilian leadership 40 to 50 years ago also imposed bureaucratic institutional constraints that limited the ability of the Services to exploit cutting-edge technologies to take advantage of space for traditional military purposes. When combined with arms control constraints and the current lack of vision among the military Services, this same dysfunctional space bureaucracy is simply not responsive to the growing threat from proliferating space technology among our adversaries as well as our friends.

What World Views Should Guide Space Exploration?

Current international relations political theory generally divides the panoply of world views into three broad outlooks: *Wilsonian idealism* or *liberalism, Marxist collectivism* or *socialism,* and *Hobbesian realism* (see figure 19–1). Arguably the most prevalent of these—certainly among practitioners if not academics—is the last, yet it has been conspicuously absent in the academic and theoretical debates concerning space exploration.

Wilsonian idealism is based on the tenets of a peaceful and democratic world order as espoused by Woodrow Wilson. It includes the notions that law and institutions are important factors leading to peace and that weapons are a basic cause of war. Hence, prevention of space weaponization through treaties and existing international organizations, completely eschewing any positive role for armed force, is its key pillar of space exploration. Equally prominent in the history of space development—due to the bipolar power structure of world politics through most of its developmental stage—has been the position of *Marxist-inspired collectivists*, who insist that space should not be appropriated by the nations or corporations of the Earth, and that whatever bounty is realized there must be shared by all peoples. Collectivist efforts are generally focused on legal and moral arguments binding states in a system of global wealth-sharing.

Figure 19–1. Triangulating the Space Exploitation Debate



Hobbesian realists, inspired in part by the political teachings of Thomas Hobbes, generally perceive the condition known as *anarchy*—that awful time when no higher power constrains the base impulses of men and states, and both survive by strength and wit alone—to be the underlying condition of international relations. Might indeed makes right to these theorists, if not morally, certainly in fact. For them, states exist in a perpetual condition of war. Periods between combat are best understood as preparation for the inevitable next conflict. The harshest view in this group is called *realpolitik*.

We advocate a position far less harsh than that of Hobbes, an outlook increasingly known as *soft realism*, as we believe that proper use of military power within a framework of laws and rules can lead to greater security and welfare for all peoples, not just the wielders of that power. We do assert, however, that the state retains its position as the primary actor in international affairs and that violence has an indisputable and continuing influence on relations between states and nonstate actors.

Still, in most academic and policy debates, the realist view has been set aside (at least rhetorically) as states jockey for international space leadership. Those who even question the blanket prohibitions on weapons or market forces in space exploration are ostracized. To actually advocate weaponization in space brings full condemnation. Accordingly, the debate has not been whether space *should* be weaponized, but how best to *prevent* the weaponization of space; not whether space *should* be developed commercially, but how to ensure the spoils of space are nonappropriable and *distributed fairly* to all. There has been little room for the view that state interest persists as the prime motivator in international relations, or that state-based capitalist exploitation of outer space would more efficiently reap and distribute any riches found there. It is for these reasons, we insist here and in several other venues, that space exploration and exploitation have been artificially stunted from what might have been.[2]

Hence, a timely injection of realist thought may be precisely what is needed to jolt space exploration from its post-Apollo sluggishness. Our intent here, then, is to add the third point of a theoretical triangle in an arena where it had been missing, so as to center the debate on a true midpoint of beliefs, and not along the radical axis of two of the three world-views.

The Misplaced Logic of Antiweaponization

Opposition to the deployment of weapons in space clusters around two broad categories of dissent: that it *cannot* be done, and that it *should not* be done.

Space Weapons *Are* Possible

Arguments in the first category spill the most ink in opposition, but they are relatively easy to dispatch. Consider first that history is littered with prophesies of technical and scientific inadequacy, such as Lord Kelvin's famous retort, "Heavier-than-air flying machines are impossible." Kelvin, a leading physicist and president of the Royal Society, made this boast in 1895, and no less an inventor than Thomas Edison agreed. The possibility of spaceflight prompted even more gloomy pessimism. A *New York Times* editorial in 1921 excoriated Robert Goddard for his silly notions of rocket-propelled space exploration (an opinion it has since retracted): "Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools." Compounding its error in judgment, opining in 1936, the *Times* stated flatly, "A rocket will never be able to leave the Earth's atmosphere."[3]

Bluntly negative scientific opinion on the possibility of space weapons writ large has been weeded out over time. No credible scientist today makes the claim of impossibility, and so less encompassing arguments are now the rule. The debate has moved to more subtle and scientifically sustainable arguments that a *particular* space weapon is not feasible. Mountains of mathematical formulae have been piled high in an effort, one by one, simply to bury the concept. But these limitations on specific systems are less due to theoretical analysis than to assumptions about future funding and available technology.[4] The real objection, too often hidden from view, is that a *particular* weapons system or capability cannot be developed and deployed within the planned budget or within narrowly specified means. When one relaxes those assumptions, opposition on technical grounds generally falls away.

Furthermore, counterexamples exist—for example, the Brilliant Pebbles space-based interceptor system was the most advanced defense concept to emerge from the Strategic Defense Initiative (SDI). After a comprehensive series of technical reviews by even the strongest critics in 1989, it achieved major defense acquisition program status in 1990, was curtailed by congressional cuts in 1991 and 1992, and then was canceled by the Clinton administration in 1993. But the cancellation of the most advanced, least expensive, and most cost-effective missile defense system produced by the SDI program was for political, not technical, reasons.[5]

The devil may very well be in the details. But when critics oppose an entire *class* of weapons based upon analyses that show *particular* weapons will not work, their arguments fail to consider the inevitable arrival of fresh concepts or new technologies that change all notions of current capabilities. Have we thought out the details enough to say categorically that *no* technology will allow for a viable space weapons capability? If so, then the argument is pat; no counter is possible. But if there are technologies or conditions that *could* allow for the successful weaponization of space, then ought we not argue the policy details first, lest we be swept away by a course of action that merely chases the technology wherever it may go?

SpaceWeapons *Should* Be Deployed

Opponents of space weapons on technical or budgetary grounds are *not* advocating space weapons in the event their current assumptions or analyses are swept aside. Rather, they argue that we *ought* not to deploy space weapons. Granted, just because a thing *can* be done does not mean it *should* be. But prescience is imperfect, new technologies emerge unpredictably, and foolish policymakers eschew adapting to them until their utility is beyond doubt. In anticipation of coming technologies that would make space weaponization a most cost-effective option, moral opposition centers on six essential arguments.

Space weapons are expensive; alternatives are cheaper and just as effective. This is the first argument against space weaponization, although it is an easy one to set aside. Of course space weapons are expensive—very expensive, though not necessarily more expensive than terrestrially based systems that may accomplish the same objectives, not to mention objectives that cannot be met otherwise—but so are all revolutionary technologies, particularly those that pioneer a new medium. Furthermore, the state that achieves cutting-edge military technology first has historically been the recipient of tremendous battlefield advantage, and so pursuit of cut-ting-edge technology continues—despite the enormous cost. Moreover, the cultural and economic infrastructure that allows for and promotes innovation in the highest technologies *tends to remain at the forefront* of international influence.

All empires decline and eventually are subsumed, but it has not been their search for the newest technologies or desire to stay at the forefront of innovation that causes their declines. Rather, it has been the *policies* of those states, generally an overexpansion of imperial control or an economic decision to freeze technologies, that result in their stagnation and demise. Space and space technology represent both the resources and the innovation that can keep a liberal and responsible American hegemony in place for decades, if not centuries, to come; furthermore, unless America maintains this technological edge, it will likely lose its preeminence.

A follow-on argument is rhetorical and usually takes the form, "Wouldn't the money spent on space weapons be better spent elsewhere?" It would be lovely if the tens of billions of dollars necessary to effectively weaponize space could be spent on education, or the environment, or dozens of other worthy causes, but this is a moot argument. Money necessary for space weapons will not come from the Departments of the Interior or State or from any other department except Defense. Any windfall for *not* pursuing space weaponization is speculative only and is therefore not transitive. This means that the funds for space weaponization will come at the expense of other military projects, from within the budget of the Department of Defense. This observation is the basis for criticism among military traditionalists, who see the advent of space weapons as the beginning of the end for conventional warfare.

Current conventional military forces and means are enough to ensure America's security needs, so why risk weaponization of space? The United States has the greatest military force the world has known; why change it when it is not broken? This argument is, obviously, tightly connected to the previous response, which points out that states failing to adapt to change eventually fall by the wayside. But more so, it shows a paucity of moral righteousness on the opposition's side. For the cost of deploying an effective space weapons program, America could buy and maintain 10 more heavy divisions (or, say, 6 more carrier battlegroups and 6 fighter wings). Let us suppose that is true. What would be more threatening to the international environment, to the sovereignty of states: a few hundred antiballistic missile satellites in low Earth orbit (LEO) backed by a handful of space lasers, or 10 heavy divisions with the support infrastructure to move and supply them anywhere on the globe?

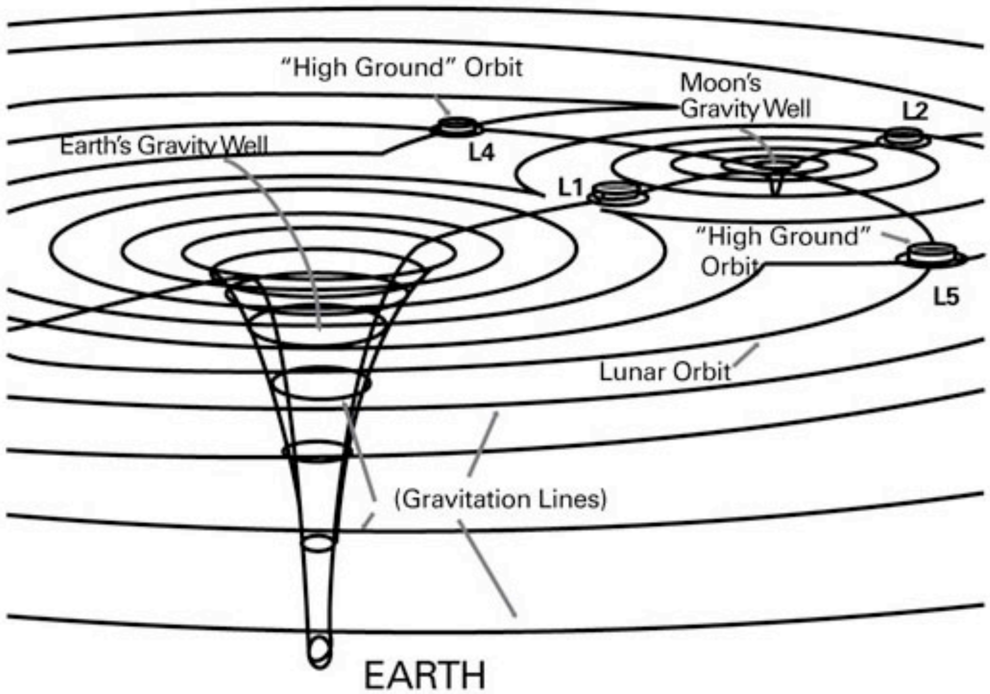
This further highlights a common ethical omission of many space weaponization opponents. Most insist they are not opposed to weapons per se, only to weapons in space. Indeed, they insist a conventional strike against a threatening state's space facility would be just as effective as destroying satellites in space and a whole lot cheaper and more reliable to boot. But what does it say about an argument that asserts weapons cannot be in space, where no people reside, and insists that wars there would be terrible, while at the same time it advocates, even encourages, such violence on Earth? Why is it that weapons in *space* are so dreadful, but the same weapons on land, on sea, and in the air are perfectly fine?

Space is too vast to be controlled. If one state weaponizes, then all other states will follow suit, and a crippling arms race in space will ensue. Space is indeed vast, but a quick analysis of the fundamentals of space terrain and geography shows that control of just LEO would be tantamount to a global gate or checkpoint for entrance into space, a position that could not be flanked and would require an incredible exertion of military power to dislodge. Thus, the real question quickly becomes not whether the United States should weaponize space first, but whether it can afford to be the *second* to weaponize space.

Space has been dubbed the *ultimate high ground* (see figure 19–2). As with the high ground throughout history, whosoever sits ensconced upon it accrues incredible benefit on the terrestrial battlefield. This comes from the dual advantages of enhanced span of command acuity (visibility and control) and kinetic power. It is simply easier and more powerful to shoot down the hill than up it.

The pace of technological development, particularly in microsatellites and networked operations, could allow a major spacefaring state to quickly establish enough independent kinetic kill vehicles in LEO (through multiple payload launches) to effectively deny entry or transit to any other state. Currently, the United States has the infrastructure and capacity to do so; China may in the very near future. Russia is also a potential candidate for a space coup. Should any one of these states put enough weapons in orbit, they could engage and shoot down attempts to place counterspace assets in orbit, effectively taking control of outer space. Indeed, the potential to be gained from ensuring spacepower projection while denying that capability in others is so great that some state, some day, *will* make the attempt.

Figure 19–2. Gravitational Terrain of Earth-Moon Space



In order to ensure that no one tries, space weapons opponents argue that the best defense is a good example. So long as the United States does not make any effort to weaponize space, why would any competing state be tempted to do so? And even if another state does attempt it, the United States has the infrastructure to quickly follow suit and commence a campaign of retrieval in space. Not only does the logic escape us, but also it seems that by waiting, the United States is *guaranteeing* what space weapons opponents fear most: a space arms race.

All states will oppose an American military occupation of space, and their combined power will accelerate the demise of the United States. There is no doubt that the United States will be opposed in its efforts to dominate space militarily. There will always be fear that any state attempting to enhance its power may use it to act capriciously, but to suggest that the inevitable result is a space arms competition is the worst kind of mirror-imaging. If the United States, in the very near future, were to seize space, it would do so in an attempt to extend its current hegemonic power. Other states may feel threatened by this and will certainly begrudge it, but would any be willing to bankrupt their economies to develop the multi-trillion-dollar infrastructure necessary to defeat the United States *in* space, all the way up the daunting gravity well of Earth? Especially after the first billions were spent and a weapons system was launched, if the United States showed the will to destroy that rocket in flight (or the laser on the ground), how long would another state be willing to sustain its commitment to replacing America as controller of space?

On the other hand, any attempt by another power to seize and control space must be viewed as an attempt to overturn the extant international order, to replace America as the global hegemon. The United States, with investment already made in the necessary space infrastructure, would be forced to compete or cede world leadership—the latter an unlikely decision, one never historically taken by the reigning hegemon. The lesson is unambiguous; if you want an arms race in space, wait for it.

But here is where the paradox of opposing weapons in space is most apparent. On the one hand, we are told that if the United States weaponizes space, it will accelerate its own demise. The expense is too great, the ill will it fosters too encumbering, and the security too fleeting. Space cannot be controlled and therefore combat will occur, because to allow the United States to control space is tantamount to serving forever under its imperial thumb. Oddly, space weaponization is said to be both empowering and crippling—whichever argument appears most persuasive at the time.

Weaponization of space will create conditions that will make space travel risky if not impossible.Having extended the illogic of opposing space weapons to the limit, opponents then take on the mechanics of war and the evils of the military. As for the first argument, orbital debris is the challenge, which the recent Chinese antisatellite (ASAT) test confirms. The destruction of its own dying satellite in 2007 created thousands of bits of debris that are now floating at orbital velocity, an expanding cloud that poses a lasting navigational hazard to legitimate space flight. True, the Chinese test was criminal, especially since it *could have* engaged with almost no debris remnants if it had altered its engagement path. In over a dozen antisatellite tests that the Soviet Union held in the 1970s and 1980s, only the first left appreciable debris. After that, the massive co-orbital ASAT engaged in a kinetic direction toward the Earth, down the gravity well, causing all of the detritus of the ASAT and target to burn up in the atmosphere. Indeed, in a scenario where the United States is controlling space, most engagements would occur in launch phase, before the weapons even reach orbit. Any debris that is not burned up or destroyed will fall onto the launching state. Because tested weapons systems have maximized destruction to validate capabilities does not mean that future engagements must create long-lasting debris fields. Satellites are very fragile, and a bump or a push in the wrong direction is all that is necessary to send them spinning off into a useless or uncontrollable orbit—if you get to space first. Space war does not have to be dirty war, and in fact spacefaring nations will go out of their way to ensure that it is not (an argument that non-spacefaring powers may wish to fight dirty, and the only reliable defense against them would be *in* space, occurs below).

The second argument concerns commerce and tourism. Opponents say that space weapons would make individuals afraid to do business in space or travel there for pleasure, for fear of being blown to smithereens. This is an emotional appeal that has no basis in fact. Currently, for example, weapons are pervasive on the seas, in the air, and on land, but wherever there is a dominating power, commerce and travel are secure. America's Navy has dominated the open oceans for the last half-century, ensuring that commerce is fair and free for *all* nations, as has its Air Force in nonterritorial airspace. A ship leaving port today is more likely than ever to make it to its destination, safer from pirates, rogue states, navigational hazards, and even weather—all due to the enforcement of the rule of law on the seas and the assistance of sea- and space-based navigational assistance. Why would American dominance in space be different?

Space weapons advocates oppose treaties and obligations and want outer space ruled at the whim of whoever holds military power. This is a false argument, completely unsupportable. There is no dichotomy demanding law *or* order. Solutions lie in the most effective combination of law *and* order. There is no desire for a legal free-for-all or an arbitrary and capricious wielding of power by one state over all others. What we advocate is a *new* international legal regime that recognizes the lawful use of space by all nations, to include its commercial exploitation under appropriate rules of property and responsible free market values, to be enforced where necessary by the United States and its allies.

Beyond Theory: Military Space Realities

In 1991, U.S. forces defeated the world's fourth-largest military in just 10 days of ground combat. The Gulf War witnessed the public and operational debut of unfathomably complicated battle equipment, sleek new aircraft employing stealth technology, and promising new missile interceptors. Arthur C. Clarke went so far as to dub Operation *Desert Storm* the world's first space war, as none of the accomplishments of America's new-look military would have been possible without support from space.[6] Twelve years later, Operation *Iraqi Freedom* proved that the central role of spacepower could no longer be denied. America's military had made the transition from a space-supported to a fully space-enabled force, with astonishing results. The U.S. military successfully exercised most of its current spacepower functions, including space lift, command and control, rapid battle damage assessment, meteorological support, and timing and navigation techniques such as Blue Force tracking, which significantly reduced incidences of fratricide.

The tremendous growth in reliance on space from *Desert Storm* to *Iraqi Freedom* is evident in the raw numbers. The use of operational satellite communications increased four-fold, despite being used to support a much smaller force (fewer than 200,000 personnel compared with more than 500,000). New operational concepts such as *reach back* (intelligence analysts in the United States sending information directly to frontline units) and *reach forward* (rear-deployed commanders able to direct battlefield operations in real time) reconfigured the tactical concept of war. The value of Predator and Global Hawk unmanned aerial vehicles (UAVs), completely reliant on satellite communications and navigation for their operation, was confirmed. Satellite support also allowed Special Forces units to range across Iraq in extremely disruptive independent operations, practically unfettered in their silent movements.

But the paramount effect of space-enabled warfare was in the area of combat efficiency. Space assets allowed all-weather, day-night precision munitions to provide the bulk of America's striking power. Attacks from standoff platforms, including Vietnam-era B–52s, allowed maximum target devastation with extraordinarily low casualty rates and collateral damage. In *Desert Storm*, only 8 percent of munitions used were precision-guided, none of which were GPS-capable. By *Iraqi Freedom*, nearly 70 percent were precision-guided, more than half from GPS satellites.[7] In *Desert Storm*, fewer than 5 percent of aircraft were GPS-equipped. By *Iraqi Freedom*, *all* were. During *Desert Storm*, GPS proved so valuable that the Army procured and rushed into theater more than

4,500 commercial receivers to augment the meager 800 military-band ones it could deploy from stockpiles, an average of 1 per company (about 200 personnel). By *Iraqi Freedom*, each Army squad (6 to 10 Soldiers) had *at least* 1 military GPS receiver.

If, as it has been said, the 1990 Gulf War was the first space war—the birth of military enhancement and enabling space capabilities that had long gestated in the role of mission support—then the twin Operations *Enduring Freedom* and *Iraqi Freedom* represent military spacepower's coming-out party. Space support enabled a level of precision, stealth, command and control, intelligence-gathering, speed, maneuverability, flexibility, and lethality heretofore unknown. U.S. combat capabilities were absolutely dominant in these conflicts—and the entire world now understands the significant military role played by space systems.

Unfortunately, the American military has bogged down in Phase IV operations in Iraq. An externally funded and supplied insurgency continues, and the death toll mounts. For critics of the George W. Bush administration's policies, the perceived inability of the U.S. Army to win this unconventional war is evidence that too much effort has been placed on conventional capabilities. A further argument persists that air and space forces are expensive luxuries that have no place in the retro-battlefield of counterterrorism. This is a position that ignores the cultural and political realities in Iraq and confuses policy for military capability.

Wherever America's ground troops engage in Iraq, they perform magnificently. In a nation as large as California with a population of more than 20 million, the 50,000 combat troops in Iraq are hard pressed to be in the right place at the right time. Support comes significantly from space and airborne assets, which are the first line of defense in the war on terror. The refuge of individuals whose intention is to spread violence randomly and without regard to the status of noncombatants is to blend into their surroundings. They are found out when they move in areas that are restricted, engage in Internet coordination or electronic communications, purchase or move incendiary materials or other weapons, or gather in significant numbers. When they do, they can be pinpointed, but with such a small force, it takes time for Soldiers to get into position and engage their targets.

Weapons in space could provide the global security needed to disrupt and counter small groups of terrorists wherever they operate, at the very moment they are identified. Currently, UAVs, dependent on space support for operations, fly persistent missions above areas of suspected terrorist activity in Iraq, providing real-time intelligence and, in some cases, onboard weapons to support ground forces in a specific area. Tactical units are informed of approaching hostiles, and due to all-weather and multi-spectral imaging systems, both friendly (Blue Force) and enemy tracking can occur throughout engagement operations. When ground troops are unable to respond to threatening situations beyond their line of sight or are unable to catch fleeing hostiles, armed UAVs can engage those threats.

The other option in a large-scale counterterror operation is to bring in an overwhelming number of troops, enough to create a line across the entire country that can move forward, rousting and checking every shack and hovel, every tree and ditch, with enough Soldiers in reserve to prevent enemy combatants from re-infiltrating the previously checked zones. America could in this manner combat low-tech terrorism with low-tech mass military maneuvers, perhaps at a cost savings over an effective space-based surveillance and engagement capability (if one does not count the value of a Soldier's life), but we do not think dollar value is the overriding consideration in this situation.

Terrorism in the form of limited, low-technology attacks is the most likely direct threat against America and its allies today, and space support is enabling the most sophisticated response ever seen. All-source intelligence has foiled dozens of attacks by al Qaeda and its associates. But what of the *most dangerous* threats today? Weapons of mass destruction, particularly nuclear but also chemical and biological ones, could be delivered in a variety of means vulnerable to interception if knowledge of their location is achieved in time for counteroperations to be effective. In situations where there is no defense available, or the need for one has not been anticipated, then time is the most precious commodity.

A limited strike capability from space would allow for the engagement of the highest threat and the most fleeting targets wherever they presented themselves on the globe, regardless of the intention of the perpetrator. The case of a ballistic missile carrying nuclear warheads is exemplary. Two decades ago, the most dangerous threat facing America (and the world) was a massive exchange of nuclear warheads that could destroy all life on the planet. Since a perfect defense was not achievable, negotiators agreed to no defense at all, on the assumption that reasonable leaders would restrain themselves from global catastrophe.

Today, a massive exchange is less likely than at any period of the Cold War, in part because of significant reductions in the primary nations' nuclear arsenals. The most likely *and* most dangerous threat comes from a single or limited missile launch, and from sources that are unlikely to be either rational or predictable. The first is an accidental launch, a threat we avoided making protections against due to the potentially destabilizing effect on the precarious Cold War balance. That an accidental launch, by definition undeterrable, would today hit its target is almost incomprehensible.

More likely than an accidental launch is the intentional launch of one or a few missiles, either by a nonstate actor (a terrorist or "rogue boat captain" as the scenario was described in the early 1980s) or a rogue state attempting to maximize damage as a prelude to broader conflict. This is especially likely in the underdeveloped theories pertaining to deterring third-party states. The United States can do nothing today to prevent India from launching a nuclear attack against Pakistan (or vice versa) except threaten retaliation. If Iran should launch a nuclear missile at Israel, or in a preemptory strike Israel should attempt the reverse, America and the world could only sit back and watch, hoping that a potentially world-destroying conflict did not spin out of control.

When President Reagan announced his desire for a missile shield in 1983, critics pointed out that even if a 99-percent-reliable defense from space could be achieved, a 10,000-warhead salvo by the Soviet Union still allowed for the detonation of 100 nuclear bombs in American cities—and both we and the Soviets had enough missiles to make such an attack plausible.

But if a single missile were launched out of the blue from deep within the Asian landmass today, for whatever reason, a space-based missile defense system with 99-percent reliability would be a godsend. And if a U.S. space defense could intercept a single Scud missile launched by terrorists from a ship near America's coasts before it detonated a nuclear warhead 100 miles up—creating an electromagnetic pulse that shuts down America's powergrid, halts America's banking and commerce, and reduces the battlefield for America's military to third world status[8]—it might provide for the very survival of our way of life.

Looking for Leadership

Such dire speculations call for enlightened leadership. Such a call is not new, but it is as yet unanswered. For example, in their February 2000 report, the co-chairmen of the Defense Science Board on Space Superiority wrote that:

> space superiority is absolutely essential in achieving global awareness on the battlefield, deterrence of potential conflict, and superior combat effectiveness of U.S. and Allied/Coalition military forces. . . . An essential part of the deterrence strategy is development of viable and visible (and perhaps demonstrated) capabilities to protect our space systems and to prevent the space capabilities being available to a potential adversary. . . . The Task Force recommends that improvements be made to our space surveillance system, higher priority and funding be placed on the "protection" of U.S. space systems, and that programs be started to create a viable and visible offensive space control capability.[9]

Despite this specific call for change near the beginning of the George W. Bush administration, one thought to be friendly to the idea of militarizing space, any move toward space superiority has so far been frustrated— as has consistently been the case during the past 50 years, when programs critical to obtaining an effective space force ran into a political/policy buzzsaw, particularly when space weapons were in any way involved. In 1983 and 1984, for example, the Reagan administration worked hard to reverse the so-called Tsongas amendment that held hostage the development and testing of the Air Force's F–15 hit-to-kill (HTK) ASAT system to a commitment that the United States would enter negotiations on a comprehensive ban of all ASAT systems. Congress, in response to the 1982 Reagan National Space Policy (which explicitly directed deployment of an ASAT system), was taken with testimony and arguments about the dangers of militarizing space and an associated arms race, the alleged lack of a requirement for an ASAT system, and suggested alternatives to developing an ASAT capability—especially including arms control.[10] A major component of the resistance came from members of the scientific community.

The Reagan administration's 1984 report to Congress and the administration's many meetings with Senators, Representatives, and their staffs eventually carried the day, and the Air Force was released to test successfully its prototype system on September 13, 1985—against a noncooperative target, which should be noted by those who claim all HTK tests have been against contrived targets.[11] An operational F–15 fighter used its prototype ASAT to shoot down a dying satellite that had been on orbit for years—against a cold space background. And that was over 20 years ago, using 25-year-old technology, in a program begun in the latter days of the Ford administration and carried through the Carter years into Reagan's second term.

So what happened? With fanfare about not militarizing space (responsive to criticism by the arms control elite and numerous nations, including the Soviet Union) and no serious Air Force advocacy, Congress defunded follow-on F–15 ASAT activities, and the United States has not built a hitto-kill ASAT, in spite of the then- (and still-) operational Soviet/Russian co-orbital ASAT and China's recent test of its direct-ascent ASAT.[12]

The 1996 National Space Policies embed force application capabilities in euphemistic arms control language, for example, as discussed by Marc Berkowitz:

> [C]ritical capabilities necessary for executing space missions must be assured. Moreover, the policy directs that, consistent with treaty obligations, the U.S. will develop, operate, and maintain space control capabilities to ensure freedom of action in space and, if directed, deny such freedom of action to adversaries. Such capabilities may also be enhanced by diplomatic, legal, or military measures to preclude an adversary's hostile use of space systems and services.[13]

The 2006 National Space Policy, released without fanfare on a Friday afternoon before a long holiday weekend, is consistent with the 1996 pol-icy—and numerous preceding space policy statements as well.[14] Among other things, it states that "freedom of action in space is as important to the United States as air power and sea power"; notes that the exploration and use of outer space "for peaceful purposes" allows "U.S. defense and intelligence-related activities in pursuit of national interests"; states that "fundamental goals" are to "sustain the nation's leadership and ensure that space capabilities are available in time to further U.S. national security, homeland security and foreign policy objectives" and "enable U.S. operations in and through space to defend our interests there"; and directs the Secretary of Defense to "maintain the capabilities to execute space support, force enhancement, space control, and force application missions."

While the policy certainly can be interpreted to support an agenda to fully militarize space, decisive leadership to do so is lacking, presumably because of the political impedance illustrated by the above historical examples. Even military experts seem inclined to shrink from advocacy of fully exploiting space for military purposes—

accepting that "space sensors are good, but space weapons are bad"—not a serious military perspective. Today, the Air Force contributes 90 percent of DOD's space personnel, 85 percent of DOD's space budget, 86 percent of DOD's space assets, and 90 percent of DOD's space infrastructure[15]—yet it has no comprehensive doctrine to guide the Nation's exploitation of space and assure U.S. supremacy—as the 2000 Defense Science Board stated should be the objective of the Nation's military space programs.[16]

Furthermore, the Defense establishment writ large also has taken little action to improve the situation, even under the leadership of former Defense Secretary Donald Rumsfeld, who in 2000 led a congressionally mandated Commission to Assess the United States National Security Space Management and Organization, fostered by former Senator Bob Smith (R–NH) to challenge the status quo of U.S. military space programs and move toward a needed U.S. Space Force.[17] The commission's unanimous bipartisan consensus conclusions and recommendations, which would move the Pentagon toward that desired objective, might have been expected to be guidelines under Secretary Rumsfeld—but, alas, there was little improvement on his watch. In fact, regressive steps, such as the disestablishment of U.S. Space Command, work in precisely the opposite direction. Meeting this challenge will rest with successor administrations.[18]

Astropolitical Realism

We aver that the application of space technology to military operations is simply the latest in a logical line of techno-innovations in the continuing process of developing military theory and strategy. In its narrowest construct, astropolitical realism comprises an extension of existing theories of global geopolitics into the vast context of the human conquest of outer space. In its more general and encompassing interpretation, it is the application of the prominent and refined realist visions of state political and military competition into outer space policy, particularly the development and evolution of a new legal and political regime that maximizes both global security and prosperity. Though historians have done an adequate job of describing the realist—even a harsh *realpolitik*—view of humanity's tendency toward confrontational diplomatic exchange in the chronology of space exploration, no similar effort has been made to place a stringent conceptual framework around and among the many vectors of space policies and chronicles.[19]

Thus, we propose fitting realist elements of space politics into their proper places in space strategy. While it may seem barbaric in this modern era to continue to assert the primacy of war and violence—"high politics" in the realist vernacular—in formulations of state strategy, it would be disingenuous and even reckless to try to deny the continued dominance of the terrestrial state and the place of military action in the short history and near future of space operations.

In the process, we advocate an open, honest debate about the future of American space intentions and the application of classical and emerging strategic theory to all realms of space exploration and exploitation— including:

- its protection as a domain for private investment and commercialization
- recognition of the emerging role of space as the critical, even quintessential, capacity for continuing American military preeminence in the international system
- a thorough understanding of the astromechanical and physical properties of outer space essential for an optimum deployment of military space assets
- a long-overdue development of a revamped legal and political regime based on current international realities and not Cold War fantasies.

Conclusion

With great power comes great responsibility. If the United States deploys and uses its military space force in concert with allies and friends to maintain effective control of space in a way that is perceived as tough, nonarbitrary, and efficient, adversaries would be discouraged from fielding opposing systems. Should the United States and its allies and friends use their advantage to police the heavens and allow unhindered peaceful use of space by any and all nations for economic and scientific development, control of low Earth orbit over time would be viewed as a global asset and a collective good. In much the same way it has maintained control of the high seas, enforcing international norms of innocent passage and property rights, the United States could prepare outer space for a long-overdue burst of economic expansion.

There is reasonable historic support for the notion that the most peaceful and prosperous periods in modern history coincide with the appearance of a strong, liberal hegemon. America has been essentially unchallenged in its naval dominance over the last 60 years and in global air supremacy for the last 15 or more. Today, there is more international commerce on the oceans and in the air than ever. Ships and aircraft of all nations worry more about running into bad weather than about being commandeered by a military vessel or set upon by pirates. Search and rescue is a far more common task than forced embargo, and the transfer of humanitarian aid is a regular mission. Lest one think this era of cooperation is predicated on intentions rather than military stability, recall that the policy of open skies advocated by every President since Eisenhower did not take effect until after the fall of the Soviet Union and the singular rise of American power to the fore of international politics. The legacy of American military domination of the sea and air has been positive, and the same should be expected for space.

As leader of the international community, the United States finds itself in the unenviable position of having to make decisions for the good of all. No matter the choice, some parties will benefit and others will suffer. The tragedy of American power is that it must make a choice, and the worst choice is to do nothing. Fortunately, the United States has a great advantage: its people's moral ambiguity about the use of power. There is no question that corrupted power is dangerous, but perhaps only Americans are so concerned with the possibility that they themselves will be corrupted. They fear what they could become. No other state has such potential for self-restraint. It is this introspection, this angst, that makes America the best choice to lead the world today and tomorrow.

America is not perfect, but perhaps it is perfectible, and it is preferable to other alternatives that will lead if America falters at the current crossroad.

Space weapons, along with the parallel development of information, precision, and stealth capabilities, represent a true revolution in military affairs. These technologies and capabilities will propel the world into an uncertain new age. Only a spasm of nuclear nihilism could curtail this future. By moving forward against the fears of the many, and harnessing these new technologies to a forward-looking strategy of cooperative advantage for all, the United States has the potential to initiate mankind's first global golden age. The nature of international relations and the lessons of history dictate that such a course begin with the vision and will of a few acting in the benefit of all. America must lead, for the benefit of all.

Notes

1. Quoted from Jacob Neufeld, *Ballistic Missiles in the United States Air Force, 1945–1960* (Washington, DC: Office of Air Force History, 1990), 35.
2. See, for example, Everett Dolman and John Hickman, "Resurrecting the Space Age: A State-Centered Commentary on the Outer Space Regime," *Comparative Strategy* 21 (Winter 2002), 1–45.
3. Cited by Herbert London, "Piercing the Gloom and Doom," *American Outlook* (Spring 1999), available at <http://ao.hudson.org/index.cfm?fuseaction=article_detail&id=1270>.
4. See, for example, Robert Preston, Dana J. Johnson, Sean J.A. Edwards, Michael D. Miller, and Calvin Shipbaugh, *Space Weapons: Earth Wars* (Santa Monica, CA: RAND Corporation, 2003).
5. See Donald R. Baucomb, "The Rise and Fall of Brilliant Pebbles," *Journal of Social, Political, and Economic Studies* 29, no. 2 (2002), 145–190.
6. Cited in John Burgess, "Satellites' Gaze Provides New Look at War," *The Washington Post*, February 19, 1991, A13.
7. Testimony of Deputy Secretary of Defense Paul Wolfowitz, on U.S. Military Presence in Iraq: Implications for Global Defense Posture, for the House Armed Services Committee, Washington, DC, June 18, 2003. See also Department of Defense, *Conduct of the Persian Gulf War: Final Report to Congress* (Washington, DC: Department of Defense, April 1992), 227–228.
8. While such a nuclear detonation would harm no one directly, the resulting electromagnetic pulse would wreak havoc on the U.S. powergrid, communication networks, and other critical infrastructure—with major national and international consequences. It could also cause significant upset and damage to satellite systems that are vital to U.S. terrestrial force operations and capabilities. See *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*, *Executive Report*, vol. I, 2004, pursuant to Public Law 201, 104th Congress, July 15, 1998.
9. Office of the Undersecretary of Defense for Acquisition and Technology, "Report of the Defense Science Board Task Force on Space Superiority," Washington, DC, February 2000. The board recommended that U.S. policymakers articulate two declaratory statements: "The United States will take all appropriate self-defense measures, including the use of force, to respond to the purposeful interference with U.S. or Allied space systems, or those systems critical in supporting national security interests"; and "The United States will take appropriate self-defense measures, including diplomatic and legal means as well as the flexible use of force, in response to the use of space by an adversary for purposes hostile to U.S. national interests." Among other things, the report concludes, "The use of space has become such a dominant factor in the outcome of future military conflict and in the protection of vital national and global interest that it should take on a

priority and funding level similar to that which existed for U.S. strategic forces in the 1960s through 1980s."

10. See "Fact Sheet Outlining United States Space Policy," July 4, 1982, Public Papers of President Ronald W. Reagan, Ronald Reagan Presidential Library, available at <www.reaganutexas.edu/archives/ speeches/1982/70482b.htm>.
11. As argued in President Reagan's March 31, 1984, report to the Congress on U.S. Policy on ASAT Arms Control, such a comprehensive ban would not be verifiable and would be ineffective in precluding the development of a number of systems—including intercontinental ballistic missiles and various space systems—that would have inherent ASAT capability and, in any case, such a ban is not in the U.S. national security interest. President Reagan declared, "[N]o arrangements or agreements beyond those already governing military activities in outer space have been found to date that are judged to be in the overall interest of the United States or its Allies."
12. The failure of the F–15 ASAT program, after a decade of research and development costing over $1.5 billion, can be traced to incoherence in program advocacy and related arms control initiatives during several administrations. See Henry F. Cooper, "Anti-Satellite Systems and Arms Control: Lessons from the Past," *Strategic Review* (Spring 1989), 40–48. For example, President Carter, while continuing the same F–15 ASAT program, proposed a comprehensive ASAT ban in 1977 in his first package of arms control initiatives—fortunately, the Soviets rejected it outright. Beginning with their 1981 UN proposal, the Soviets proposed a comprehensive ban—while conducting major military exercises including multiple tests of their co-orbital ASAT. The arms control community, including many in the scientific community, judged that the Reagan policy meant an end to arms control. See, for example, Paul B. Stares, *The Militarization of Space: U.S. Policy, 1945–1984* (Ithaca, NY: Cornell University, 1985).
13. A comprehensive discussion of the 1996 U.S. space policy is given by Marc J. Berkowitz, "National Space Policy and National Defense," *Spacepower for the New Millennium* (Colorado Springs: U.S. Air Force Institute for National Security Studies/McGraw-Hill, 2000), 37–59.
14. The unclassified summary of the 2006 National Space Policy, released by the White House on August 31, 2006, is available at <www.ostp.gov/html/US%20National%20Space%20Policy.pdf>.
15. Michael E. Ryan and F. Whitten Peters, *The Aerospace Force: Defending America in the 21st Century—A White Paper on Aerospace Integration* (Washington, DC: Department of the Air Force, May 2000), 5.
16. For a critical review of this lack of vision, see Peter L. Hays and Karl P. Mueller, "Going Boldly—Where? Aerospace Integration, the Space Commission, and the Air Force's Vision for Space," *Aerospace Power Journal* (Spring 2001).
17. The Commission's report, issued pursuant to Public Law 106–65 on January 11, 2001, is available at <www.defenselink.mil/pubs/space20010111.pdf>.
18. For a discussion of these considerations, see "What Do You Leave Behind? Evaluating the Bush Administration's National Security Space Policy," *George C. Marshall Institute Policy Outlook*, December 2006, available at <www.marshall.org/pdf/materials/490.pdf>.
19. See Walter McDougall's incomparable . . . *the Heavens and the Earth* (New York: Basic Books, 1986).

Chapter 20:

Preserving Freedom of Action in Space: Realizing the Potential and Limits of U.S. Spacepower

Michael Krepon, Theresa Hitchens, and Michael Katz-Hyman

Our working definition of *spacepower* is the sum total of capabilities that contribute to a nation's ability to benefit from the use of space. Space-power, like other types of power, can wax or wane depending on a country's choices and those of its potential adversaries. Wise national decisions can lead to cumulative increases in spacepower, but even they can be negated, if, for example, significant debris-increasing events in space impair spacepower for all nations.

There is widespread agreement on what most of the key elements of spacepower are, but not all those elements are equal. Key elements would surely include possessing the relevant technology base, physical infrastructure, and workforce necessary to excel in space. Space prowess is also measured by how purposefully and successfully these essential elements are applied to specific missions. Many missions increase the sum total of a nation's capability in space. Metrics would include utilizing space for exploration and the advancement of knowledge; facilitating commercial transactions, resource planning, and terrestrial economic development; monitoring planetary health; mapping; providing a medium for telecommunications and broadcasting; assisting first responders, search and rescue operations, and disaster relief; providing early warning of consequential events; and utilizing space assets to enhance military and intelligence capabilities. The commercial, communication, and military uses of space have become less separable.

Since meaning is partly defined by circumstances—and since circumstances, with respect to the utilization of space, are so favorable for the United States—it is understandable why passionate and articulate American advocates of spacepower often define this term in a muscular way. Many forceful advocates equate spacepower with military missions because U.S. forces are extraordinarily dependent on space assets that confer significant advantages while saving countless lives on the battlefield, and because the negation of these assets would be so harmful.[1]

While the military uses of space are growing for the United States and other spacefaring nations, sweeping analogies between spacepower and terrestrial military power are unwise. In space, power is not accompanied by weapons—at least not yet. And in space, weapon-enabling technologies are widely applicable to nonmilitary pursuits. Weapon capabilities—or hard power—that can be utilized in space are currently confined to gravity-bound battlefields. In contrast, the soft power aspects of space prowess are unbounded, with satellites used for direct broadcasting and communication becoming conveyor belts for the projection of national culture and economic transactions. The long history of international cooperative research among civil space agencies reflects another element of soft space-power. Collaborative efforts such as the Apollo-Soyuz mission, the International Space Station, and the space shuttle attest to the utility of soft spacepower as a diplomatic instrument. China, an emerging spacepower, is following this well-trodden path, at least in part, by forging space cooperation agreements with nations such as oil-rich Venezuela and Nigeria.

Nowhere is soft spacepower more evident than in the commercial realm, where economic competition is sometimes fierce but multinational cooperation is nonetheless required. The world relies at present on five major multinational corporations for the provision of global telecommunications. Global and national reliance on space assets has become intertwined not only for communications, but also for banking, disaster monitoring, weather forecasting, positioning, timing and navigation, and myriad other activities central to modern life. Many satellites primarily operated for commercial and civil uses can also serve military purposes. The use of space for commercial and economic development, as well as for other soft power applications, can be jeopardized if the deployment and use of weapons in space occur. This is because once weapons are used in space, their effects may not be controllable, as it is difficult to dictate strategy and tactics in asymmetric warfare. Consequently, weapons effects may not be limited to a small subset of satellites or those of a particular nation. In this sense, hard and soft spacepower cannot be decoupled. The misapplication of hard spacepower could therefore have indiscriminate effects, particularly if a destructive strike against a satellite produces significant and long-lasting debris.

The misapplication of hard power on Earth could also adversely affect relations between major powers, friends, and allies. However, the interconnectedness of hard and soft spacepower means that poor decisions by one spacefaring nation are more likely to negatively affect all other spacefaring nations, a situation that does not arise in nonnuclear, terrestrial conflict. Recovery from poor decisions in space also takes far longer than from nonnuclear, terrestrial conflict. For example, when conventional battles take place on the ground, sea, and air, debris is a temporary and geographically limited phenomenon. Minefields can be marked or cleared, and chemical spills can be contained or cleaned—although this may take large amounts of both time and money. Battlefield debris in space, however, can last for decades, centuries, or even millennia, thereby constituting an indiscriminate lethal hazard to space operations. Debris generated in space also tends to spread to other orbits over time, and environmental cleanup technologies in space do not appear promising at present.[2] In gravity-based warfare, the victor's spoils are gained through unhindered access. But such access is likely to be lost in the event that weapons are used in or from space, even for the "victor."

Battlefields in space are therefore fundamentally different from those on land, at sea, or in the air. The potentially disabling problem of space debris is now well recognized even by advocates of hard spacepower. Therefore, hit-to-kill kinetic energy antisatellite (ASAT) weapons that have been tested occasionally constitute a significant potential danger to space operations, as was most evident in China's test in January 2007, which created the worst debris-generating event in the history of the space age.[3] The earliest

ASAT weapons—nuclear warheads atop ballistic missiles—would produce indiscriminate and lethal effects, as the United States learned after conducting a series of atmospheric nuclear tests in 1962. Nonetheless, this method of space warfare could still be employed. Currently, the preferred U.S. methods of using force to maintain "space control" entail nondestructive techniques (although U.S. officials and military leaders have not ruled out destructive methods). But bounding the unintended negative consequences of warfare in space depends on questionable assumptions, beginning with the dictation of rules of warfare against weaker foes. In unfair fights, however, weaker foes typically play by different rules. And if debris-causing space warfare hurts the United States severely, it is reasonable to expect that U.S. fastidiousness in engaging in warfare in space may not be reciprocated—as the Chinese kinetic-kill ASAT test seemed to indicate.

While appreciation of soft spacepower has expanded, arguments over the military uses of space have actually narrowed over time. In an earlier era, there were heated debates over the propriety of using space for monitoring secret military activities. Beginning in the 1970s, national technical means used to monitor nuclear forces received formal treaty protection. Subsequent debates focused on the propriety of using space to assist military operations. During the administrations of Presidents Jimmy Carter and Ronald Reagan, Soviet negotiators sought expansive definitions of space weapons (including the space shuttle) to constrain perceived U.S. military advantages in space. These negotiating gambits have long since lost their audience. The use of satellites to assist military operations on Earth is no longer controversial; instead, it has become the primary (and widely envied) metric of spacepower.

While debates over spacepower and its advancement have become more narrowly drawn, they continue to be quite heated. Current debates focus not on the military uses of space but rather on its weaponization. This dividing line is admittedly not clear-cut and is fuzziest on the issue of jamming, when disruptive energy is applied not against satellites per se, but against satellite communication links. Another gray area in the spectrum leading from militarization to weaponization relates to lasing objects in space.

While acknowledging gray areas (and discussing them further below), we submit that they do not absolve or oblige us to obliterate useful distinctions between the militarization and weaponization of space. It is true, for example, that long-range ballistic missiles that carry deadly weapons transit space en route to their targets. But ballistic trajectories constitute ground-based weapons aimed at ground-based targets, rather than being weapons based in space or aimed at space-based targets. Thus, we distinguish between transitory phenomena and permanent conditions. Similarly, we differentiate between the use of lasers for range finding, space tracking, and communication purposes, and the use of lasers to temporarily disable or destroy satellites. One type of activity provides substantial benefit while the other invites great risk. We further argue that U.S. national security and economic interests are advanced by working to clarify this distinction and by seeking the concurrence with and reinforcement of it by other key spacefaring nations.

By distinguishing between the militarization and the weaponization of space, we argue that analogies between spacepower and other forms of military power have only limited utility. In other realms of military affairs, we measure power by metrics such as the number of weapons available, various characteristics that make them more effective, and their readiness for employment. Accordingly, the distinction between militarization and weaponization is meaningless when we discuss air, ground, and naval forces. In contrast, spacepower is defined at present in the absence of the deployment and use of weapons in space. We argue that the absence of "dedicated" space weapons is favorable to the United States.

While some have compared space to another "global commons," the high seas, we believe this analogy to be deeply flawed. Warships provide backup for sea-based commerce, but they are essentially instruments of warfighting. Satellites, on the other hand, usually serve multiple purposes in both military and nonmilitary domains. A ship damaged in combat can seek safety and repairs at a friendly port. The debris from combat at sea sinks and rarely constitutes a lingering hazard. Defensive measures are easier to undertake at sea than in space. If space weapons are deployed and used, no nation can expect there to be safe havens in space. And if the most indiscriminate means of space warfare are employed, debris will become a long-lasting hazard to military and nonmilitary satellite operations.

All countries would be victimized if a new precedent is set and satellites are attacked in a crisis or in warfare. As the preeminent space power, the United States has the most to lose if space were to become a shooting gallery. The best offense can serve as an effective defense in combat at sea, but this nostrum does not apply in space, since essential satellites remain extremely vulnerable to rudimentary forms of attack. The introduction of dedicated and deployed weapons in space by one nation would be followed by others that feel threatened by such actions. The first attack against a satellite in crisis or warfare is therefore unlikely to be a stand-alone event, and nations may choose different rules of engagement for space warfare and different means of attack once this threshold has been crossed.

Our analysis thus leads to the conclusion that the introduction and repeated flight-testing of dedicated ASAT weapons would greatly subtract from U.S. spacepower, placing at greater risk the military, commercial, civil, and lifesaving benefits that satellites provide. Instead, we propose that the United States seek to avoid further flight testing of ASATs while hedging against hostile acts by other spacefaring nations.

We argue that realizing the benefits of spacepower requires acknowledgment of four related and unavoidable dilemmas. First, the satellites upon which spacepower depends are extremely vulnerable. To be sure, advanced spacefaring nations can take various steps to reduce satellite vulnerability, but the limits of protection will surely pale beside available means of disruption and destruction, especially in low Earth orbit (LEO). Vulnerabilities can be mitigated, but not eliminated.

Second, the dilemma of the profound vulnerability of essential satellites has been reinforced by another dilemma of the space age: satellites have been linked with the nuclear forces of major powers. Nuclear deterrence has long depended on satellites that provide early warning, communications, and targeting information to national command authorities. Even nuclear powers that do not rely on satellites for ballistic missile warning may still rely on them for communications, forecasting, and targeting. To interfere with the satellites of major powers has meant—and continues to mean—the possible use of nuclear weapons, since major powers could view attacks on satellites as precursors to attacks on their nuclear forces.

The third dilemma of spacepower is that space disruption is far more achievable than space control. A strong offense might constitute the best defense on the ground, in the air, and at sea, but this principle holds little promise in space since a strong offense in this domain could still be negated by asymmetric means. Space control requires exquisitely correct, timely, and publicly compelling intelligence; the readiness to initiate war and to prevent another nation from shooting back; as well as the ability to dictate the choice of strategy and tactics in space. It takes great hubris to believe that even the world's sole superpower would be able to fulfill the requirements of space control when a $1 bag of marbles, properly inserted into LEO, could destroy a $1 billion satellite. The ability of the United States to dictate military strategy and tactics in asymmetric, gravity-bound warfare has proven to be challenging; it is likely to be even more challenging in space, where there is less margin for error.

The fourth overarching dilemma relating to spacepower therefore rests on the realization that hard military power does not ensure space control, particularly if other nations make unwise choices and if these choices are then emulated by others. The United States has unparalleled agenda-setting powers, but Washington does not have the power to dictate or control the choices of other nations.

These dilemmas are widely, but not universally, recognized. Together with the widespread public antipathy to elevating humankind's worst practices into space, they help explain why the flight-testing and deployment of dedicated space weapons have not become commonplace. These capabilities are certainly not difficult to acquire, as they are decades old. Indeed, tests of dedicated ASAT weapons have periodically occurred, and such systems were deployed for short periods during the Cold War. If the weaponization of space were inevitable, it surely would have occurred when the United States and the Soviet Union went to extraordinary lengths to compete in so many other realms. The weaponization of space has not occurred to date and is not inevitable in the future because of strong public resistence to the idea of weapons in space, and because most national leaders have long recognized that this would open a Pandora's box that would be difficult to close.

Much has changed since the end of the Cold War, but the fundamental dilemmas of space control, including the linkage of satellites to nuclear deterrence among major powers, have not changed. The increased post– Cold War U.S. dependence on satellites makes the introduction of dedicated space weapons even more hazardous for national and economic security. Advocates of muscular space control must therefore take refuge in the fallacy of the last move, since warfighting plans in space make sense only in the absence of successful countermoves. Offensive counterforce operations in space do not come to grips with the dilemmas of spacepower, since proposed remedies are far more likely to accentuate than reduce satellite vulnerability.

This analysis leads inexorably to a deeply unsatisfactory and yet inescapable conclusion: Realizing the enormous benefits of spacepower depends on recognizing the limits of power. The United States now enjoys unparalleled benefits from the use of space to advance national and economic security. These benefits would be placed at risk if essential zones in space become unusable as a result of warfare. Spacepower depends on the preservation and growth of U.S. capabilities in space. Paradoxically, the preservation and growth of U.S. spacepower will be undercut by the use of force in space.

Because the use of weapons in or from space can lead to the loss or impairment of satellites of all major space powers, all of whom depend on satellites for military and economic security, we believe it is possible to craft a regime based on self-interest to avoid turning space into a shooting gallery. This outcome is far more difficult to achieve if major space powers engage in the flight-testing and deployment of dedicated ASAT weapons or space-to-Earth weapons. We therefore argue that it would be most unwise for the United States, as the spacepower with the most to lose from the impairment of its satellites, to initiate these steps. Similar restraint, however, needs to be exercised by other major spacefaring nations, some of which may feel that the preservation and growth of U.S. spacepower are a threat, or that it is necessary to hold U.S. space assets at risk. The United States is therefore obliged to clarify to others the risks of initiating actions harmful to U.S. satellites without prompting other spacefaring nations to take the very steps we seek to avoid. Consequently, a preservation and growth strategy for U.S. spacepower also requires a hedging strategy because, even if the United States makes prudent decisions in space, others may still make foolish choices.

Hedging

The exercise of restraint from using weapons in space is not easy for the world's most powerful nation or for other nations fearing catastrophic losses that they believe might be averted by disabling U.S. satellites. How, then, might U.S. spacepower influence the decisions of other nations to leave vulnerable satellites alone?

We maintain that a prudent space posture would clarify America's ability to respond purposefully if another nation interferes with, disables, disrupts, or destroys U.S. satellites, without being the first to take the actions that we wish others to refrain from taking. Thus, our proposed hedging strategy would not include the flight-testing and deployment of dedicated ASAT or on-orbit weapons because such steps would surely be emulated by others and would increase risks to vital U.S. space assets. Whatever preparations the United States takes to hedge against attacks on its satellites must be calibrated to maximize freedom of action and access in space. Hedging moves that create an environment where the flight-testing and deployment of space weapons would be a common occurrence would thus be contrary to U.S. military and economic security.

Responsible hedges by the United States include increased situational awareness, redundancy, and cost-effective hardening of satellites and their links. The strongest hedge the United States possesses is its superior conventional military capabilities, including long-range strike and special operations capabilities. Since an attack on a satellite can be considered an act of war, the United States could respond to such an attack by targeting the ground links and launch facilities of the offending nation or the nation that harbors a group carrying out such hostile acts. Far more punishing responses might be applicable. A hedging strategy is also likely to include ground-based research and development into space weapons technologies, activities that are under way in major spacefaring nations.

The demonstration of dual- or multi-use space technologies that could be adapted, if needed, to respond to provocative acts would constitute another element of a responsible hedging strategy. Such technologies could include on-orbit rendezvous, repair, and refueling technologies and other proximity operations. These activities are also essential for expanded scientific and commercial use of space and would be key enabling technologies for long-duration missions such as the return to the Moon and the exploration of Mars.

A prudent hedging strategy would also align U.S. military doctrine and declaratory policy with America's national security and economic interest in preventing weapons in space and ASAT tests. In the context of a proactive Air Force counterspace operations doctrine and official disdain for negotiations that might constrain U.S. military options in space, the hedging strategy we advocate might be perceived as preliminary steps toward the weaponization of space, which we would oppose. Wise hedging strategies would also be accompanied by constructive diplomatic initiatives.

The flight-testing of multipurpose technologies, the possession of dominant power projection capabilities, and the growing residual U.S. military capabilities to engage in space warfare should provide a sufficient deterrent posture against a "space Pearl Harbor."[4] These capabilities would also clarify that the United States possesses the means to defend its interests in a competition that other major space powers claim not to want, as well as to react in a prompt and punishing way against hostile acts against U.S. space assets.

If all responsible spacefaring nations adhere to a "no further ASAT test" regime, and an adversary still carries out a "space Pearl Harbor" by using military capabilities designed for other purposes, the United States has the means to respond in kind. U.S. latent or residual space warfare capabilities exceed those of other spacefaring nations and are growing with the advent of ballistic missile defenses. We maintain that the existence of such capabilities constitutes another element of a hedging strategy, while providing further support for our contention that dedicated ASAT tests and deployments are both unwise and unnecessary.

Space Preservation and Growth Strategy

A successful hedging strategy preserves and grows U.S. spacepower. In contrast, the flight-testing and deployment of dedicated ASAT and on-orbit weapons produce conditions whereby U.S. space assets are unlikely to be available or could be gravely impaired when needed. Space control operations that foster the preservation and growth of U.S. spacepower are to be welcomed; space control operations that would have the net effect of placing U.S. satellites at greater risk are to be avoided.

The U.S. Air Force's doctrine on space control operations, *Counter-space Operations*, requires the identification of adversary space assets and space-related capabilities on Earth. Identified targets include on-orbit satellites (including third-party assets), communication links, launch facilities, ground stations, and command, control, computers, communications, intelligence, surveillance, and reconnaissance (C^4ISR) resources.[5] Many of these satellites or space-related assets can be targeted using multipurpose conventional capabilities. For example, launch facilities and ground stations can be targeted by ground forces, warships, and air-power. Communication links can be jammed using proven systems, and elements of C^4ISR can be neutralized using cyber attacks. Many space powers possess these capabilities to varying degrees, which may help explain why dedicated systems to attack satellites have rarely been flight-tested or deployed.

The vulnerability of terrestrial space assets can be mitigated in a number of ways. Equipment can be hidden, hardened, or operated stealthily. Depending on the order of battle and opposing military capabilities, some assets could be protected by overwhelming force, and assets lost in battle can sometimes be replaced. These considerations are quite different in space, where force replacement is usually problematic and protection measures operate, at best, on the margins of economic and technical possibility.

Major space powers should be adept at locating satellites in Earth orbit. Maneuvering in space, unlike terrestrial warfare, is usually very limited. While satellites can be placed in orbits that pass over regions with limited space surveillance capabilities, the nature of orbital mechanics dictates that, at some point, satellites will be visible to ground observers.[6] Fuel is a more precious commodity in space due to its weight and very limited prospects for refueling. Maneuvering for most spacecraft is limited to normal station-keeping operations. Moreover, satellites, unlike tanks, cannot be suitably armored for combat. They can be hardened to withstand some types of electromagnetic interference and small impacts, but it is not feasible to shield against an impact from even a marble-sized debris hit, much less an intentional physical attack. Spacecraft shielding increases launch weight and costs by approximately $10,000 per pound.[7]

Operating satellites in formations is quite different from operating aircraft carrier battlegroups. Valuable warships can survive direct hits of various kinds, and the debris from losses at sea sinks to the bottom of the ocean. In contrast, the debris from satellite warfare could impair constellations in space, placing at risk the orbit of the high-value satellites meant to be protected. Arming satellites with defensive weapons is not a satisfactory solution for many reasons. Unlike warships or tanks that can maneuver and fire many weapons, satellites have little carrying capacity beyond that required to perform their missions. The fundamentals of space warfare described above—including the difficulties in dictating tactics and the choice of weapons, as well as the consequences of space debris—appear immutable. The marginal cost of attack will always be less than the marginal cost of defense, since attacking does not necessarily require technological sophistication and limited attacks can cause grievous injury.

If essential but vulnerable satellites cannot be effectively defended by space weapons, their protection rests largely on deterrence. When offense is too lethal to use because its net effect would be to harm vital national assets and interests, the default option for freedom of action in space is to accept mutual vulnerability. Nuclear deterrence had many detractors during the Cold War, even though it helped prevent nuclear exchanges between well-armed foes. The more power a nation possesses, the harder it is to accept vulnerability. But the benefits of hard and soft spacepower inescapably depend on satellites that are far easier to attack than to defend.

Asymmetric capabilities and vulnerabilities in space do not negate the precepts of deterrence or the essence of mutual vulnerability. During the Cold War, for example, Beijing faced not one but two hostile superpowers and yet chose to maintain nuclear forces that were significantly inferior to those of the United States and the Soviet Union. Presumably, China's leadership concluded that relatively few mushroom clouds were needed to clarify superpower vulnerability.

We argue, by analogy, that asymmetries related to dependence on space and capabilities in space do not alter the fundamentals of vulnerability and deterrence. The country with the most to lose from attacks on satellites, the United States, also has the most capabilities to respond with lethal force, which would be more indiscriminate because of the impairment or loss of its satellites. We have argued elsewhere that space warfare and its effects are unlikely to be country-specific. Because space warfare can be more indiscriminate than terrestrial warfare, and because all space-faring nations are increasingly dependent on space assets for national and economic security, all major powers face the same fundamental dilemma that satellites are both essential and extraordinarily vulnerable, and that the use of weapons in space is likely to have unintended, negative consequences. Mechanical objects may be the initial victims of space warfare, but satellites are unlikely to be the only victims, since they are directly linked to soldiers, noncombatants, and nuclear weapons.

Nuclear deterrence was based on the repeated testing of nuclear weapons and their means of delivery, as well as on the deployment of many dedicated weapons systems in a high state of launch readiness. If we were to adopt such practices for dedicated ASAT or space-to-Earth weapons, satellite security would be greatly diminished, and relations among major powers, along with international space cooperation, would deteriorate. At best, a very uneasy standoff in space could result from the flight-testing and deployment of dedicated ASAT weapons. In our view, no further ASAT testing is required because, for all practical purposes, this uneasy standoff already exists. Major spacefaring nations have already clarified their ability to disrupt or destroy satellites. Since these capabilities are well understood, they do not need to be demonstrated by further testing, the net effect of which would be more worrisome than reassuring.

Mutual assured destruction in space is therefore far easier to maintain than nuclear deterrence was during the Cold War, because mutual vulnerability from the use of weapons in or from space does not require repeated demonstrations of the weapons in question. And unlike nuclear deterrence, which had the practical effect of limiting freedom of action, acceptance of mutual vulnerability in space would maximize freedom of action and access. Despite these significant differences, there are two principal connecting threads between the acceptance of mutual vulnerability between major nuclear powers and major space powers. First, attacks on satellites in crises between major powers risk the use of nuclear weapons. And second, existential vulnerability to nuclear and satellite attacks is not solvable by military means.

Code of Conduct

We view a code of conduct for responsible spacefaring nations as a necessary complement to a hedging strategy and as an essential element of a space posture that provides for the preservation and growth of U.S. space capabilities. A code of conduct makes sense because, with the increased utilization and importance of space for national and economic security, there is increased need for space operators and spacefaring nations to act responsibly. While some rules and treaty obligations exist, there are many gaps in coverage, including how best to avoid collisions and harmful interference, appropriate uses of lasers, and notifications related to potentially dangerous maneuvers. Because the increased utilization of space for security and economic purposes could lead to friction and diminished space assurance, it serves the interests of all responsible spacefaring nations to establish rules of the road to help prevent misunderstandings, catastrophic actions in space, and grievances.

Another reason for pursuing rules of the road is that interactive hedging strategies could generate actions in space that diminish space security by nations concerned about the import of technology demonstrations and flight tests. We have therefore argued that hedging strategies are best accompanied by diplomatic initiatives to set norms that increase the safety and security of satellites vital to U.S. national and economic security. A code of conduct would serve these purposes.

No codes of conduct or rules of the road are self-enforcing. Despite traffic laws, some drivers still speed. But having rules of the road reduces the incidence of misbehavior and facilitates action against reckless drivers. We acknowledge that there are no traffic courts for misbehavior in space, but we nonetheless argue that having agreed rules of the road in this domain will also reduce the incidence of misbehavior, while facilitating the isolation of the miscreant as well as the application of necessary remedies. Without rules, there are no rule breakers.

Traditional arms control was devised to prevent arms racing between the superpowers. With the demise of the Soviet Union, concerns over arms racing have been replaced by concerns over proliferation and nuclear terrorism. Cooperative threat reduction initiatives have been designed to deal with contemporary threats. These arrangements have taken myriad forms, including rules of the road to prevent proliferation. Since the flight-testing, deployment, and use of weapons in space would increase security concerns, and since security concerns are drivers for proliferation, agreed rules of the road for space could supplement other codes of conduct that seek to prevent proliferation.

Codes of conduct supplement, but differ from, traditional arms control remedies. Skeptics of new arms control treaties to prevent ASAT tests and space-based weapons argue that it would be difficult to arrive at an agreed definition of space weapons, and that even if this were possible, it would be hard to monitor compliance with treaty obligations. A code of conduct would focus on responsible and irresponsible activities in space that, in turn, would obviate the need for an agreed definition of space weapons. For example, a code of conduct might seek to prohibit the deliberate creation of persistent space debris. Again, our focus is on behavior, not an agreed definition of space weapons. Moreover, the deliberate creation of persistent space debris is very hard to hide and can be monitored by existing technical means.

The United States has championed codes of conduct governing militaries operating in close proximity at sea in the 1972 Incidents at Sea Agreement, as well as in the air and on the ground, in the 1989 Dangerous Military Practices Agreement. More recently, the United States has championed codes of conduct to reduce proliferation threats, including The Hague Code of Conduct (2002) and the Proliferation Security Initiative (2003). The 2001 Space Commission Report chaired by Donald Rumsfeld also endorsed rules of the road for space.[8]

Codes of conduct typically take the form of executive agreements in the United States. They can begin as bilateral or multilateral compacts and they can expand with subsequent membership. Codes of conduct are either an alternative to, or a way station toward, more formal treaty-based constraints that often take extended effort.[9]

Some rules of the road, formal agreements, and elements of a code of conduct already exist for space. The foundation document that defines the responsibilities of spacefaring nations is the Outer Space Treaty (1967). Other key international agreements and institutions include the Liability Convention and the International Telecommunications Union.

There is growing sentiment among space operators to develop and implement several key elements of a code of conduct, including improved data sharing on space situational awareness; debris mitigation measures; and improved space traffic management to avoid unintentional interference or collisions in increasingly crowded orbits. A more comprehensive code of conduct might include elements such as notification and consultation measures; provisions for special caution areas; constraints against the harmful use of lasers; and measures that increase the safety, and reduce the likelihood, of damaging actions against manmade space objects, such as harmful interference against satellites that create persistent space debris. Key elements of a code of conduct are useful individually, but they are even more useful when drawn together as a coherent regime.

Situationa Awareness

Space situational awareness (SSA)—the ability to monitor and understand the constantly changing environment in space—is one of the most important factors in ensuring the safety and security of all operational satellites and spacecraft. SSA provides individual actors with the ability to monitor the health of their own assets, as well as an awareness of the actions of others in space. Transparency measures can be particularly helpful in providing early warning of troubling developments and in dampening threat perceptions. One measure of U.S. spacepower and space prowess is America's unparalleled space situational awareness capabilities. Thus, the United States is in a position to become a leader in building space transparency, which is the foundation stone of norm setting and rules of the road in space.

Traffic Management

The International Academy of Astronautics (IAA) "Cosmic Study on Space Traffic Management" defines *space traffic management* as:

> the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference.[10]

We also endorse intermediate steps toward this outcome and advocate empowering or creating an industry advisory group that could recommend actions and participate in the work of international bodies.

Notification and Consultations

The development of more formal processes for notification of satellite maneuvers is critical for ensuring space situational awareness; without such notification, satellite tracking and collision avoidance become much more difficult. Prelaunch notification could assist space surveillance as well as traffic management. Models for prelaunch notification could be the 2000 U.S.Russian Joint Data Exchange Center[11] and the 2000 U.S.-Russian Pre-and Post-Launch Notification Agreement.[12] Elements from these agreements—as well as other ideas for data provision—might be studied by the United Nations Committee on the Peaceful Use of Outer Space's (COPUOS's) Scientific and Technical Subcommittee and translated into recommendations for either a voluntary regime or a possible multilateral accord.

Special Caution Areas

The IAA Cosmic Study mentions two different approaches to what the Dangerous Military Practices Agreement has termed *special caution areas*. In space, these might consist of provisions for safe distances or zones around satellites or more general "zoning" rules that restrict certain activities in certain orbital planes. Further in-depth study of the technical requirements and legal considerations surrounding the establishment of special caution areas is required before judgments can be made on the practicality and utility of such approaches; this is work that the IAA or other organizations could easily pursue.

Debris Mitigation

The deliberate generation of persistent space debris constitutes a hazard to space operations. Debris mitigation is therefore a pressing problem related to space traffic management. It is also the code of conduct element that has been furthest developed. The Inter-Agency Space Debris Coordination Committee (IADC), comprised of the space agencies of the world's major space powers, has developed a number of debris mitigation guidelines. Several nations have incorporated the agreed measures into their national laws and regulatory systems, and others are moving to do so. The United States is a leader in codifying strong debris mitigation guidelines. Thus, the United States is well placed to use this element of its soft spacepower to set strong international norms and work toward legally binding, formal international accords.

No Harmful Use of Lasers

There are at least two precedents for restricting the use of lasers during peacetime: the Prevention of Dangerous Military Activities Agreement and the Incidents at Sea Agreement.[13] The multiple applications of lasers highlight the utility of establishing rules of the road that distinguish between acceptable uses—such as range-finding, communication, and information-gathering—and uses that could be considered acts of war, such as dazzling, blinding, and damaging satellites. Norms regarding laser power/configuration for tracking purposes might be discussed to reduce the likelihood of damage to satellites and to reduce miscalculation. We endorse the convening of a panel of technical specialists, perhaps under the auspices of the IAA, to discuss this. COPUOS might usefully propose procedures for dealing with laser incidents.

Increasing Satellite Safety and Reducing the Likelihood of Satellite Damage

A national space strategy designed to preserve and grow U.S. capabilities in space would benefit from steps to increase satellite safety and reduce the potential damage to satellites upon which that strategy rests. This would, of course, include technical protection measures. However, it would also entail proactive diplomatic measures to prevent weapons-related creation of space debris. As advocates of U.S. spacepower, we therefore believe it would be wise to set rules of the road against the further testing of ASATs or other weapons based in space that would create debris by applying energy against targets. The use of weapons that produce indiscriminate and long-lasting damage in ground combat has justifiably earned widespread opprobrium. The use of certain weapons in space could be doubly injurious, since they could produce indiscriminate and long-lasting damage in orbit that, in turn, could prompt similar damage on Earth.

Conclusion

We have argued that spacepower rests on a broad foundation, building upward to the orbital dance of satellites. We further argue that space-power is inextricably linked to, but different from, other forms of military power. The fundamental paradox of spacepower is that satellite effectiveness and vulnerability are inseparable, which makes hard power projection in and from space an extraordinarily risky undertaking. The preservation and growth of U.S. spacepower therefore requires the protection of satellites—vital assets that can readily be lost and quite difficult to replace in combat—by other means. We propose to address this dilemma through a variety of initiatives, including a hedging strategy and diplomatic initiatives centered on a code of conduct for responsible spacefaring nations.

Notes

1. See, for example, David E. Lupton, *On Space Warfare: A Spacepower Doctrine* (Maxwell Air Force Base, AL: Air University Press, June 1998); Colin S. Gray, "The Influence of Spacepower upon History," *Comparative Strategy* 15, no. 4 (October–December 1996), 293–308; James Oberg, *Spacepower Theory* (Washington, DC: U.S. Government Printing Office, 1999); and Air Force Doctrine Document 2–2, *Space Operations* (Maxwell Air Force Base, AL: Air Force Doctrine Center, November 27, 2001).
2. J.C. Liou and N.L. Johnson, "Risks in Space from Orbiting Debris," *Science* 311 (January 20, 2006), 340.
3. Frank Morring, Jr., "Worst Ever: Chinese Anti-satellite Test Boosted Space-debris Population by 10% in an Instant," *Aviation Week and Space Technology*, February 12, 2007, 20.
4. Department of Defense, "Report of the Commission to Assess United States National Security Space Management and Organization" (Washington, DC: Department of Defense, 2001), 22.
5. Air Force Doctrine Document 2.2–1, *Counterspace Operations* (Washington, DC: Department of the Air Force, August 2, 2004), 32–33.
6. Even classified satellites, for which no orbital data is publicly available, have been tracked by amateur ground observers using nothing more than a camera and a stopwatch. See, for example, the *Visual Satellite Observer's Home Page* Web site at <www.satobs.org/>.
7. Futron Corporation, "Space Transportation Costs: Trends in Price per Pound to Orbit 1990–2000," available at <www.futron.com/pdf/resource_center/white_papers/FutronLaunchCostWP.pdf>.
8. "Report of the Commission to Assess United States National Security Space Management and Organization," 18.
9. For more information regarding space code of conduct approaches, see Michael Krepon and Christopher Clary, *Space Assurance or Space Dominance: The Case Against Weaponizing Space* (Washington, DC: The Henry L. Stimson Center, 2003), and Theresa Hitchens, *Future Security in Space: Charting a Cooperative Course* (Washington, DC: Center for Defense Information, September 2004).
10. Corrine Contant-Jorgenson, Petr Lála, and Kai-Uwe Schrogl, eds., "Cosmic Study on Space Traffic Management" (Paris: International Academy of Astronautics, 2006), 10, available at <http://iaaweb.org/iaa/Studies/spacetraffic.pdf>.

11. Peter L. Hays, "United States Military Space into the Twenty-first Century," Institute for National Security Studies Occasional Paper 42 (Colorado Springs: U.S. Air Force Academy, September 2002), 115–116.
12. U.S. Department of State Fact Sheet, "Memorandum of Understanding on Notification of Missile Launches," December 16, 2000, available at <www.state.gov/t/ac/trt/4954.htm>; Philipp C. Bleek, "U.S., Russia Sign Missile- and Space-Launch Notification Deal," *Arms Control Today* (January–February 2001), available at <www.armscontrol.org/act/2001_01_02/usruslaunch.asp>; Hays, 116.
13. The Prevention of Dangerous Military Activities Agreement prohibits uses of lasers that might harm personnel or equipment; text of the agreement can be found in *International Legal Materials* 28, no. 2 (1989), 877–895. The Incidents at Sea accord prohibits the illumination of the bridges of the other parties' ships; see "Agreement Between the Government of the United States of America and the Government of the Union of Soviet Socialist Republics on the Prevention of Incidents on and over the High Seas," available at <http://dosfan.lib.uic.edu/acda/treaties/sea1.htm>.

Chapter 21:
Balancing U.S. Security Interests in Space

Michael E. O'Hanlon

What should the United States do with its future space policy? Available options range from hastening to develop and deploy space weapons that could destroy ballistic missiles, other satellites, or ground targets, to banning the weaponization of space altogether through international treaty. This chapter takes a middle path, not in the interest of triangulation or compromise for its own sake, but because the extreme options would poorly serve American security interests. At some point, a clearer decision in favor of one end of the weaponization/arms control spectrum or the other could be appropriate. But in light of strategic and technological realities, this is not the time.

Space systems were a focus of arms control debate during the Cold War, and many would still like outer space, the last physical frontier of the human experience, to be a sanctuary from military competition.[1] These proponents favor binding, permanent, multilateral bans on space weaponry. Beyond their philosophical motivation, American opponents of the weaponization of space make a practical national-interest argument: as the world's principal space power today, the United States stands to lose the most from weaponization, since it could jeopardize the communications and reconnaissance systems on which the U.S. military and economy so disproportionately depend.[2] Opponents of weaponizing space also point to the world's growing economic dependence on space assets and to the risk of damaging those assets should weaponry be based in or used outside of the atmosphere.

Non-American opponents of weaponizing space also worry about a unilateralist America pursuing its own military advantage at the expense of other countries, most of which do not favor putting weapons in space. This dispute has much of its origins and motivation in the history of the ballistic missile defense debate, as well as in the antisatellite weapons debate of the 1980s. But it has taken on a new tone in what many view as an era of American unipolarity or hegemony. In recent years, China and Russia have been consistent in their opposition to the weaponization of space and in their desire for a treaty banning the testing, deployment, and use of weapons in space.[3] So have a number of U.S. allies, including Canada, which proposed in 1998 that the United Nations (UN) convene a committee on outer space during its conference on disarmament in Geneva.[4] The UN General Assembly passed resolutions for more than 20 straight years opposing the weaponization of space.

In contrast, developing more military applications for outer space is an important imperative for most American defense planners today. Much thinking about the so-called revolution in military affairs and transformation of defense emphasizes space capabilities. Ensuring American military dominance in the coming years—something proponents tend to see as critical for global stability as well as for unilateral advantage—will require the United States to remain well ahead of its potential adversaries technologically. For some defense futurists, the key requirement will be to control space, denying its effective use to U.S. adversaries while preserving the unfettered operation of American satellites that help make up a "reconnaissance-strike complex." Others favor an even more ambitious approach. Given that fixed bases on land and large assets such as ships are increasingly vulnerable to precision-strike weaponry and other enemy capabilities—or to the political opposition of allies such as Turkey, Saudi Arabia, and France, which have sometimes opposed use of their territories or airspace for military operations (as in the 2003 war in Iraq and in the 1986 U.S. bombing of Libya)—these advocates favor greater U.S. reliance on long-range strike systems, including platforms in space.[5]

Advocates of space weaponry also argue that, in effect, space is already weaponized, at least in subtle ways. Most medium- and long-range rockets capable of carrying nuclear weapons already constitute latent anti-satellite (ASAT) weapons. Likewise, rockets and space-launch vehicles could probably be used to launch small homing satellites equipped with explosives and capable of approaching and destroying another satellite. Such capabilities may not even require testing, or at least testing that is not easily detectable from Earth. Advocates of weaponization further note that the United States is willing to use weapons to deny other countries' wartime use of the atmosphere, the oceans, and land, raising the question of why space should be a sanctuary when these other realms are not. As Barry Watts put it, "Satellites may have owners and operators, but, in contrast to sailors, they do not have mothers."[6]

And of course, not all countries that publicly oppose putting weapons in space are true to their rhetoric in practice. The People's Republic of China (PRC) is the most notable example, with its early 2007 ASAT test destroying an old PRC weather satellite, increasing low Earth orbit space debris by 10 percent and shattering an effective moratorium on the testing of ASAT systems that was more than two decades old. In fairness to Beijing, it could be argued that it had a right to "catch up" with the United States— not only with the ASAT technology the Pentagon had developed in the 1970s and 1980s, but also with latent modern ASAT capabilities in the form of American ballistic missile defense systems. That said, it was China and only China that ended the effective international moratorium on actual testing of antisatellite systems, and it was the PRC that chose to take actions at blatant odds with its own official negotiating position in international talks over space weaponry. The point of this assessment is not to vilify China's behavior; in fact, in many ways, such a demonstration of capability is consistent with how a rising power historically would be expected to handle such a situation. Its behavior fits squarely within the trajectory that realists at least would predict. That is true even if it may have reflected poor coordination and communications within the PRC government (since the blow to China's international image may not be offset by the acquisition of useful new capabilities).[7] But whatever one's views on that point, China's ASAT test would seem to reaffirm that the United States must fashion its military space policy based more on a hardheaded assessment of capabilities and potential capabilities than on ideological positions, be they of the pro–arms control or pro–space weaponization variety.

Specific military scenarios can bring these more abstract arguments into clearer focus. Consider just one possibility. If, in a future Taiwan Strait crisis, China could locate and target American aircraft carriers using satellite technology, the case for somehow countering those satellites through direct offensive action would be powerful. This decision might be made easier if China itself initiated the use of ASATs, perhaps against Taiwan, but it could be an option the United States would have to consider seriously even if China had not. If jamming or other means of temporary disruption could not be shown to reliably interrupt China's satellite activities, outright destruction would probably be seriously proposed. This scenario is investigated in greater detail below, not out of any conviction that the United States and China are headed for military rivalry or conflict, but out of the belief that such scenarios must concern American force planners as they think through the pros and cons of various policy options.

No space-based missile defense or antisatellite weapons (with the possible exception of an isolated experimental launcher or two) were deployed during the Cold War. That did not, however, reflect any decision to keep space forever free from weaponry. Nor do existing arms control treaties ban such weapons. Instead, they ban the deployment or use of nuclear weapons in outer space, prevent colonization of heavenly bodies for military purposes, and protect the rights of countries to use space to verify arms control accords and to conduct peaceful activities.[8] In addition, in 2000, the United States and Russia agreed to notify each other of most space launches and ballistic missile tests in advance.[9] Most other matters are still unresolved. And the concept of space as a sanctuary will be more difficult to defend or justify as the advanced targeting and communications capabilities of space systems are increasingly used to help deliver lethal ordnance on target.[10]

Some scholars do argue that the Strategic Arms Reduction, Interme-diate-Range Nuclear Forces, and Conventional Armed Forces in Europe treaties effectively ban the use of ASATs by one signatory of these treaties against any and all others, given the protection provided to satellite verification missions in the accords. But these treaties were signed before imaging satellites came into their own as targeting devices for tactical warfighting purposes, raising the legal and political question of whether a satellite originally protected for one generally nonprovocative and stabilizing purpose can be guaranteed protection when used in a more competitive fashion. Moreover, no one argues that these treaties ban the development, testing, production, or deployment of ASATs.[11] Nor do any involve China.

The United States currently conducts few space weapons activities, but that could change quickly. From time to time, a Pentagon official speaks of the need to be forward-leaning on the space weaponization issue, and periodically, the open press reports consideration of at least small amounts of research and development funding for dedicated antisatellite weapons. As best as one can tell from the outside, such programs do not appear to have much momentum as of now. Yet it is hard to be sure and very hard to predict the future.

In this light, should the United States agree to restraints on future military uses of outer space, in particular the weaponization of outer space? Any useful formal treaties would have to be multilateral in scope. It makes little sense to consider bilateral treaties because it is unclear what country should be the other party to a treaty. At this point, any space treaty worth the effort to negotiate would have to include as many other space-faring countries as possible, ranging from Russia and the European powers to China, India, and Japan. To be sure, that accords would be multilateral does not mean that they should be negotiated at the United Nations, where many space arms control discussions have occurred to date. There is a strong and perhaps ideological pro–arms control bias in the UN Conference on Disarmament, where these discussions have taken place. In addition, some countries may be using those fora to score political points against the United States rather than to genuinely pursue long-term accords for promoting international stability. The United Nations might ultimately be involved to bless any treaty, but it might be best to negotiate elsewhere.

On the other hand, should the United States accelerate any space weaponization programs? Here again, my conclusion is one of caution. Although opposed to most types of binding arms control (which would deprive the United States of options that may someday be necessary), I do not believe that the United States would benefit from exercising most of those options at present. Some additional capabilities, such as improved space situational awareness, make sense, as do more hardening for key satellites and more redundancy in communications and reconnaissance systems. But weapons, at present, do not make sense—with the exception of certain ballistic missile defense capabilities designed for a different purpose (even if they admittedly often have some inherent ASAT potential).

Before going into these issues in more detail, it is useful to provide clear strategic and military context to the discussion with a fuller examination of what a space-related military contingency could entail in the future. It is along these lines that a China scenario merits further study.

Scenario: Possible War Against China Over Taiwan

Given trends in military reconnaissance, information processing, and precision-strike technologies, large assets (such as aircraft carriers and land bases) on which the United States depends are likely to be increasingly vulnerable to attack in the years ahead. Land bases can to an extent be protected, hardened, and made more numerous and redundant, but ships are a different matter. How fast, and whether, China can exploit these trends remains unclear. But the trends are real nonetheless. As a recent example, China reportedly has tested an antiship cruise missile with a 155mile range—more than twice that originally expected by U.S. intelligence. And its space assets are surely growing in scope. Even if it does not have an extensive imaging satellite network in a decade or so, it may be able to orbit one or two reconnaissance satellites that could occasionally detect large ships near Taiwan. That might be good enough. If China could find major U.S. naval assets with satellites, it would only need to sneak a single airplane, ship, or submarine into the region east of Taiwan to have a good chance of sinking a ship.

Knowing the U.S. reluctance to risk casualties in combat, China might convince itself that its plausible ability to kill many hundreds or even thousands of U.S. military personnel in a single attack would deter the United States from entering the war in the first place. Such a perception by China might well be wrong (just as Argentina was wrong to think in 1982, in a somewhat analogous situation, that it could deter Britain from deciding to take back the Falkland Islands); but it could still be quite dangerous, given the resulting risks of deterrence failure and war.

China is certainly taking steps to improve its capabilities in space operations. According to a Pentagon assessment, "Exploitation of space and acquisition of related technologies remain high priorities in Beijing. China is placing major emphasis on improving space-based reconnaissance and surveillance. . . . China is cooperating with a number of countries, including Russia, Ukraine, Brazil, Great Britain, France, Germany, and Italy, in order to advance its objectives in space." China will also surely focus on trying to neutralize U.S. space assets in any future such conflict; no prudent military planner could do anything else, and the early 2007 ASAT test would seem to confirm this logic. According to the Pentagon, in language written before that 2007 test:

> Publicly, China opposes the militarization of space, and seeks to prevent or slow the development of anti-satellite (ASAT) systems and space-based ballistic missile defenses. Privately, however, China's leaders probably view ASATs—and offensive counterspace systems, in general—as well as space-based missile defenses as inevitabilities. . . . Given China's current level of interest in laser technology, Beijing probably could develop a weapon that could destroy satellites in the future.[12]

Exactly how many U.S. satellites, and of what type, China might be able to damage or destroy is hard to predict. But it seems likely that low-altitude satellites as well as higher altitude commercial communications satellites would be vulnerable. Low-altitude imaging satellites are vulnerable to direct attack by nuclear-armed missiles, at a minimum, by high-energy lasers on the ground, and quite possibly by rapidly orbited or predeployed microsatellites as well. They are sufficiently hardened that they would have to be attacked one by one to ensure their rapid elimination. And they are sufficiently capable of transmitting signals through or around jamming that China probably could not stop their effective operation in that way. But they are few enough in number, and sufficiently valuable, that China might well find the means to go after each one.

For higher altitude military satellite constellations, including the global positioning system (GPS), military communications, and electronic intelligence systems, China's task would be much harder. Such constellations often have greater numbers of satellites than do low-altitude imagery systems. They are probably out of range of most plausible laser weapons, as well as ballistic missiles carrying nuclear weapons. They might, however, be reached by microsatellites deployed as hunter-killer weapons, particularly if those microsatellites had been predeployed (a few might be orbited quickly just before a war, but launch constraints could limit their number, since microsatellites headed to different orbits would probably require different boosters). They might also be reachable by an ASAT similar to what China tested in 2007, once placed on a larger rocket.[13]

Finally, high-altitude commercial communications satellites are quite likely to be vulnerable. Their transmissions to Earth might well be interrupted for a critical period of hours or days by jamming or a nuclear burst in the atmosphere. For example, disruption of ultra-high-frequency radio signals due to a nuclear burst can last for many hours over a ground area of hundreds or even thousands of kilometers per dimension. Unhardened satellites might be damaged by a large nuclear weapon at distances of 20,000 to 30,000 kilometers.They might even be vulnerable to laser blinding.

So it appears that China will remain quite far behind the United States in military capability, relatively rudimentary in its space capabilities and lacking in sophisticated electronic warfare techniques and similar means of disrupting command and communications. But it could hamper some satellite operations, and it could have an "asymmetric capability" to find, target, and attack U.S. Navy ships (not to mention commercial ships trying to survive the postulated blockade of Taiwan).

Some might argue that the above analysis overstates the potential role of satellites. For example, even if China would have a hard time getting aircraft close enough to track U.S. ships, given American air supremacy, it might have other means. For example, it may be able to use a sea-based acoustic network. Such a system most likely would be deployed on the seabed, as with the U.S. sound surveillance system (SOSUS) array. On that logic, China may have so many options and capabilities that it need not depend on any one type, such as space assets.

Or China may not be able to make good use of any improvements it can achieve in its satellite capabilities. To use a reconnaissance-strike complex to attack a U.S. carrier, one needs not only periodic localization of the carrier, but also real-time tracking and dissemination of that information to a missile that is capable of reaching the carrier and defeating its defenses. The reconnaissance-strike complex must also be resilient in the face of enemy action. The PRC is not close to having such a capability either in its constituent parts or as part of an integrated real-time network.

But the case for concern in general, and for special concern about Chinese satellite capabilities in particular, is still rather strong. If China does improve its satellite capabilities for imaging and communications, the United States could be quite hard-pressed to defeat them without ASAT capabilities. Destroying ground stations could require deep inland strikes— and may not work if China builds mobile stations. The sheer size of the PRC also makes it difficult to jam downlinks; the United States cannot flood all of China continuously with high-energy radio waves. (Although the United States may be able to jam links to antiship cruise missiles already in flight, if it can detect them, it would be imprudent to count on this defense alone.) Jamming uplinks may be difficult as well if China anticipates the possibility and develops good encryption technology or a satellite mode of operations in which incoming signals are ignored for certain periods of time. Jamming any PRC radar-imaging satellites may work better, since such satellites must transmit and receive signals continuously to function. But that method would work only if China relied on radar, as opposed to optical, systems.

In regard to the argument that China could use SOSUS arrays or other such capabilities to target U.S. carriers, making satellites superfluous, it should be noted that the United States has potential means for countering any such efforts. To deploy a fixed sonar array in the vast waters east of Taiwan where U.S. ships would operate in wartime, China would need to pre-deploy sensors in a region many hundreds of kilometers on a lateral dimension at least. This could be technically quite difficult in such deep waters. Although the United States has laid sonar sensors in waters more than 10,000 feet deep, the procedure is usually carried out remotely from a ship or by a special submarine, and hence becomes more difficult as depth increases. In addition, the United States would have a very good chance of recognizing what China was doing. Even though peacetime protocols would prohibit preemptive attacks, the United States could be expected to know where many of China's underwater assets had been deployed, allowing attacks of one kind or another in wartime. The United States is devoting considerable assets to intelligence operations in the region already, for example, with its attack submarine force. It would similarly have a good chance of detecting and destroying Chinese airborne platforms, including even small unmanned aircraft systems, used for reconnaissance purposes.

On balance, growing Chinese satellite capabilities for targeting and communications could be an important ingredient in what Beijing might take (or mistake) for a war-winning capability in the future. China would not need to think it had matched the U.S. Armed Forces in most military categories, only that it had an asymmetric ability to pose greater risks to the United States than Washington might consider acceptable in the event of a future Taiwan Strait crisis.

China might also have the means to attack U.S. space assets, particularly lower-flying reconnaissance satellites, by 2010 (if it does not already). It is not entirely out of the question that China might use nuclear weapons to do so systematically, knowing that such a strike might greatly weaken U.S. military capabilities without killing many, if any, Americans. China attaches enough political importance to holding onto Taiwan that it might well prove quite willing to run some risk of escalation in order to do so—especially if its leaders thought they had deduced a clever way to escalate without inviting massive retaliation. Whether it could disrupt or destroy most satellites is unclear. Whether it could reach large numbers of GPS and communications assets in medium Earth orbit and geosynchronous orbit is doubtful. But for these and other reasons, it is also doubtful that the United States could operate its space assets with impunity, or count on completely dominating military space operations, in such a scenario.

The United States is not in danger of falling behind China, Iran, or any other country in military capability in the coming years and decades, and its own capabilities will probably grow, in absolute terms, faster than those of any other country. But its relative position could still suffer in a number of military spheres, including space-related activities. Its satellites will be less dependable in conflict than they are today or have been in recent years. Other countries may also mimic the U.S. ability to use satellites and accompanying ground assets for targeting and real-time attack missions. The trends are not so unfavorable or so rapid as to require urgent remedial action. Indeed, the United States has military and political reasons to show restraint in most areas of space weaponry. But passive defensive measures should be expanded and some potential offensive capabilities investigated so as to retain the option of weaponizing them in the future, if necessary.

Arms Control and Weaponization Options

Proposals for space arms control may be grouped into three broad categories. First are outright prohibitions of indefinite duration and broad scope. Second are confidence-building measures, such as requirements for advance notification of space launches and keep-out zones around deployed satellites. Third are informal understandings, worked out in talks or more likely established through the unilateral but mutual actions of major powers.

Overall, space arms control should not be a top priority for the United States in the future, contrary to what many arms control traditionalists have concluded. Some specific accords of limited scope, such as a treaty banning collisions or explosions that would produce debris above a certain (low) altitude, and confidence-building measures such as keep-out zones near deployed satellites, do make sense. But the inability to verify compliance with more sweeping prohibitions, the inherent antisatellite capabilities of many missile defense systems, and the military need to counter efforts by other countries to use satellites to target American military assets all suggest that comprehensive accords banning the weaponization of space are both impractical and undesirable. That said, the United States should not want to hasten the weaponization of space and indeed should want to avoid such an eventuality. It benefits from its own military uses of space greatly and disproportionately at present. It should take unilateral action, such as by declaring that it has no dedicated antisatellite weapons programs, to help buttress the status quo as much as possible.

One type of arms control accord on activities in space would be quite comprehensive, calling for no testing, production, or deployment of ASATs of any kind, based in space or on the ground, at any time; no Earth-attack weapons stationed in space, ever; and formal, permanent treaties codifying these prohibitions. These provisions are in line with those in proposals made by the Chinese and Russian delegations to the UN Conference on Disarmament in Geneva. They also are supported by some traditional arms control proponents who argue that space should be a sanctuary from weaponization and that the Outer Space Treaty already strongly suggests as much.[14]

These provisions suffer from three main flaws. To begin, it is difficult to be sure that other countries' satellite payloads are not ASATs. This is especially true in regard to microsatellites, which are hard to track. Some have proposed inspections of all payloads going into orbit, but this would not prevent a "breakout," in which a country on the verge of war would simply refuse to continue to abide by the provisions. Since microsats can be tested for maneuverability without making them look like ASATs and are being so tested, it will be difficult to preclude this scenario. A similar problem arises with the idea of banning specific types of experimentation, such as outdoor experiments or flight testing.[15] A laser can be tested for beam strength and pointing accuracy as a ballistic missile defense device without being identified as an ASAT. A microsat can be tested for maneuverability as a scientific probe, even if its real purpose is different, since maneuvering microsats capable of colliding with other satellites may have no visible features clearly revealing their intended purpose. Bans on outdoor testing of declared ASAT devices would do little to impede their development.

Second, more broadly, it is not possible to prevent certain types of weapons designed for ballistic missile defense from being used as ASATs. This is in essence a problem of verification. However, the issue is less of verification per se than of knowing the intent of the country building a given system—and ensuring that its intent never changes. The latter goals are unrealistic. Some systems designed for missile defense have inherent ASAT capabilities and will retain them, due to the laws of physics, regardless of what arms control prohibitions are developed, and countries possessing these systems will recognize their latent capabilities.[16] For example, the American midcourse missile defense system and the airborne laser would both have inherent capabilities against low Earth orbit (LEO) satellites, if given good information on a satellite's location—easy to obtain—and perhaps some software modifications. The United States could declare for the time being that it will not link these missile defense systems to satellite networks or give them the necessary communications and software capabilities to accept such data. But such restraints, while currently worthwhile as informal, nonbinding measures, are difficult to verify and easy to reverse. Thus, no robust, long-term formal treaty regime should be based on them. Indeed, the problem goes beyond missile defense systems. Even the space shuttle, with its ability to maneuver and approach satellites in low Earth orbit, has inherent ASAT potential. So do any country's nuclear weapons deployed atop ballistic missiles. Explicit testing in ASAT modes can be prohibited, but any prohibition could have limited meaning.

Third, it is not clear that the United States will benefit militarily from an ASAT ban forever. The scenario of a war in the Taiwan Strait is a good example of how, someday, the United States could be put at serious risk by another country's satellites.[17] That day is not near, and there are many other possible ways to deal with the worry in the near term besides developing destructive ASATs. But over time, a possible need for such a weapon cannot be ruled out.

There is a stronger argument for banning Earth-attack weapons based in space. Most such weapons would probably require considerable testing. That means that testing might well be verifiable (especially if testing via ballistic missile were also prohibited). Furthermore, prohibitions on such weapons will cost the United States little, since it will retain other possible recourses to delivering weapons quickly over long distances (as may other countries). So a ban may make sense. The most powerful counterargument to banning ground-attack weapons in space is that the long-term need for them cannot be easily assessed now. But physical realities do suggest that the United States will be able to make do without them or to find alternatives.

A number of specific prohibitions, fairly narrowly construed, are worth considering as well. They could be carefully tailored so as not to preclude development of various capabilities in the future, given the realities and security requirements noted. But they nevertheless could help to reassure other countries about U.S. intentions at a time of still-unsettled great power relations and help protect space against the creation of excessive debris or other hazards to safe use over the longer term. Measures could include the following:

- temporary prohibitions, possibly renewable, on the development, testing, and deployment of ASATs, Earth-attack weapons, or both
- bans on testing or deployment of ASATs above set altitudes in space
- bans on debris-producing ASATs
- no first use of ASATs and space weapons.

Compliance with temporary formal treaty prohibitions would be no more verifiable than permanent bans. But they could make sense when future strategic and technological circumstances cannot easily be predicted.

There are downsides to signing accords from which one might very well withdraw, of course. If and when the United States could no longer support the prohibitions involved, it would likely suffer in the court of international public opinion by its unwillingness to extend the accord, even if the accord was specifically designed to be nonpermanent. The experience of the United States in withdrawing from the Anti-Ballistic Missile Treaty suggests that the damage from such decisions can be limited. But that experience also suggests that it requires a great deal of effort to lay the diplomatic foundation for withdrawal, that bitterness about such a decision can persist thereafter, and that withdrawal from one treaty regimen— however outdated—might be used as a justification by other states to withdraw from more important and less outdated treaties that they find undesirable. On balance, accords of indefinite duration should not be entered into unless one expects to remain part of them indefinitely, so I tend to oppose most such accords.

Bans on testing or employing ASATs that produce debris make sense and could well be codified by binding international treaty. Destructive testing of weapons such as the Clinton administration's midcourse missile defense system or other hit-to-kill or explosive devices against objects in satellite orbital zones would not only increase the risks of an ASAT competition, it would also create debris in LEO regions that would remain in orbit indefinitely (that is, unless the testing occurred in what are effectively the higher parts of the Earth's atmosphere, where air resistance would ultimately bring down debris and where few if any satellites fly in any case). The U.S. military worries about this debris-producing effect of testing. To date, tests of the midcourse system have occurred at roughly 140 miles altitude, producing debris that deorbits within roughly 20 minutes, but future tests will be higher. A ceiling of 300 to 500 miles might be placed on such tests and a ban placed on using targets that are in orbit.

Another category of arms accords includes those that do not limit the weapons capabilities of states but instead seek to establish rules or guidelines for how states use their military assets. The goals would be to reduce tension, improve communications, and build safety mechanisms into how countries make military use of outer space. This arms control concept would build on some of the agreements that the nuclear superpowers signed to reduce the potential for unintentional nuclear confrontation during the Cold War, including the 1972 Incidents at Sea Agreement and agreements to set up communications hotlines.[18] Here the stakes might not be so great, but they could still be great enough to justify some straightforward measures and rules of the road—as long as no great effort has to be expended to work out some commonly accepted practices.

One such idea is that of establishing keep-out zones around deployed satellites. There is no reason for a satellite to approach within a few tens of kilometers—or, in some orbits, within even hundreds of kilometers—of another satellite. Any close approach can thus be assumed to be hostile and ruled out as an acceptable action. States might consider formalizing this understanding of keep-out zones. The idea makes particularly good sense if there is a way to monitor compliance. Future American satellites are expected to have more sensors capable of surveying the environment around them, so this approach may work.[19]

What real strategic purpose would be served by such zones? Unless satellites were themselves given self-defense capabilities—making them difficult to distinguish from offensive ASATs—the zones could not be enforced. And any country wishing to develop a close-approach capability for the purpose of ultimately launching a large-scale ASAT surprise attack could develop that capability despite the existence of keep-out zones, by testing against its own space assets or even against empty points in space.

That said, the idea may still make sense, even though keep-out zones would not substantially limit military capabilities. First, creating such zones would add another step that any state planning an attack would have to address. ASATs could not easily be predeployed near other satellites without arousing suspicion (especially if the United States and other countries deployed satellites with sensors capable of monitoring their neighborhoods). Second, any state violating the keep-out zones would tend to tip off the targeted country about its likely intentions; conversely, respecting the zones would constitute a form of restraint that could calm nerves to some modest but perhaps worthwhile degree. And the United States has no need to place satellites near other countries' space assets in any case, so it would not be giving up anything to endorse such a rule of the road. On balance, this idea is a worthy one for a treaty regime, though not worth a great deal of top-level time to negotiate.

What of advance notice of space launches? Again, this type of accord, such as that reached between the United States and Russia during the Clinton administration, would not prevent a country from breaking out suddenly, nor would it place a meaningful constraint on capabilities. But as long as it was observed, countries would have additional reassurance that others were playing by the rules. They would also have time to prepare to observe the deployment of satellites from any launch, allowing slightly greater confidence that ASATs were not being deployed. As a peacetime rule of the road at least, it makes sense. Some have also suggested allowing international monitoring of space payloads prior to their launch.[20] This seems questionable, though, since satellites could be effective ASATs without carrying payloads that made that obvious.

On balance, several of these confidence-building measures are marginally useful. They will not prevent the United States from retaining its hedges against a future need for ASATs, whether in the form of dual-purpose ballistic missile defense programs or even dedicated antisatellite systems. They will not prevent China or another country from quietly building inherent ASAT capability either. But they will add an extra step or two that other countries choosing to weaponize space would need to deal with before threatening American interests.

A final category of measures would not involve arms control at all— in the formal sense of signed treaties and binding commitments—but rather unofficial and unilateral restraints. Such restraints would not force the United States to tie one hand behind its back and leave other countries free to develop space weapons; rather, by adopting the restraints and thereby setting a precedent and a tone, the United States would aim to encourage other countries to reciprocate. To the extent others did not show restraint, the policy could be reconsidered. This approach has several precedents in international affairs. For example, during the first Bush administration, the United States reduced the alert levels of some nuclear forces and took tactical nuclear weapons off naval vessels in part to encourage similar Soviet actions, which followed.[21] This approach can work more quickly than formal arms control; it can also preserve flexibility should circumstances change. It is perhaps most useful when it is not absolutely critical that all countries immediately comply with a given set of rules or restraints. In other words, if the United States would have ample time to change its policy in the event that other countries failed to cooperate, without doing harm to its security interests in the interim, there is much to be said for this approach.

Since the United States is not presently building or deploying space weapons, informal restraint would presumably apply to research and development and testing activities. As one example, if a treaty to accomplish this goal could not be quickly negotiated, the United States could make a unilateral pledge not to create space debris through testing of any ASAT.[22] The flexibility associated with such a pledge might permit it to go further and also pledge not to produce any ASAT that would ever create debris, given that even if the United States needs a future ASAT, it would have alternative technological options.

The United States might also consider making a clear statement that it has no dedicated ASAT programs and no intention of initiating development or deployment of any, if that is true. It could also declare that it will not test any systems, including high-powered lasers, microsatellites, and ballistic missile defenses, in an ASAT mode. The latter approach would have the greatest chance of eliciting verifiable reciprocation by other countries.

The downsides to such statements are that if and when U.S. policy requirements changed, the statements would have to be repudiated, raising alarms abroad and risking a greater diplomatic problem than would occur if the United States had never held itself to informal restraints. The advantages are that they might buy the United States some time, allowing it to play its part in stigmatizing space weapons it has no strategic interest in developing or seeing developed any time soon.

Conclusion

While I have spent considerable time on arms control options, it is worth concluding with an observation on which military measures do make some sense now (even as options are preserved for considering others in the future). First, improved American space surveillance is needed, largely to know what other countries are doing with their microsatellites. Second, individual American satellites would also benefit from local situational awareness so that Department of Defense officials will know if satellites are approached closely. Third, and most of all, the vulnerability of key U.S. satellites to a Rumsfeldian Space Pearl Harbor—admittedly a melodramatic and exaggerated image, but still a useful caution and reminder—should be mitigated. This requires hardening against electromagnetic pulse and shielding optical components against blinding lasers. Someday, it could require creating mechanisms to deal with excess heat from lasers with prolonged dwell times. It also argues strongly in favor of redundancy. That need not mean rapid-launch satellite replenishment capability. But it does argue for a portfolio of reconnaissance capabilities, including airbreathing capabilities.

Military space policy is and will remain complex, with judgments constantly required about which programs make strategic sense and serve American national security objectives. To be sure, that argument is frustrating for those who would prefer the analytical and rhetorical simplicity of the argument that space must remain man's last unmilitarized frontier or that space, like all other frontiers, will eventually be militarized, so we may as well get on with it first. But a balanced approach reflects reality and the complex web of interests that the United States needs to advance in the years ahead.

Notes

1. This section draws heavily on Michael E. O'Hanlon, *Neither Star Wars nor Sanctuary: Constraining the Military Use of Space* (Washington, DC: Brookings Institution, 2004).
2. See, for example, Theresa Hitchens, "Monsters and Shadows: Left Unchecked, American Fears Regarding Threats to Space Assets Will Drive Weaponization," *Disarmament Forum* 1 (2003), 24.
3. See transcript of the panel discussion held in the United Nations on October 19, 2000, by the NGO Committee on Disarmament, available at <www.igc.org/disarm/T191000outerspace.htm>; and statement by Hu Xiaodi, ambassador for disarmament affairs of China, at the Plenary of the Conference on Disarmament,June 7, 2001, available at

<www3.itu.int/missions/China/disarmament/2001files/disarmdoc010607.htm>; and "China, Russia Want Space Weapons Banned," *Philadelphia Inquirer*, August 23, 2002.

4. See Canadian Working Paper Concerning Conference on Disarmament Action on Outer Space, January 21, 1998, available at <www.fas.org/nuke/control/paros/docs/1487.htm>; James Clay Moltz, "Breaking the Deadlock on Space Arms Control," *Arms Control Today* (April 2002), available at <www.armscontrol.org/act/2002_04/moltzapril02.asp?print>.
5. Peter L. Hays, *United States Military Space: Into the Twenty-first Century* (Montgomery, AL: Air University Press, 2002), 11–13; Alvin and Heidi Toffler, *War and Anti-War: Survival at the Dawn of the 21st Century* (Boston: Little, Brown, 1993); Stuart E. Johnson and Martin C. Libicki, eds., *Dominant Battlespace Knowledge* (Washington, DC: National Defense University Press, 1996); Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report* (Washington, DC: U.S. Government Printing Office, 1993); William Owens, *Lifting the Fog of War* (New York: Farrar, Straus and Giroux, 2000); Daniel Goure and Christopher M. Szara, eds., *Air and Space Power in the New Millennium* (Washington, DC: Center for Strategic and International Studies, 1997); Defense Science Board 1996 Summer Study Task Force, *Tactics and Technology for 21st Century Military Superiority* (Washington, DC: Department of Defense, 1996); James P. Wade and Harlan K. Ullman, *Shock and Awe: Achieving Rapid Dominance* (Washington, DC: National Defense University Press, 1996); George and Meredith Friedman, *The Future of War: Power, Technology, and American World Dominance in the 21st Century* (New York: Crown Publishers, 1996); John Arquilla and David Ronfeldt, eds., *In Athena's Camp: Preparing for Conflict in the Information Age* (Santa Monica, CA: RAND Corporation, 1997); National Defense Panel, *Transforming Defense: National Security in the 21st Century* (Arlington, VA: The Pentagon, December 1997); and Joint Chiefs of Staff, *Joint Vision 2010* (Washington, DC: Department of Defense, 1996) and *Joint Vision 2020* (Washington, DC: Department of Defense, 2000).
6. Barry D. Watts, *The Military Use of Space: A Diagnostic Assessment* (Washington, DC: Center for Strategic and Budgetary Assessments, 2001), 29–30.
7. Bates Gill and Martin Kleiber, "China's Space Odyssey," *Foreign Affairs* 86, no. 3 (May– June 2007), 2–6.
8. Paul B. Stares, *Space and National Security* (Washington, DC: Brookings Institution, 1987), 147.
9. Peter L. Hays, "Military Space Cooperation: Opportunities and Challenges," in *Future Security in Space: Commercial, Military, and Arms Control Trade-Offs*, ed. James Clay Moltz, Occasional Paper No. 10 (Monterey, CA: Monterey Institute of International Studies, 2002), 37.
10. This view is hardly confined to conservatives; see, for example, Ashton Carter, "Satellites and Anti-Satellites: The Limits of the Possible," *International Security* 10, no. 4 (Spring 1986), 47.
11. Jonathan Dean, "Defenses in Space: Treaty Issues," in Moltz, 4.
12. Department of Defense, *Annual Report to Congress: The Military Power of the People's Republic of China*, July 28, 2003, 36, available at <www.defenselink.mil/pubs/2003chinaex.pdf>.
13. Geoffrey Forden, "After China's Test: Time for a Limited Ban on Anti-Satellite Weapons," *Arms Control Today* 37, no. 3 (April 2007), 19–23.
14. See Rebecca Johnson, *Missile Defence and the Weaponisation of Space*, International Security Information Service Policy Paper on Ballistic Missile Defense No. 11 (London: International Security Information Service, January 2003), available at <www.isisuk.demon.co.uk>; Jonathan Dean, "Defenses in Space: Treaty Issues," in Moltz, 4; George Bunn and John B. Rhinelander, "Outer Space Treaty May Ban Strike Weapons," *Arms Control Today* 32, no. 5 (June 2002), 24; and Bruce M. Deblois, "Space Sanctuary: A Viable National Strategy," *Aerospace Power Journal* (Winter 1998), 41.
15. For a proposal along these lines, see Michael Krepon with Christopher Clary, "Space Assurance or Space Dominance? The Case against Weaponizing Space," Henry L. Stimson Center, 2003, 109–110.
16. For an earlier, highly sophisticated argument along these lines, see John Tirman, ed., *The Fallacy of Star Wars* (New York: Vintage Books, 1984).
17. See O'Hanlon.
18. For a good discussion, see Krepon and Clary, 114–124.

19. For an example of a specific proposal along these lines, see Michael Krepon, "Model Code of Conduct for the Prevention of Incidents and Dangerous Military Practices in Outer Space," Henry L. Stimson Center, 2004, available at <www.stimson.org/wos/pdf/codeofconduct.pdf>.
20. Krepon and Clary, 93.
21. For a summary, see David Mosher and Michael O'Hanlon, *The START Treaty and Beyond* (Washington, DC: Congressional Budget Office, October 1991), 34–35; Ivo H. Daalder, *Cooperative Arms Control: A New Agenda for the Post–Cold War Era*, CISSM Papers No. 1, University of Maryland at College Park (October 1992), 23–27.
22. Hays, "Military Space Cooperation: Opportunities and Challenges," in Moltz, 42.

Chapter 22:

International Perspectives: Russia

James E. Oberg

Russia spent the year 2007 commemorating its half-century of activity in space and the men who helped make it happen. Events celebrated included the 150^{th} anniversary of Konstantin Tsiolkovsky's birth, the birth centenary of Sergei Korolev, and the 50-year anniversary of the launch of the world's first artificial satellite in the Soviet Union. But with good reason, Russia was also celebrating the improving prospects for its space future. Lamentable hangovers from its more recent "space slump" have been fading away, although not entirely.

Not far from the main launch pad at the Baykonur cosmodrome—a pad that hosted the Sputnik blastoff on October 4, 1957, and the Yuri Gagarin blastoff on April 12, 1961, and that still hosts Soyuz booster launches—stands a simple obelisk. It is surmounted by a full-size metal sculpture of Sputnik and supports a small plaque that reads, "Here through the genius of Soviet man began the relentless assault on space." But the succeeding 50 years saw a mixture of relentless assault and single-minded perseverance with wasteful detours, dead-ended spectacles, desperate gambles, and shriveling budgets. Interplanetary probes pioneered the routes to nearby planets but could reach no farther. Operating lifetimes of affordable satellites were so short that mass quantities had to be successively launched into orbit—with the unintended benefit of providing a major surge (or casualty replacement) capability for military systems. Endurance marathons on manned space stations and resolute repair missions in the face of daunting breakdowns demonstrated the resilience of manned spaceflight—and the inability of the Soviet economy to industrially exploit the opportunities of the space frontier.

Many space strategies have evolved to keep pace with these changing circumstances. Where once the Soviet Union saw itself as a lone pioneer leading humanity into space, Russia now portrays itself as an essential partner of other spacefaring nations. Where once Soviet scientists foresaw national wealth from exploiting space conditions and space-based vantage points, Russian government planners now see their main space-related cash flow in sales of know-how, goods, and services to other spacefaring powers. Where once fleets of military space systems were seen as force multipliers for the Soviet armed forces on expansive missions, a much more constrained Russian military establishment now struggles not to be left hopelessly behind by U.S. and other national military space infrastructures, even as its fear of military confrontation ebbs.

Fifty years on, top Russian leaders have paid homage to the value of the country's space activities. "The industry is an integral part of the national defense industry and one of the flagship national industrial branches," Russian deputy prime minister and defense minister Sergei Ivanov said recently while addressing Russia's Defense Industry

Commission in Moscow.[1] "Thus, space industry development is a must for ensuring Russia's independent space exploration." At another event, Ivanov stressed the role of a nation's military-industrial complex as "a locomotive of high technology, economy and knowledge practically in all countries of the world," [2] and added, "We are not an exception from this rule, because over half of the country's total scientific potential is still concentrated in the defense and industrial complex sphere."

Russian President Vladimir Putin directed the head of the Federal Space Agency, Anatoli Perminov, to work out a 30-year strategy extending to about 2040. "He wants the guidelines of the development of space exploration in the country determined," Perminov explained. "That includes above all the development of existing launching sites, the group of space assets in orbit in different departments—communications, remote sensing, weather watch and so on. Naturally, some work is to be done for defense that includes new carrier rockets and the ground infrastructure and control of space systems in orbit."

To examine the route from where Russia is in space to where it wants to be, it is useful to survey the human, financial, administrative, and technical resources at its disposal, and then extrapolate from there.

The Human Factor

The fundamental basis for any activity is the team of people who are to carry it out. Here, Russia is still struggling with personnel management issues that stretch back to the very beginning of the space era. A successful resolution of these issues—still in doubt—is fundamental to any hope of success in the coming decades.

To a far greater extent than in the United States, Russia created and then depended on a large cadre of specialists hired as young people in the Sputnik era. They worked together for decades and knew each others' specialties. Along the way, they brought in a few apprentices, but as a rule they relied on their own experience, memories, intuition, and expertise, which were rarely documented in a form accessible to others.

As a result, the average age of space workers in many key facilities in the 1990s was only a few years less than the average male life expectancy of 59. If 20-year-old military draftees in the Russian Space Forces are counted, a lower value can be obtained (47 is the current official average age), but unquestionably this remains a critical challenge for the coming decade when half a century of expertise must be transferred or lost (and then slowly and painfully reacquired).

"Staffing is a painful problem for us," Perminov said at a news conference in 2006. "It has always been a big problem and it is particularly an acute problem now."[3] "If there is no inflow of young specialists," Russian prime minister Mikhail Fradkov had told reporters in July 2005, "everything could be lost, regardless of the money invested." [4]

Sergei Ivanov had told newsmen much the same thing in late 2006. The chiefs of defense enterprises, he said, are concerned "not so much about financing as about who will work, where to get qualified personnel." One press report attributed to Ivanov the idea that "a shortfall of such cadre is increasingly apparent."[5] Ivanov concluded, "The shortage of personnel is the main problem facing the rocket and space industry."[6]

Perminov has directly addressed his strategy for finding such employees. They come from institutes such as Bauman University and the Moscow Aviation Institute, as well as from the military. "They mostly work at space launch sites, in particular, Baykonur," Perminov noted. [7] But new employees in their late 40s will not help drive down the average age of the team.

Recruitment remains hit-or-miss, with some organizations showing large influxes of young people, as long as the cash flow remains healthy. But to a large extent, every new employee is a potential ex-employee to a degree rarely seen in the previous generation. In those days, there were few other jobs with as much prestige, intellectual stimulation, or access to exclusive privileges, but today that has all changed, and young people know it. There are enthusiasts and loyalists—often the children of current or past workers—but there just are not enough of them to even replace the bodies, much less the experienced minds, now hemorrhaging irretrievably from the industry.

The way in which Russian space workers are organized into teams has also evolved. Under the Soviet regime, federal agencies and industrial enterprises were often arbitrarily yoked together on projects that operated by fiat, not by budget (there was no quantitative "cash flow" to gauge levels of effort). Conflicts and alliances developed in an almost byzantine style (some mergers were actually sealed by marriages, or even what looked like exchanges of hostages). Operating as quasi-autonomous satrapies, space and rocket firms were vertically integrated, often possessing their own support industries, hospitals, and even their own food supplies.

Major Players

Only in 1993, in response to negotiations with the United States, did Moscow convert an administrative ministry into an executive agency with its own budget—the "Russian Space Agency," or Roskosmos (the name has evolved over the years). A parallel military command, usually called some variation of "Russian military space forces" and transferred among major branches of the armed forces every few years, handled infrastructure operations and military-related space vehicles. Both agencies dealt with a crazy-quilt array of academic and industrial entities.

The most important firms are:

- Energiya Rocket and Space Corporation, Moscow: human spacecraft, Progress freighters, Block-D upper stages, and communications satellites, and operates Mission Control Center. Management was replaced recently in a "hostile takeover" by the Russian Space Agency.
- Khrunichev State Research and Production Space Center, Moscow: Proton rockets, space station large modules, Rokot intercontinental ballistic missile

(ICBM)–derived small launchers, and small satellites. This firm is the developer of the Angara booster family. Its finances are shaky.
- Progress State Research and Production Rocket Space Center, Samara: Soyuz booster fabrication and reconnaissance satellites
- Applied Mechanics Scientific and Production Organization, Krasnoyarsk: communications and navigation satellites
- Lavochkin Design Bureau, Moscow-Khimki: lunar and planetary probes, military reconnaissance satellites, and other small satellites
- Moscow Institute of Thermal Technologies: sole remaining active ICBM/submarine-launched ballistic missile (SLBM) manufacturer (Topol, Bulava missiles, START–1 small satellite launcher)
- Production Association Polyot, Omsk: Kosmos satellite launcher, global navigation satellite system (GLONASS) navigation satellites, Angara booster elements
- Gagarin Cosmonaut Training Center, Zvyozdny: cosmonaut training. Currently undergoing a tumultuous transfer from military to civilian management.
- Krasnoznamensk (Golytsino-2), near Moscow: central space communications and control hub, operated by military space forces.

Other smaller entities build weather and Earth resources satellites, perform basic research, and provide support services.

A major challenge today is the consolidation of hundreds of these groups, large and small, that make up the Russian space industrial base. Perminov recently put the total at "about 112 spearhead enterprises," and his job is to reduce this number to a dozen. Specific skills are to be retained, while duplication in support technologies is to be eliminated.

Andrei Kislyakov, a retired space official who now writes for the Novosti news agency, has described the lack of progress toward this goal over the past several years: "On October 11, 2001, the Russian government approved the federal target program 'Overhauling and Expanding the Defense Industry in 2002–2006.' A conference on July 6 [2006] that discussed the same issue indicated there had been no achievements in this sphere. . . . Anatoly Perminov said Russia's 100-plus space-rocket companies will be merged into 10 integrated companies, and the entire industry will have just 3 or 4 corporations by 2015. It is a tried and tested way. Unfortunately, they are only now starting to implement this plan, rather than in 2001." [8]

Budgetary Concerns

These enterprises and their overseeing bureaucracies had been operating on dwindling funds since the late 1980s—an impoverishment that grew even worse with the collapse of the Soviet Union and the loss of many industrial elements to newly independent nations. But the 20-year-long specter of poverty has faded. According to Perminov, "This year [2006] for the first time the entire sum allocated for the federal space program, as far as the Federal Space Agency is concerned, has been disbursed."[9]

This financial well-being is largely based on reliance on what is euphemistically called "extra-budget sources" (in reality, sales to Western customers). "This year [2006] 23 billion rubles has been provided for the federal space program," Perminov explained. "Next year it will be 24.4 billion rubles, with no account of extra revenues. Combined with other programs, this makes a total of 35 billion to 36 billion rubles." [10] That means that about 12 billion rubles, or a third of the total space budget, has to be raised commercially.

This fraction has remained fairly constant in recent years. In 2006, for the period 2006 to 2015, 305 billion rubles (about $10 billion) had been allocated, with the expectation that an additional 130 billion rubles will come from "off-budget sources." That equals about $400 million per year of foreign funding, or about 30 percent of the operating funds (by comparison, from 1996 to 2000, 60 percent of the space budget was foreign funding, and in the first half of this decade, the figure has been about 30 percent). [11]

At least the space industry can again pay its workers. "As for salaries, we have done away with this problem," Perminov declared. "This year [2006] there are no enterprises with arrears of wages." Salaries range from 11,000 rubles to 20,000 rubles, not generous in Russian terms by any means—but a living wage, especially in two-income families.[12]

Launch Sites

Baykonur

The primary Russian space launch facility at Baykonur is undergoing profound transition as operating elements of the Russian Military Space Forces hand over facilities to the civilian Federal Space Agency. Progressive infrastructure collapse has been locally reversed through investments by commercial satellite launch groups. Political arrangements with the government of Kazakhstan have stabilized, although both Russian and Kazakh officials have begun expressing anxiety about signs of Islamic extremist activities among the local population.

"A lot of work has been done to transfer Baykonur facilities from the Defense Ministry to Roskosmos," Perminov noted in December 2006. "A total of 62 facilities were handed over this year and the remaining ones will be handed over by the end of 2007. All the facilities have been accepted, and operational units have been appointed."[13]

Management and maintenance of decaying structures have been a challenge. When the massive Building 254, built in the late 1970s to house the Buran shuttle, was converted to processing modules and spacecraft for the International Space Station, the Buran orbiter that had made the program's single orbital flight in late 1988 was moved to Building 112 next door (it was built in the mid-1960s for the abortive Soviet man-to-the-Moon program). A low bay of that building had already been converted to house payload processing for the commercial Soyuz launch company Starsem, and an adjoining medium bay was modified to process Soyuz booster processing after the condition of the original assembly hall (built in 1956) deteriorated dangerously. But the high bay area housing the

Buran collapsed in 2001, killing six workers and destroying the flown shuttle. Yet the pressing need for booster processing facilities—and the availability of investment funds—led to the decision to repair and reopen one of the two collapsed high bays.

Plesetsk

The mainly military space and missile launch facility north of Moscow has also been undergoing significant infrastructure enhancement, both in space operations and in worker living conditions. In particular, launch pads for Russia's first new booster in more than 20 years, the Angara family, are nearing completion.

Sergey Ivanov has described the Angara launch site as a "task of state importance" and asserted that the new pads will give Russia "a guaranteed, and independent from any political or economic circumstances, access to outer space." Once operational, the pads will allow the transfer of military and dual-purpose spacecraft launches from Baykonur to Plesetsk.[14] This will involve launchings into all operational orbits including geosynchronous (24-hour equatorial), either through use of a larger plane change during direct ascent or via fuel-efficient but operationally complex orbital plane change maneuvers utilizing lunar fly-by (currently, such orbits can only be reached from Baykonur).

Kapustin Yar

Russia's original missile launch facility on the lower Volga River continues in operation for military missile (including antiaircraft) testing, and spartan living conditions have slightly improved according to press reports in 2006. It retains the capability for small satellite launchings.

Svobodny

The Far East launch site for small commercial satellites, once touted as a replacement for major Baykonur operations but threatened with closure, faced an uncertain future. Regional governor Leonid Korotkov told reporters in December 2006 that he had attended a meeting of the Russia Security Council in Moscow where it was decided not to "liquidate" the center. One of its decisions was to propose to the government and the Defense Ministry "to find forms of the rational use of the cosmodrome in the interests of defense, security and the economy of the country," Korotkov said. "This decision gives certain hopes for the preservation of the cosmodrome's infrastructure." [15]START–1 satellite launchers (converted ICBMs) operate from the site's Pad 5. In 2009, the Kremlin blessed the creation of a new major launch site near the site, to be called Vostochny and to be capable of human space launches.

Kourou

Development of a Soyuz launch vehicle capability at the French launch site in French Guiana is proceeding. In a formal ceremony in February 2007, Russian officials laid a stone from the Sputnik pad in Baykonur at the Kourou space launch site. [16] The Russian side is investing 121 million euros of its own money build the Kourou facility. The total cost, shared with the European Space Agency, is more than 300 million euros, with a first launch expected in late 2009 and more than five launches per year (including potentially manned launchings) subsequently. [17]

Dombarovsky

A new satellite launch site was introduced in mid-2006 with the orbiting of a commercial payload (Bigelow Aerospace's Genesis-1 inflatable habitat prototype) aboard a modified Satan SS–18 ICBM (called Dnepr with the addition of a third stage) from the missile field in southwest Siberia. A special hotel and payload processing hangar has been built in the support town of Yasny for foreign customers, and more launchings are planned. Use of the military base simplifies launch preparations and eliminates issues of environmental concerns by the Kazakh government, especially useful in light of the mid-2006 launch failure of the same category of booster from Baykonur that resulted in significant contamination issues in a sparsely populated region south of Baykonur.

Sea Launch

The international consortium that launches Ukrainian-built Zenit rockets from a floating platform based in California continues in operation despite a lift-off booster explosion in early 2007 that damaged the platform. The project had already been facing major cash flow problems due to the inability to perform a critical originally intended mission function—to reload the launch platform with a second launch vehicle and payload while at sea. With launches limited to a single shot per time-consuming cruise, earnings are severely constrained.

Russia's interest is with the use of a Russian-built upper stage, the D block, a booster that has been phased out of most other Russian launches (on Proton it has mostly been replaced with a competing vendor's upper stage, called Briz), resulting in significant income loss to its manufacturer, the Energiya Rocket and Space Corporation.

Rumors persist that Ukraine, eager to establish a Zenit launch capability at the Brazilian Alcantara launch site, is considering moving Sea Launch operations permanently to Brazil, where the existing floating launch platform could be anchored just offshore of Alcantara and could be rapidly reloaded after each commercial launch. In late 2006, Ukraine completed fabrication of a launch platform for the smaller Tsyklon-4 booster, intended for installation at Alcantara to allow commercial launchings on behalf of the two-nation Alcantara-Tsyklon-Space corporation. [18]

Submarine-launched Boosters

A converted SLBM booster, renamed Shtil, carried a small German science satellite into orbit most recently on May 26, 2006, launched from the submarine *Ekaterinberg* in the Barents Sea. But launch failures have bedeviled this attempted conversion of rockets from the Makeyev Bureau. The old rocket factory had been the manufacturer of all but the most recent submarine missiles but is now facing bankruptcy after transfer of all future military missile contracts to another vendor. Operational advantages of this submarine option appear dubious, and cost advantages are far outweighed by the daunting failure rate, arguably a consequence of the financial collapse of the missile firm that is desperately seeking to avoid dissolution.

Launch Vehicles

Russia's family of satellite launch vehicles has been undergoing significant upgrading, but plans to shift to a new generation of launchers—the Angara series—continue to recede into the indefinite future.

Soyuz-2

This is the biggest recent success story for Russian space rocketry. Three successful missions with this upgraded booster occurred in 2006, and more are planned (including from Kourou). The upgrades include a digital control system that flies a more efficient ascent profile and allows a reduction in unburned propellant, a new telemetry system, addition of wider and longer payload farings, replacement of non-Russian vendors, more efficient main stage engines, and an entirely new third-stage rocket engine. Combined, these improvements increase the payload of the vehicle by 1,200 kilograms (almost 20 percent). The booster is designed for human launches as well.

This upgrade will allow years of future use for a booster that has, in its basic form, been launched almost 1,800 times in the past 50 years. One of its anticipated future missions, using a Fregat fourth stage, will be to carry a pair of replacements of improved GLONASS-K navigation satellites in 2010, a significant cost reduction of the three-per-launch Proton missions now needed. [19]

Proton

Russia's most powerful launch vehicle (approximately 20 tons in low Earth orbit) continues in use, in recent years exclusively for geosynchronous-bound missions. The Proton-M upgrade is now entering service and, as with the Soyuz-2, uses a digital flight control system and upgraded first-stage engines, resulting in a 6 percent payload performance improvement. The next major upgrade in development will be a cryogenic upper stage.[20] Once operational, it will make the Proton competitive with Ariane-V for geosynchronous orbit missions.

Angara

The long-anticipated "ecologically friendly" booster family called Angara had been held up for years as Russia sought Western funding. "This system has been in development for more than a decade," Russian Space Forces commander Colonel General Vladimir

Popovkin told reporters. "Eventually, an understanding has been reached on how it should be funded and when it should be created." [21]

Russia spent 1.8 billion rubles ($75 million) on space center development in 2007, most of it at Plesetsk, and most of that for the Angara launch support complex. This money came from the Defense Ministry budget, not the Russian Space Agency. [22]

Angara is being built by the Khrunichev State Research and Production Space Center, the builders of the Proton system. But unlike the military-derived missiles that use highly toxic hypergolic propellants, Angara is to use more benign kerosene and liquid oxygen. Depending on the number of engines and strap-on stages, the system will offer small, medium, and large (Angara-5) versions [23] and will replace the Proton rocket (and Soyuz as well, perhaps) about 10 years from now. A special Angara-5 version called Baiterek will operate under Kazakh auspices from Baykonur, and one Proton launch pad is already undergoing modifications.

These delays are more than merely inconvenient—they threaten the very financial rationale for the project. Roskosmos official Aleksandr Chulkov had told *Izvestia* in August 2005 that funding problems continued to delay the new launch vehicle family. "The Angara rocket, however promising it may be, will not be ready in the next three years," he admitted. By then, he warned, competition from comparable boosters in China, India, and Ukraine may have locked up the international market: "Ukrainian rockets are serious competitors for Russian cosmonautics, and it will be very difficult to take away the leading position which we ensured for them." As a result of the delays, paying customers such as Panamsat have cancelled launch contracts worth in aggregate up to $700 million in the past 2 years. They have switched to other rockets and may never come back to Angara.

URAL

A joint Russo-French project called URAL aims at a fully reusable advanced launch vehicle burning liquid hydrogen and methane. Whether it is an actual hardware development project or a foreign-subsidized hobby shop for underemployed Russian space engineers is impossible to tell.

Air Launch

A project involving an Antonov-124 aircraft and a two-stage satellite launcher called Polyot has been in the works for a number of years but moved closer to reality in 2006 with the beginning of construction of ground facilities on Biak Island in Indonesia. Flight tests are promised for 2009 with an operational launch the following year.

Satellite Deployments

Russia's collection of about 100 operational satellites displays some striking features that are consequences of the severe budget constraints of the past 20 years. The number of science satellites, or the number of specific applications satellites, is seriously deficient. Networks of military satellites—such as early warning and navigation systems—have also been severely degraded.

In the late 1990s, as orbiting payloads broke down or exhausted their control propellants, gaps appeared in the applications networks (*constellations* in U.S. terminology, *groupings* in Russian). Despite new launches after 2000, failure rates exceeded replacement rates. "Two years ago, it was our understanding that it was simply going to collapse," Perminov said in November 2006. "Now that failure has been stalled." [24]In December 2006, Perminov claimed that the situation had stopped deteriorating and was turning around: "Regarding the composition of space assets in orbit—the composition has improved, but mainly in terms of quality. As of today, 53 percent of space vehicles are operating within their design life spans. Last year that parameter was not so good." [25]

Figures released by Perminov indicate that the existing Russian deployment of satellite constellations (involving 96 spacecraft, a quarter the size of the U.S. contingent) meets only 26 percent of the defined needs of Russia. Funding of future replacement vehicles is supposed to raise that level to 51 percent by 2010 and to 90 percent by 2015. Another Russian space official said that only 39 of 99 existing spacecraft were "fully operational," while the rest were operating in degraded mode well beyond their design lifetimes.

It is astonishing to note that Russia does not have a single functioning weather satellite in orbit. Russian meteorologists have had to purchase their images from foreign satellites. A new-model Meteor payload was to be launched in 2007, but the launch slipped into 2009. Ultimately, three will be placed in polar orbit and two in geosynchronous orbit.[26]

In terms of civilian remote sensing satellites, the dearth of payloads is finally being remedied. Perminov boasted of a remote Earth sensing Resurs-DK with a resolution of 1 meter, launched in 2006. "We faced a systemic crisis last year [2005]," he admitted. "At the start of last year we didn't have a single remote Earth sensing probe. And the launching of that probe—and it is now in operation and bringing good results and provides a high quality of pictures."[27]

Russia has also continued to operate the experimental small-size Monitor-E opto-electronic surveillance satellite, which uses panchromatic cameras (with a resolution of about 10 meters) and spectral-zone cameras (with a resolution of 22–24 meters) to fill commercial orders, according to Novosti commentator Yuri Zaitsev.[28]

For military photoreconnaissance satellites, recent years have been very hard, with long gaps when no observation satellites of any kind were in orbit. Russia "periodically launches the Yenisey, Araks, Neman, and Oko heavy and medium optical reconnaissance satellites," noted journalist Viktor Myasnikov, who continued:

> But they were all developed in the last century and are distinguished by a short period of operation in orbit. And even then [they] do not always make it to the end. It is believed that all Russia's spacecraft, regardless of

> purpose—reconnaissance, meteorological, communications, and so forth—trail their American and European counterparts by two or three generations. And it is not a question of a lack of money but of backward scientific policy oriented toward instant impact, not the long-term development of new ideas.[29]

Russia intends to remedy that backwardness by promoting its global positioning system (GPS)-equivalent, GLONASS. But when it comes to commercial applications of an originally all-military project, they are running into structural hurdles. One basic problem was the espionage laws that, until January 1, 2007, made it illegal for Russian citizens to even *know* their true latitude and longitude to the accuracy that GLONASS can provide.

Reporter Yuri Gavrilov described the spacecraft-specific problem in December 2006:

> The collapse of defense enterprises in the middle of the last decade and the relatively short lifespan of domestic satellites—around 3 years—have turned into serious problems in space. Today only 14 GLONASS satellites fly around the Earth; moreover, only 4 of them are new-generation satellites with an operating endurance of 7 years. Every satellite costs more than $10 million; its launch and operation require another $35 million. It is clear that the military will not be able to cope with this task alone.[30]

"We hope we will have 18 spacecraft in orbit by late 2007–early 2008, and there will be a whole orbital group of 24 spacecraft by late 2009," he went on. Perminov said the main task now is "to create ground equipment for ordinary people so that they could enjoy the fruit of this space system." [31]

Sergei Ivanov raised this theme at a conference at the St. Petersburg Institute of Radio-Navigation and Time. He was there to consult with specialists on how to carry out the president's directive to accelerate the bringing of the dual-use navigation system online. According to the new program, both military and civilian users were to have access to GLONASS by the end of 2007. Civilian users are supposed to make up 80 percent of the users in the country. "Without being able to enter the market and provide citizens and their children with the opportunity of navigational support, as is already done, the system will not function as we want," Ivanov told reporters. "The very main thing is the influence of GLONASS on the socio-economic development of the country and providing it with greater transparency and less corruption." [32]

Space analyst Yuri Zaitsev of *Novosti*, among others, has highlighted the flaw in the commercialization strategy—nobody in Russia is really making GLONASS receivers for public purchase:

> Unfortunately, the system's ground segment still leaves a lot to be desired. Starting on January 1, 2007, all restrictions on the purchase and use of GPS receivers will be lifted all over Russia, but batch production of them

> has not yet been launched. Moreover, electronic maps of all of Russian territory will only be compiled by late 2007. Consequently, commercial use of the global positioning system for civilian purposes is still out of the question.[33]

Zaitsev has indicated another reason for skepticism that Moscow's top-down approach to motivating potential private GLONASS users will ever work. Two decades earlier, the Soviet Union teamed up with Western countries in deploying orbital transponders to enable search and rescue for downed aircraft (SARSAT, or "search and rescue satellite-aided tracking"). Hundreds of thousands of such beacons have been installed on Western aircraft and boats, but as recently as 2006, Zaitsev notes, only "a few hundred" SARSAT-compatible beacons had ever been installed on Russian vehicles of all types, and many of them probably are no longer functioning.

Resumption of Science Missions

Zaitsev pointed out that although "unfortunately, no full-fledged scientific satellites have been launched in Russia this year," Russian scientists still were able to utilize science data from their instruments aboard other space probes. Also, in exchange for providing a launch vehicle, "they have priority rights for the use of 25 percent of observation time aboard the International Gamma Ray Astrophysics Laboratory, which has enabled them to find out the nature of the cosmic microwave background radiation spread evenly throughout the Milky Way galaxy." [34] Still, this led to widespread complaints from within Russia's space science community.

But this may soon change, since the Russian Space Agency has added budget line items for future missions. Russia's Lavochkin Bureau, which built the Soviet lunar and planetary probes of the early space age, now has government contracts for nine deep-space probes.

In 2007, the first of these, a Spektr observatory with a 12-meter-diameter dish antenna, was to have been launched into high Earth orbit, but it has been delayed. Russia is also dusting off (and replacing lifetime-expired components in) an already mostly built payload called RadioAstron. It will be followed by Spektr-UF, which will carry an ultraviolet telescope with 20 times the sensitivity of Hubble's instruments into a very high orbit that allows continuous observations with much-reduced Earth interference. A space infrared observatory named Millemetron has also been approved for launch by 2015. It will use a cryogenically-cooled 12-meter-diameter mirror that will be deployed after launch into a high Earth orbit.

A Spektr payload devoted to X-ray astronomy, formerly called Spektr-Roentgen-Gamma, has been folded in with similar European projects and now carries the ungainly title Spektr-RG/eRosita/Lobster. The payload will be carried into a low equatorial orbit by a Soyuz-2 booster to be launched from Kourou.

Several planetary missions have been funded, the first in more than a decade. The Fobos-Grunt 3-year round-trip mission, scheduled to begin in 2009, will leave a long-lived Russian-built science orbiter near Mars, along with a Chinese hitchhiker beacon. The probe is expected to be followed in 2011–2012 by a set of small Mars surface landers. And a Moon orbiter called Luna-Glob has been contracted with a Moscow geochemistry institute that has been out of the lunar science business for almost 30 years. The probe will search for lunar polar ice [35] and will detect gravitational irregularities to help map the Moon's internal structure.

A probe named Intergeliozond has also been approved for an attempt to reach nearer the Sun's surface than any previous space mission. After a Venus swing-by, the probe's perihelion would be 42,000,000 kilometers away, and further fly-by maneuvers will cut that distance in half, and ultimately even far lower. An ion drive will also twist the orbital plane until it passes over the solar polar regions.

The Soviet Union's greatest deep-space successes were with its missions to Venus, and they will be resumed by a probe called Venera-D that will orbit the planet conducting remote observations. Serious studies have resumed for a long-lifetime Venus surface mission, but no formal project has been approved so far.

Manned Program and Vehicles

Soyuz Manned Spacecraft

Introduced 40 years ago, the Soyuz has undergone numerous modifications and upgrades. Most significantly, an entirely new generation of Soyuz has been officially approved for introduction in 2011–2012. This project clearly indicates that follow-on human space vehicles (for example, the Kliper project) are much further away.

The new Soyuz will be designed with a flight control system making one-man operation the norm so that two nonprofessional passengers can be carried safely. Major hardware changes will be made in the craft's service module and other systems in the command module. It will double the current 180-day on-orbit dwell capability. It will also be capable of being manufactured in a lunar variant, including a stronger heat shield, thermal control system, and longer-range communications capabilities. These options are nominally in support of a serious offer to make a commercial circumlunar mission for space tourists—but at a price of $400 million for two seats.

Sharing many basic systems with Soyuz is the robotic supply craft called Progress. Introduced 30 years ago for use with Salyut and Mir space stations, the vehicle has seen more than 100 missions, every one of which has succeeded (occasionally on the second, and once on the third, docking attempt). It delivers about 2,300 kilograms of payload to the space station.

Utilization and Expansion of International Space Station

Russia plans to double production of Soyuz and Progress vehicles in 2009 to support a six-person crew on the International Space Station (ISS) and to transport U.S. personnel in the period after shuttle retirement but prior to the beginning of Orion missions—perhaps 5 years or longer. The National Aeronautics and Space Administration (NASA) has agreed to a Soyuz launch price of $65 million (three seats) and will purchase seats for cash during this period. A contract for services worth more than $800 million was signed early in 2007.

In late 2006, the design for Russia's next add-on ISS module, called the Multipurpose Laboratory Module, was finalized. Originally intended to be basically a rebuilt spare Functional Control Block module in storage at the Khrunichev plant (like the unit that served as the base of the initial ISS orbital assembly), it now will utilize more control systems provided by Energiya-RCC (based on their Yamal bus) in order to reduce the space allocated to equipment that is applicable only to the initial rendezvous and docking phase. This will double the available volume for scientific equipment.[36] The unit will be docked to one of the side-facing service module ports sometime in 2009–2010. Another module will provide a fourth docking port to support the higher traffic rates.

Russia plans to support and help operate the ISS through at least 2020. But it remains to be seen whether the scientific returns from its participation will have any more impact on Russian industrial technology than did the ambitious program of orbital research in the 1980s—that is, zero.

It is just as likely that Russia sees its ISS role as dues for membership in the high-status club of top world spaceflight players. It is also relatively cheap insurance that the massively profitable foreign space sales activities will continue without interference by the governments of the United States and the European Union.

Kliper

Supporting the theory that Russia's main space efforts are aimed at securing additional foreign funds is the recent history of the much-touted Kliper six-person spacecraft. Officials have stated that it has been "approved for development" in the years after the Soyuz upgrade becomes operational, but significant design work is now being redone, and the hoped-for European and Japanese funding has not yet materialized.

The deputy chief of Roskosmos, Viktor Remishevsky, acknowledged in October 2006 that "this is the next stage in developing a manned space ship, and that Roskosmos had issued an RFP [request for proposal] for the spacecraft, but then withdrew it." He added that the Russian Space Agency had concluded that the budgetary funds allocated (about 9 billion rubles through 2015, of which 500 million are available by 2010) would not be sufficient to create a six-seat space ship that can fly to the Moon or to a space station, fly from Plesetsk, land on runways, and perform other required functions. Additional nonbudgeted funds are needed to realize the project—tens of billions of rubles—and there were no longer any credible sources of such financing.

In addition, the design teams had settled on a spacecraft that would weigh between 13 and 14 tons, and there is no man-rated booster available. The Angara-3 could do it in theory, but it has been so often delayed that officials were unwilling to fund and develop a manned spacecraft in the hope that the new booster would be done on time.[37]

After years of seeking subsidies and cooperation from European space agencies, Moscow in 2009 formally approved a fully domestically funded follow-on manned spacecraft with requirements very similar to NASA's Orion program. An upgraded Soyuz booster was also selected for the new vehicle, bypassing the Angara program entirely.

Ground Simulations

Another human spaceflight project that looks more like a foreign funding magnet than a serious scientific effort is a planned 500-day isolation study with six volunteers simulating a Mars mission. In 2007, facilities were developed at the Institute for Medical and Biological Problems in Moscow for an exercise, pending receipt of enough European money (and crew volunteers). Past isolation studies have had mixed results (at best) and produced no significantly usable operational or medical insights, but this project began short- and medium-term simulations in 2008–2009 with significant European participation and funding, with the 500-day mission delayed into 2010.

The Parom Ferry

There are also some commercially feasible proposed Russian spacecraft that might well be worthy of outside funding. Probably the most attractive is the small space tug called Parom that has been designed based on existing space hardware to substitute for one of the major capabilities of the soon-to-grounded NASA space shuttle—its ability to bring large cargoes (structural elements, supplies) gently to the space station.

It is useful to do a more detailed treatment of the Parom project because it is a good example of Russian space engineers playing to their strengths and providing specific, critical services to international space activities. As such, it is an illustrative case study in the ways that Russia can successfully exploit and build upon its existing strengths.

With the approaching irrevocable grounding of the space shuttle fleet, space planners must face the need to replace piecemeal as many of its capabilities as possible. And as the construction of the International Space Station has demonstrated, a key ability is not just to carry payloads into orbit, but also to accurately bring them to a desired point in space and attach them to a structure already there.

Without the shuttle acting as such a carrier, each payload designed to visit a space station must have its own navigation, guidance, control, and mating hardware. That hardware, and the power systems and propellant tanks to feed it, often can outweigh the deliverable payload on every launch and then often gets in the way of operations once the delivery has been performed.

Now the Russians have proposed building the Parom, a specific spacecraft that promises to perform these tasks efficiently (and to use another critical word again, *gently*—a trait that makes building the payloads much easier). Functionally, it is the full equivalent of the harbor tugs in major Earthside ports. Cargoes without their own propulsion are towed to locations where they are wanted. The tugboat then moves on to another cargo, stopping occasionally for refueling and maintenance.

The Parom that the Energiya Rocket and Space Corporation (Russia's manufacturer and operator of most human-related space vehicles) wants to build is a Soyuz-sized flying docking tunnel surrounded by propellant tanks, thrusters, solar cells, and avionics bays. It can dock in either direction, can thrust in either direction, and can be refueled repeatedly. Its components are to be designed for a 15-year lifetime involving up to 60 round trips between low orbit and the space station.

The basic mission profile is simplicity itself. Based at a docking bay at the ISS (perhaps only an attach point with minimal interface with the station), it departs for a lower orbit when a station-bound cargo canister (or assembly component) is placed into a parking orbit by any of a number of launch vehicles. The cargo vehicle must have a simple end-mounted mechanism for mechanical attachment and for short-term stabilization and power—nothing more sophisticated is needed. Parom approaches and docks to the cargo vehicle, and then pushes it up to the space station, where it docks its free end to a fully functional port. At that point, Parom's hatches can be opened and crewmembers can enter the cargo canister, if that is the mission. Or propellant can be fed through transfer lines into the station (and into Parom's own tanks, whenever needed).

Alternately, the station's robot arm can grapple the payload, detach it from Parom, and place it where needed—perhaps in an assembly area or over a common berthing mechanism on the U.S. side that allows transfer of full-size science racks or other large cargoes. Or perhaps the payload can be delivered to applications not yet even imagined. Parom is to have the flexibility to accommodate practically anything that anyone can get into a parking orbit, up to a mass of 12 metric tons and possibly more than twice that.

The range of delivery options made available by such a spacecraft is as wide as space itself. Parom could visit free-flying materials processing modules co-orbiting with the ISS, bringing them in for annual servicing and then redeploying them on its way out for a parking orbit pickup. Some Russian designs have Parom providing the space-to-space transport for the proposed Kliper follow-on human spacecraft, also still on the drawing board (and also awaiting funding from foreign partners).

Parom-class tugs could carry satellites into higher orbits for deployment, or emplace and then retrieve co-orbiting science and industrial satellites near the ISS. They could operate autonomously in geosynchronous orbit and even around the Moon, carrying cargo canisters that include additional propellant supplies. In another application, ISS-based Paroms (and more than one may be stationed there once the Russians install additional docking ports) might be able to serve as emergency crew refuges, with portable consumables packages for life support.

Practically all of the components of this Parom design have already been flight-tested. The structural framework is easy to build, and the power, control, approach, and docking systems would be outgrowths of existing Soyuz and Progress systems. Those avionics boxes that could not last 15 years can be designed for in-space changeout.

Russia has twice used tugboat-style vehicles to bring components to a space station. For both the Kvant module (Mir, 1987) and the Pirs airlock module (ISS, 2001), the component was mounted atop a detachable propulsion module that later departed. In both cases, however, rendezvous guidance gear was installed on the station-bound component, not on the proto-tugboat that was the ancestor of the Parom design.

In October 2006, Energiya president Nikolay Sevastyanov told a space conference, "We want to lower the cost of cargo supplies by a factor of four." His deputy chief designer, Nikolai Bryukhanov, had recently told reporters that "with consideration for the cost of the development and manufacture of the tug, the system will repay in less than two years of use"—clearly implying that customers would be expected to pay for the service. Once funding was approved, Bryukhanov promised the spacecraft could be ready in 5 years.

The following month, Energiya's plan received the blessing of Russian Federal Space Agency head Anatoly Perminov, who touted its benefits at a press conference and announced plans to conduct its first flight within 3 years (it was not clear if this would be a test flight and proof of concept or the first fully operational vehicle).

The plans are to phase out Progress flights soon afterward, although cargo canisters carrying 4 tons of supplies (instead of the 2.5 tons carried inside each Progress) would then be launched regularly for pickup by the operational Parom tug. How many would eventually be deployed remains unclear; but in the case of logistical support for a post-shuttle space station, Parom could well be the answer to a worrisome problem. And the way that the spacecraft is developed, funded, and operated could be the general operating concept for Russia's expanded successes in space in years to come.

Conclusion

For the foreseeable future, Russia appears committed to internationalization of its main nonmilitary space activities, mainly as a crutch in obtaining services disproportionate to contributed resources ("For 5 percent of the investment we get 30 percent of the resources" is a frequent comment in justification of the space station partnership) and as a badge of major player status in the world.

At the same time, Russia shows no signs of developing a capability for major innovation in spacecraft engineering or of demonstrating more than lip-service interest in quantum advances in space operations capabilities. Incremental progress has been the watchword for decades, usually not by choice but out of necessity because all previous attempts at breakout projects (human lunar flight, advanced robotic Mars probes, the Buran shuttle, the Polyus-Skif family of orbital battle stations) ended in humiliating frustration.

Providing commercial launch services for foreign customers has provided multidimensional benefits to Russia. Beyond the significant cash flow, such activities fund booster upgrades and, in the case of converted military missiles, fund validation of lifetime extension efforts for still-deployed missile weapons.

Military applications of space systems remain uninspired, with critical constellations (such as the missile early warning net) still significantly degraded and likely to remain so for many years. Russian officials have evidently decided that, despite any public posturings over U.S. military threats, there is essentially no prospect of actual hostilities in the foreseeable future and hence little pressure to reconstitute military space assets to a Soviet-era level. Russia retains a nuclear-armed operational antimissile system around Moscow that, if upgraded to hit-to-kill guidance, could provide significant antisatellite capability; it is also developing small robotic rendezvous spacecraft similar to U.S. projects that have potential antisatellite capabilities at any altitude into which they can be launched.

Attempts at domestic commercialization of space-related services, including communications, navigation, and mapping, remain seriously—perhaps irremediably—hamstrung by the recent resurgence of a traditional Russian top-down structure of authority. Bureaucrats are being ordered to implement wider use of space infrastructure, and after many years of rosy reports of progress, Moscow may realize that it is almost all, as usual, a sham.

There is still little indication of successful exploitation of space discoveries and space-developed technologies (what NASA and the Europeans call spin-offs) as a means of improving the technological skills of Russian industry. The space industry, as a component of the national defense industry, remains strictly compartmentalized from Russia's civil economy, and the resurgence of broad espionage laws (and several recent highly publicized convictions) will keep this ghettoization in force. This in turn may require other government measures, from patent purchase to industrial espionage, to acquire technologies that some Russian industries may already possess but are in practice forbidden to share internally.

Russian space-related scientific and exploratory research, after hitting rock bottom a decade ago, is showing signs of a modest rebound. Russian space scientists may be able to resume making respectable contributions to the world scientific literature in the coming decade, another ticket to world-class status that spreads prestige to all of Russia's science reputation.

But even if the main values of the Russian space program remain symbolic, these symbols have computable value to the nation's self-confidence and to the reputation of its technology—either for commercial export or as a reflection of the efficacy of its weapons. The modest but steady resource commitment to the space program reflects the government's assessment of the degree of value, now and in the foreseeable future.

However, none of these intentions has much chance of success unless the Russians find a way out of the looming demographic crisis that mass mortality is confronting them with. In a society and an industry where monopolization of knowledge was power and sharing it often led to legal prosecution, behavior must change, and fast. This must be done so that space workers a decade from now, without the in-the-flesh guidance and advice of the old-timers, will be able to draw on their team knowledge that survived the passing of its original owners and was preserved in an accessible, durable form. The alternative is a return to the learning curve of more frequent oversights, mistakes, and inadequate problem solving of the dawn of the space age—with its daunting costs in time, treasure, prestige, and even human lives.

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Chapter 23:

Russian Perspectives on Spacepower

Alexei Arbatov

Achievements in space exploration and utilization are that part of its Soviet heritage that the Russian Federation views with great pride and satisfaction. In 1957, the Union of Soviet Socialist Republics (USSR) was the first nation in the history of the world to put a satellite in space, and in 1961 it followed with the first manned space flight. During the Cold War, Soviet spacepower was second to none—in some respects behind and in others ahead of that of the United States.

Since the collapse of the Soviet Union in 1991, due to a protracted economic decline and depression, Russian space potential and activities have suffered greatly. The end of the Cold War added to this decline since during the decades of arms race and confrontation, Soviet space activities had been closely associated with military purposes and requirements. (In fact, the first Sputnik was a byproduct of the development of intercontinental ballistic missiles [ICBMs], which were needed to negate U.S. strategic nuclear superiority stemming from its geographic remoteness and forward-based aircraft and missile deployments in Europe and Asia.)

After 1991, the sharp decline of the defense and space budgets and disintegration of scientific centers and industrial cooperation, exacerbated by the loss of assets of other former Soviet republics that were newly independent (the foremost being Ukraine, Belarus, Kazakhstan, and Tajikistan), led to a virtual collapse of Soviet spacepower. The only exception was the commercial space launching program, which largely utilized Soviet/Russian converted ICBMs retired from service (such as START–1, Dnepr, Zenit, and Rokot). This program provided at least some revenue that saved Russian spacepower from total demise during the 1990s.

Nonetheless, by the beginning of the current decade, Russian space activities were badly undercut. Overall Russian space assets decreased 150 percent during the 1990s and in 2004 consisted of 96 satellites (70 percent military and dual-purpose), of which 65 percent were beyond service lifetime (33 military and 29 civilian and dual-purpose). The American space constellation consisted of 415 military and civilian satellites. The U.S. space budget ($16.4 billion) was 20 times bigger than Russia's ($0.8 billion). In contrast to the 12 or 13 U.S. radioelectronic and electronic-optical reconnaissance satellites, Russia had only 1 in orbit at any given time.[1]

Obsolete naval communication satellites Molniya-1T, Molniya-3, and Parus could not be replaced by the new Meridian-type craft due to shortage of funding. Out of eight needed missile attack early warning satellites (71X6 and 73D6), only three were in orbit. The Russian global navigation satellite system (GLONASS) consisted of only 14 instead of

24 satellites, which were not enough even for the permanent coverage of Russian territory. Hence, Russian combat aircraft, including strategic bombers, had to rely on the U.S. analogous global positioning (NAVSTAR) space system. Likewise, the Russian Northern Fleet had to receive ice condition information from Canadian Radarsat-1 spacecraft.[2]

During the last several years, Russian spacepower has been gradually recovering from the crisis. Presently there are 99 Russian satellites in space (70 percent military and dual-purpose). New vintage satellites were placed in orbit (Meridian, new type early warning, communication, and reconnaissance systems), and the number of GLONASS satellites was increased to 17. New space launchers are under intensive development (Angara, START–1, Soyuz 2–1B). The Plesetsk space and missile launching range is undergoing broad modernization (for Angara and Soyuz 2–1B vehicles). With the Angara launcher, Plesetsk for the first time will be able to reach geostationary orbit and loft superheavy loads in space. Space Forces (a separate branch of the armed services) is withdrawing from Baykonur range (in Kazakhstan) and curtailing its assets at Svobodniy range (in the Far East) to a minimal scale. The personnel level presently is 50,000 military and 25,000 civilians and is not being reduced any further. [3]

Altogether, Russia (by joint efforts of Space Forces and Roskosmos) is conducting about 25 space launches annually for its own needs. A new space command and control site was commissioned in Armavir to make up for the two sites left in Ukraine (Yevpatoria and Dunayevtzy). Missile early warning radars of the Missile-Space Defense (part of Space Forces) were modernized in Pechora, Irkutsk, Balkhash (Kazakhstan), and Lekhtusi (Belarus). A new rapid-deployment radar system was tested successfully near Saint Petersburg. In addition to the electro-optical space monitoring station in Nurek (Tajikistan), a new site was commissioned in Karachaevo-Cherkessia (North Caucasus).[4]

The Federal Space Program

The Russian government sees spacepower as one of the most important attributes of authority and prestige of a nation in the world today. In fact, Moscow believes that a country cannot claim the status of great power without developed space assets and activities—both civilian and military. Space systems are interpreted in Russia as orbital groups of spacecraft and land-based command-control and information relay sites, as well as space launch ranges, launchers, and support infrastructure. In the course of the few last decades, those systems and facilities have become the most important—in some cases, the crucial—resource in supporting military, socioeconomic, commercial, and scientific activities of the world.

The Federal Space Program approved in November 2005 envisions $12 billion in outlays until 2015. The program and other official directives postulate the following goals of Russian space activities:

- expanding the commercial, economic, scientific, and defense usage of outer space
- expanding international cooperation in the civilian exploitation of space

- ensuring Russian access to outer space
- preserving the Russian position at the cutting edge of space technological development.

In order to achieve these goals, Russia must fulfill the following tasks:

- maintenance and development of a modern and effective space constellation
- deployment and exploitation of the Russian segment of the International Space Station (ISS) consisting of 5 modules (presently Russia is mostly engaged in transportation)
- providing of Russian contribution in the COSPAS-SARSAT system (2 satellites)
- development of advanced variable mission space launchers (Angara) and modernization of the existing ones (Proton, Soyuz-2)
- maintenance of the civilian space range at Baykonur and civilian-military range at Plesetsk
- improvement of the quality of satellites (extending maximum service lifetime from 2 years to 10–12 years)
- reforming space industries (presently consisting of 112 enterprises and 250,000 employees to be concentrated in 3 or 4 holdings)
- further increasing Russia's share in the world commercial space launch market (presently 40 percent, compared to 30 percent for the United States, 16 percent for China, 6 percent for the European Union, and 2 percent for India).

International Cooperation

Russia is heavily dependent on international cooperation in space exploration and exploitation, both as a donor and as a recipient, as well as a delivery service manager. Presently approximately 180 countries participate in space activities in some way. At least 40 of these are associated with the use of outer space information and support for military systems and forces, and 19 nations have scientific and industrial potential for manufacturing their own spacecraft. In various orbits, there are currently more than 700 space satellites of civilian, military, and dual purpose types, among those about 400 American and 100 Russian, including the International Space Station.

By the level of budget allocation, Russia is lagging far behind the leading spacefaring nations. The United States is firmly in first place, followed by the European Union (through the European Space Agency [ESA]), Japan, China, Russia, and then India. At the same time, the space plans and ambitions of Russia, and its remaining scientific-industrial potential and infrastructure, are much greater than its current budgets would imply.

Hence, Russia has a major interest in expanding its role in international space cooperation. Furthermore, Russia's role in world trade is much too dependent on its export of raw natural resources, which is characteristic of developing countries. Besides trade in arms and nuclear materials and technologies, cooperation in space activities is one of very few high-technology export items that Russia can pursue in the near- to mid-term future. That is why this trade channel is so important to Russia both from the angle of status and prestige and in view of the revenues it brings to its underfunded space programs and assets.

For Russia, the most valuable international projects are the following:

- the International Space Station, with the United States and many other foreign states (Canada, Japan, and 17 member-states of the ESA)
- COSPAS-SARSAT
- a big unfolding space antenna (Roskosmos and Energiya with ESA and Italy)
- microsatellites (150 kilograms) for Earth sounding (Roskosmos with EADS-Astrium)
- advanced Manned Transportation System (based on modernized Soyuz launch vehicle for orbital and Moon flights)
- cooperation with ESA and France on the launching complex for Soyuz 2–1T from Kourou space range in French Guiana
- cooperation with ESA and India on new space navigation systems
- long-term international projects of flights to Mars and Venus.[5]

Russia's attitude to recipient nonspace nations in the Middle East, East-South Asia, and Latin America is motivated by commercial and political interests. Moscow's cooperation with spacefaring nations is a combination of the donor-recipient model. The main partners are ESA (foremost France, Italy, and Germany), the United States, Japan, China, India, Ukraine, Belarus, Kazakhstan, and Brazil.

In addition, Russian willingness to provide launch and satellite services to some states is motivated by its interests, which initially shaped its 1999–2000 proposals on the global system of control over missile and missile technology nonproliferation. That initiative was formally introduced at the 2000 Non-Proliferation Treaty review conference and envisioned provision of space services to states refraining from developing their own missile capabilities and abiding by the Missile Technology Control Regime.[6]

Military Space Requirements

Russia's military space requirements and programs are different from those of the United States. Having very limited, if any, conventional long-range power-projection capability (or long-range precision-guided weapons), Russia does not heavily rely on space systems for its conventional operations. Only reconnaissance and communications systems are of some value. In contrast to the USSR, Russia's faraway naval deployments are not conducted on a permanent basis, except when on infrequent naval exercises.

As for strategic forces, Russia deploys only 1 or 2 ballistic missile submarines at sea at any given time, and its heavy and middle-range bombers fly only during rare exercises. These would surely benefit from better space communication and navigation capabilities, but those capabilities are not crucial.

However, Russia's dependence on missile early warning satellites is truly decisive. Due to financial problems and mistaken decisions on a strategic modernization program in 2000–2001, Russian strategic forces are becoming more vulnerable. Russia's ever smaller number of submarines and bombers is not survivable in bases and on airfields. Its mobile missile force is shrinking because many more obsolete SS–25 ICBMs are withdrawn than new SS–27s are deployed. Its silo-based ICBMs (including new SS–27s) and fewer mobile SS–27s in shelters increasingly depend on launch-on-warning (LOW) to maintain deterrent capability. On top of all this, out of eight big missile early-warning radars, five are deployed outside of Russian territory (in Belarus, Ukraine, Azerbaijan, and Kazakhstan) and cannot be relied upon in time of a hypothetical crisis involving a strategic nuclear threat.

Russian official and unofficial attempts from 2001 to 2005 to come to an agreement with the United States to cut strategic forces to lower than 1,700 to 2,200 warhead levels (Moscow 2002 Strategic Offensive Reduction Treaty) to reduce U.S. counterforce capability, or to jointly lower the readiness for launch status of strategic forces (for the same purpose), proved to be futile.

Hence, Russia has a heavy and growing reliance on the LOW concept and early warning satellites. The fact that this system does not have a much higher priority in Russia's space and defense program reflects Moscow's relaxed attitude toward the probability of a confrontation with the United States and its allies and a huge lack of coordination in Moscow's strategic forces, programs, posture, and support systems. Nonetheless, it is not an acceptable justification: strategic posture is such an important element of national security that internal contradictions are not to be looked at with complacency. Development and deployment of space weapons, particularly those of antisatellite class, would greatly exacerbate this instability against the background of the U.S., Russian, and potentially Chinese strategic postures.

All in all, it may be stated flatly that Russia has great interests and ambitions in outer space, both civilian and military, but those interests are confined to unarmed craft. This position stems from both Russia's overwhelming dependence on international cooperation in outer space and the severe shortage of funding for defense in general and military space programs in particular.

Hence, Russia has an extremely negative view of development and deployment of space weapons of any kind (deployed in space or designed for attacking space objects). In contrast to the USSR, which was the first nation to deploy operational ballistic missile defense (BMD) and antisatellite (ASAT) systems in the 1970s, Russia has neither the resources nor the perceived strategic requirements for pursuing space weapons. Russia would see any such development and deployment as a major provocation and a threat to its security and national interests. Moreover, Russia's future attitude toward other states and their treatment as partners or opponents will be heavily affected by their posture with respect to space weapons. In this sense, new U.S. Air Force space doctrine and various Pentagon statements on the subject are universally seen in Russia with great concern and hostility.

Only some major provocation might change Russia's policy on the issue. One is a potential U.S. deployment of space-based ASAT systems, threatening Russian early-warning satellites (which are deployed not only at geosynchronous orbits but also partly at Molniya-type highly elliptical orbits and pass at low altitude over the south polar zone). As a system for retaliation or for a direct attack on U.S. space-based ASAT craft, Russia might contemplate reviving its direct ascent ASAT systems or resuming its land-based laser program with inherent antisatellite potential.

Another trigger may be a massive U.S. deployment of space-based BMD intercept or support systems, which would threaten Russia's strategic nuclear deterrent capability. Undoubtedly, Moscow's first choice in both cases would be an asymmetric response: enhancing satellite survivability, reducing reliance on LOW, or developing BMD penetration systems. However, if that would not be enough or turn out to be too expensive, Russia may eventually go for space weapons of its own.

ASAT Systems

Apart from routine commercial competition and disputes around places in geostationary orbit and radio communication frequencies, the real conflicts in space may stem from attacks on or interference with another state's spacecraft.

In many cases, some violation of the standard operation of an individual space system may result in almost-total failure of the normal functioning of military, commercial, and other systems and structures. The hypothetical deployment of the means of destruction or interference of various physical natures, threatening spacecraft operations (foremost, that of early warning satellites) may in a crisis situation lead to a high level of strategic instability, encouraging reliance on a preemptive nuclear strike.

At the same time, a significant escalation in the number of some types of reconnaissance satellites could undercut the survivability of certain strategic forces (primarily ground-mobile missiles and missile submarines at sea) and devalue their deterrent capability, thus putting a premium on a first disarming strike or launch-on-warning—thus also leading to dangerous strategic destabilization. Both such satellites and orbital antisatellite systems provide a high incentive for the development of antisatellite weapons of various basing modes. Such is one of the most significant facets of the dialectics of strategic space systems interaction.

Apart from a number of research and development projects of the United States and the Soviet Union in the 1950s and early 1960s, the first ASAT system was developed and deployed by the Soviet Union. It was a co-orbital satellite-killing vehicle guided by radar and infrared sensors developed in the Kometa design bureau. The launcher was a modified SS–9 (RS–36) and SS–18 (RS–36M) heavy ICBM system. The first test in space was conducted in 1968, and tests continued until 1982. Several launchers were deployed at Tyuratam (Baykonur) space range in 1979. The Soviet ASAT was capable of intercepting satellites at altitudes of up to 1,000 kilometers, but it was a slow action system with dubious effectiveness. When the United States responded with its own

ASAT system based on the F–15, Moscow changed its position and came forward with the proposal of a bilateral moratorium on ASAT testing, which was turned into a unilateral moratorium in 1983, observed by the USSR/Russia since then.

There is some evidence that Russia experimented with a direct-access ASAT system similar to the American one and based on the MiG–31 fighter-interceptor, and prepared to deploy some direct-access SS–19 (Ur-100UTTX)–based ASAT systems at Svobodniy test range. But neither was ever tested or deployed. The Soviet first-generation A–35 Moscow BMD system, deployed in the 1970s, had some collateral ASAT capabilities, as does the follow-on A–135 system presently deployed. However, both rely on nuclear intercept; hence, their effect would be suicidal for Russia's own satellites.

The history of negotiations on space (including antisatellite weapons) in the 1980s proved the great difficulty of creating treaty-based limitations on space systems. Currently, for a number of reasons, the political and international law environment (foremost, a collapse of the 1972 ABM Treaty after U.S. withdrawal in 2002) for such negotiations and agreements is even less favorable, despite the end of the Cold War 15 years ago. In fact, the U.S. Ground Based Interceptor (GBI)–type BMD system under deployment is already an effective ASAT system for destroying satellites at up to 1,500 kilometers altitude. The only thing missing is a global deployment to provide for fast interception at various orbits and testing against a target satellite.

Defining Space Weapons

Besides political and strategic obstacles to effective negotiations on space weapons, there are legal problems with the definitions of such systems. It seems that the preferable definition is as follows: *space weapons* are means of destruction and disruption of functioning of space objects, specifically developed and tested for this purpose in any basing mode; and means of destruction of any target of any location, if such means are developed and tested for deployment at Earth orbits (that is, designed to perform at least one revolution around the Earth). Hence, space weapons are distinguished either by their designated targets (space objects) or by their own basing mode (at Earth orbit).

A simpler and less strict definition of space weapons could be a weapons system (means of destruction) that is a space object or is designed to destroy space objects. However, many types of weapons or destruction systems have multiple uses, and their development, testing, and deployment cannot be directly limited by international treaties. These types include, for example, laser, kinetic, electromagnetic, particle beams, and other weapons of similar type (except nuclear weapons, which are prohibited from being deployed in space, albeit without verification procedures, by the 1967 Outer Space Treaty and from being tested by the 1963 Partial Test Ban Treaty).

Many systems, intended for other missions—offensive ballistic missiles of various types if fused for space burst, fractionally orbital bombardment systems, maneuverable satellites, and manned spacecraft—may have collateral capabilities to destroy space objects.

Of particular importance are strategic antiballistic missile systems of any type of deployment (basing mode) that have implicit antisatellite potential, especially against low- and medium-altitude (up to 1,500 kilometers) satellites. It might be possible to only impose a ban on testing strategic antimissile systems against space objects, somewhat limiting their combat effectiveness in this role. Such limitation would be ineffective against nuclear antimissile interceptors, although the United States does not develop or deploy such systems, while Russia has a limited number around Moscow with low-altitude range. U.S. interceptors of GBI type designed to hit missiles at mid-course multiple independently targetable reentry vehicle–dispensing phase would be theoretically able to use the same guidance systems against satellites at low- to mid-altitude orbits. Still, some dedicated tests against satellites would probably be needed to be sure of their effectiveness for such missions.

To bolster responsibilities of spacefaring nations and to formalize the bounds of those responsibilities, it might be possible as a first step to develop and voluntarily accept a code of conduct in space activities (CoCSA). Its goal would be to ban activities aimed at destroying or interfering with the functioning of space systems, as well as constraining development, deployment, and use of weapons systems intended for such actions.

This kind of ban would naturally operate under peacetime conditions, but it may lower the technological and operational capabilities of states for destabilizing actions (and consequently for triggering uncontrolled escalation) under conditions of crisis or even armed conflict. Some of its regulations could be adhered to even in times of war (in a manner similar to the non-use of chemical weapons in World War II). The CoCSA would have to impose a ban on testing, development, and employment of all means of destruction of space objects, on means of disrupting their functioning, as well as of all weapons (means for destroying targets) of space-basing mode (that is, deployed on Earth orbits). As a code, it would not need a refined verification system, counting rules, or limitation definitions. Its effectiveness would be mostly political as an agreement on intent, but it still would have a marginal utility (like The Hague Code of Conduct with respect to missile nonproliferation).

In the longer term, under favorable political and strategic circumstances, the CoCSA could become important as a basis for legally binding agreements, which would capitalize on its most important and practical points and depend on availability of tangible definitions and verification capabilities.

Notes

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Chapter 24:
Spacepower in China

Dean Cheng

For the purposes of this volume, *spacepower* has been variously defined as:

- the ability of a state or nonstate actor to achieve its goals and objectives in the presence of other actors on the world stage through exploitation of the space environment[1]
- the pursuit of national objectives through the medium of space and the use of space capabilities[2]
- the total strength of a nation's capabilities to conduct and influence activities to, in, through, and from space to achieve its objectives. [3]

This view of space is paralleled in the 2006 Chinese white paper, "China's Space Activities in 2006." This paper, issued by China's State Council, the highest governmental body in the People's Republic of China (PRC), notes that a key principle underlying the development of China's space industry is that it is "a strategic way to enhance its economic, scientific, technological, and national defense strength, as well as a cohesive force for the unity of the Chinese people."[4]

Indeed, insofar as the People's Republic of China is concerned, China has been interested in spacepower—the use of space and space-related activities in support of national goals—since 1956. In that year, Qian Xuesen helped found China's aerospace industry, and that date is considered by Chinese historians and policymakers as marking the start of China's space program.

This chapter examines China's space capabilities in the context of their role in support of furthering national objectives. It begins with a brief historical overview of the Chinese space program. It then provides a survey of China's space capabilities as of 2007 and assesses the contributions of space to China's national interests and objectives.

Historical Development of China's Space Program

When the People's Republic of China was founded in 1949, China had been at war almost continuously, either internally or externally, since the early 1930s. This near-continuous state of war had not only wrought massive devastation over much of China, but also had sapped China's intellectual base and destroyed much of its limited industrial foundation. To remedy this, Mao Zedong and other top leaders placed high priority on developing the country's scientific and technological capabilities.

The intent was to facilitate the strengthening of China's economy and its technological and industrial base, and, just as important, foster the development of an indigenous arms industry. From the outset, it was envisioned that China would develop the ability to manufacture the accoutrements of a major power: nuclear weapons, missiles, and satellites. Mao saw this as essential for reducing China's vulnerability to external aggression and pressure, because "in today's world, if we don't want to be bullied, we must have these things."[5]

A key component of this effort would be the development of an aeronautics industry. Airpower had proven essential in World War II, and aviation was seen as a hallmark of advanced science and technology. Consequently, the Chinese leadership felt that both national security and prestige required the development of a Chinese aeronautics industry. Two key individuals helped to shepherd its development: Professor Qian Xuesen and Marshal Nie Rongzhen.

Qian Xuesen, an American-trained physicist who had worked at what became the Jet Propulsion Lab and with Theodore von Karman, in 1955 joined the larger wave of Chinese scientists returning to "help build a new China." Qian was and remains a controversial figure. At the time, he was accused of being a communist, and U.S. authorities delayed his return to China for fear that he might bring back information with him to help the Chinese communist regime.

Soon after his return, Qian forwarded "A Proposal to Establish China's Defense Aviation Industry" to the senior Chinese leadership, calling for the creation of an aerospace industry that would design and build not only aircraft, but also rockets and missiles. This proposal was incorporated into the "National Long-Term Plan for the Development of Science and Technology, 1956–1967," which provided a broad blueprint for PRC efforts to develop their scientific and technical capabilities. Also incorporated into the plan were projects to develop nuclear energy, as well as jet and rocket technology.[6]

As part of the plan, the Fifth Research Academy of the Ministry of National Defense was established, with Qian at its head. This academy was responsible for missile development. Chinese histories of the country's space, missile, and strategic weapons programs generally start with the founding of the Fifth Academy.

Qian's ideas aligned neatly with those of Marshal of the People's Liberation Army (and later Vice Premier) Nie Rongzhen. Nie, a compatriot of Mao Zedong and Deng Xiaoping, was not only a senior member of the People's Liberation Army (PLA), but also a major promoter of science and technology. In the wake of the massive casualties incurred by Chinese forces in the Korean War, Nie, along with several other senior PLA leaders, recognized that simply relying on massed forces against a more technologically advanced opponent (as represented by the United Nations forces) was insufficient.[7] Nie noted that "since the Korean War, we have often been disturbed by the point [that] we lagged far behind the then-enemy in military technologies."[8]

Nie believed that only by developing its scientific and technical industrial base could China build up both its *military* power and *overall* Chinese capabilities, what is now often referred to as "comprehensive national power." Nie believed that it was essential for the PRC to pursue the broad development of such capabilities if it was going to compete not only militarily but also economically and politically with the other major powers. Consequently, he and Qian may be considered the key movers responsible for China's strategic weapons, missile, and space efforts.

Nie's and Qian's interests converged, as Nie oversaw the Aviation Industrial Commission, which had control over Qian's Fifth Academy. Nie, in turn, reported directly to the Central Military Commission, the highest level of authority for the PLA, and the Politburo of the Central Committee of the Chinese Communist Party. This is symptomatic of the high level of interest that space and strategic programs have consistently enjoyed from the earliest days of the PRC. Space also garnered the interest of the "Great Helmsman" himself, Mao Zedong. Chinese histories of their space program inevitably refer to the impact of the statement made by Mao in 1958 that "we must have satellites, too." [9]

Turmoil and Self-Reliance

Even the interest of Mao Zedong was not enough to overcome the limitations of China's backward state. China had neither the trained manpower nor the industrial base to support what was, in the 1950s, cutting edge research into spaceflight. Worse, the situation was exacerbated by the nationwide turmoil sparked by Chinese political upheavals. The first major disruption was the Great Leap Forward. This was one of Mao's early efforts to showcase the achievements of China under communism, and one of the great tragedies of the 20th century. The situation was so chaotic that even members of the nuclear, missile, and space development teams suffered from malnutrition.

The situation was compounded by the Sino-Soviet split, which led to the withdrawal of Soviet experts, often leaving projects that were only half completed. With the split, Chinese leaders began to propound the "two bombs, one satellite" line, which called for indigenous development of an atomic bomb, a hydrogen bomb, and a satellite. The point was to underscore that the PRC could, by dint of its own efforts, manufacture the most advanced weapons and master the most cutting edge technologies on its own. This emphasis on indigenous development became a political rallying cry, and the line is still regularly invoked.

The combination of limited industrial base and turmoil in domestic and foreign policies led to the deferral of space developments for nearly a decade. Once the Chinese had succeeded in developing their own nuclear deterrent, exploding an atomic bomb in 1964 and a hydrogen bomb in 1967, however, the emphasis shifted back to developing China's space capabilities. Indeed, even as development of thermonuclear weapons was progressing, Qian Xuesen and Nie Rongzhen were pushing for a renewed satellite effort. In 1965, Nie's National Defense Science and Technology Commission submitted a "Report on the Development of Artificial Satellites," which called for making satellite development a priority. By May, the report had been incorporated into the state plan, and engineering development was begun on developing a satellite, Project 651. [10] As part of that effort, in 1968 the Party leadership established a Chinese Academy of Space Technology (CAST) with Qian as its dean.

Once again, however, domestic politics interfered with China's space development efforts. In 1966, Mao Zedong initiated the Great Proletarian Cultural Revolution, and for the second time in a decade, China was plunged headlong into political turmoil. This included the space and missile programs.

In order to insulate these efforts from the excesses of Red Guard interference, the Central Military Commission placed CAST under the National Defense Science and Technology Commission. In effect, the satellite program was placed in military hands. [11] Similarly, the military was made responsible for the construction of the satellite tracking, telemetry, and control systems essential for supporting satellite operations, and for the various launch sites. [12] Eventually, many of the key persons were also placed under military protection, including Qian Xuesen.

Despite the chaos, the Chinese scientists were able to meet their goals. On April 24, 1970, China's launched the Dongfanghong-1 (DFH–1), making the PRC only the fifth country to launch a satellite into orbit. As per Mao's instructions, the DFH–1 was both larger and more capable than the first-time satellites of either the United States or the Soviet Union. The satellite launch, coming 6 years after China's first atomic explosion and 3 years after China's first thermonuclear weapon, marked the culmination of the "two bombs, one satellite" effort.

Ironically, it was the rise of Deng Xiaoping that probably saw the greatest cutbacks in the Chinese space program. With Deng's rise after the fall of the Gang of Four, he shifted focus from preparing for what Mao had termed "large war, early war, nuclear war," to the expectation that, for the foreseeable future, the keynote of the times would be "peace and development." Consequently, Deng set forth the general Chinese guideline of "civil-military combined, wartime-peacetime combined, give preference to military goods, have the civilian nurture the military." These guidelines, which remain a cornerstone of Chinese national development strategy, touted the conversion of the military-industrial base to a more civilianized one. For the Chinese space program, that shift meant declining resources, since there was much less pressing military concern for either missiles or space capabilities.

This ambivalence toward the Chinese space program only lasted a few years, however, before there was renewed focus on its development. In March 1986, four major Chinese scientists approached Deng Xiaoping and pressed for a new commitment of resources toward science and technology (S&T). Three of the four scientists—Wang Daheng,[13] Chen Fangyun,[14] and Yang Jiachi[15] (along with Wang Ganchang [16])—were part of the aerospace program. They all emphasized that science and technology were essential for future economic and technological advances, and required significant outlays of both financial and political capital. Deng eventually approved, and Plan 863, formally termed the National High-Technology Research and Development Plan, was born. [17]

This plan has served as a key blueprint for major research and development efforts into S&T and high technology in China, including not only aerospace, but also biology, information technology, robotics, and advanced materials. Plan 863 has been renewed with each subsequent Five-Year Plan and remains an ongoing effort to foster Chinese scientific and technical capabilities, including those in space.

Chinese space efforts received further impetus with the collapse of the Soviet Union. The collapse served to provide China access to Soviet space technology, often at bargain prices. At the same time, by removing the strictures of the Cold War from the international space market, it provided an opportunity for new players, including China, to enter the global space market. This coincided with Chinese efforts to foster commercialization of its space industries; not surprisingly, China became a player in the international space launch market at this time.

Current Chinese Capabilities

Over the course of 50 years, the PRC has developed a robust space capability. It possesses multiple launch sites and produces not only its own launchers, but also a range of satellites.

Organization

The Chinese military has long had a role in space development. Construction of China's launch facilities, for example, was undertaken by the General Logistics Department, one of the four general departments that oversee all PLA activities. Until 1999, China's space program itself was overseen by the Commission on Science, Technology, and Industry for National Defense (COSTIND), which had authority over all military production in China. This included oversight of the nuclear, aviation, ordnance, and space ministries, as well as research, development, and production of certain high-technology items (including space). COSTIND, however, was not solely a military organization; it had influence over civilian science and technology (if only through its responsibilities for defense conversion) and reported directly to the State Council, as well as the Central Military Commission.[18]

A major reorganization in 1998, however, resulted in the restructuring of several key organizations overseeing China's space program. COSTIND's responsibilities were parceled out; responsibility for defense research, development, and acquisition was assigned to a new General Department, the General Armaments Department (also known as the General Equipment Department). The General Armaments Department is responsible for the construction and maintenance of Chinese space launch facilities.[19]

Defense industries, meanwhile, would be managed by a rump COSTIND, which would report only to the State Council. [20] Under this smaller COSTIND, a separate civilian space bureaucracy was established. The China National Space Administration (CNSA) has responsibility for space policy formulation and day-to-day program management. It manages two state-owned enterprises, **China Aerospace Science and Technology Corporation** (CASC) and China Aerospace Science and Industry Corporation (CASIC), each of which, in turn, oversees a group of smaller state-owned enterprises and corporations.

CASIC oversees the China Jiangnan Aerospace Industry Corporation, China Sanjiang Aerospace Industry Corporation, and the China Haiyang Machinery and Electronics Technology Institute (formerly the Third Academy). Included under CASC oversight are the Chinese Academy of Space Technology (formerly the Fifth Academy), the China Academy of Launch Vehicle Technology, and the China Great Wall Industry Corporation. [21] CASC is the backbone of China's aerospace industries, manufacturing launch vehicles, satellites, and ground equipment.

Launchers

The primary Chinese launcher is the Long March series of rockets. Over the past 50 years, the PRC has fielded some 14 versions of the Long March system, allowing it to cover the gamut from low Earth to geosynchronous to polar orbits. The primary variants of the Long March series currently in commercial service include:

- CZ–2C, a two-stage rocket used for low Earth orbit, first launched in November 1975
- CZ–2D, a two-stage rocket used for two-stage orbit, first launched in August 1992
- CZ–3A, a three-stage rocket. Using cryogenic fuel, it is capable of geosynchronous transfer orbit (GTO) with a payload of 2.6 tons. It was first launched in 1994.
- CZ–3B, a three-stage rocket, with a GTO payload of 5.1 tons, first launched in 1996
- CZ–4B, a three-stage rocket used for polar/Sun-synchronous orbit. It was first launched in May 1999. [22]

In addition, the Chinese use the Long March 2F for their manned space missions. This is a man-rated version of the CZ–2E, a CZ–2 core with four additional strap-on, liquid-fueled boosters.

Launch Sites and Mission Control

To accommodate their various launchers, the PRC has constructed multiple launch sites, giving it, like the United States and Russia, the ability to launch multiple rockets at the same time.

China's launch sites include:

- the Jiuquan Satellite Launch Center in the Gobi Desert, which focuses on low- and medium-orbit satellites. Jiuquan also has been the site of all Shenzhou launches. Many CZ–2 launches are conducted here.
- the Taiyuan Satellite Launch Center, in northern China, which is used for polar orbiting missions. Many CZ–4 launches are conducted here.
- the Xichang Satellite Launch Center, in southwest China, which supports all Chinese launches destined for geosynchronous orbit. Many CZ–3 launches are conducted here.

There have also been reports that the Chinese are building a new spaceport on Hainan Island.

China's space missions are controlled and coordinated from near Xi'an in central China. The Chinese Tracking, Telemetry, and Control (TT&C) network controls five domestic ground stations, as well as four space-tracking ships, which provide the PRC with overseas tracking abilities.

China has also signed agreements with Sweden, France, and Brazil to access space-track information from those nations. As part of a global network of TT&C facilities, the PRC has also established its first overseas bases in Namibia and Kiribati. In 2003, when Kiribati decided to recognize Taiwan, however, the PRC dismantled the station. The 2006 Shenzhou-VI mission was supported by additional facilities in Malindi, Kenya, and Karachi, Pakistan.[23] Interestingly, the PRC constructed a dedicated facility, the Beijing Aerospace Directing and Controlling Center (BADCC), to manage just its manned space flights.

Satellites

China fields a range of indigenously produced satellites, including communications, weather, Earth imaging/remote sensing, and navigation satellites.

Communications satellites: Dongfanghong . The April 1984 launch of the DFH–2 made China only the fifth nation to independently launch a satellite into geosynchronous orbit. This was an experimental satellite with two transponders, which provided the basis for the subsequent DFH–2A series of communications satellites. The Chinese eventually fielded three DFH–2A satellites (out of four launched), each fitted with four transponders, allowing them to provide global, 24-hour, all-weather television broadcasting nationwide, as well as the capacity to handle 3,000 telephone calls simultaneously. [24] The DFH–2As replaced previously leased platforms and ended Chinese dependence upon foreign satellite providers.

These were followed by the DFH–3, of which seven were in operation as of July 2005.[25] The DFH–3 satellite had three-axis stabilization, providing a superior platform for its 24 C-band transponders, including 6 that are 16 watt, used for television, and 18 that are 8 watt, low-rate transponders for transferring telephone calls, telexes, and telegrams. They can transmit 6-channel color television programs and 15,000 telephone calls simultaneously (using frequency compression technology, they can transfer even more). The lifespan was projected for 8 years. The DFH–3 greatly alleviated the growing pressures on China's satellite communications infrastructure. This satellite also represents China's first communications satellite intended for civilian use. Twenty-two of its 24 transponders are used by the Ministry of Posts and Telecommunications for public purposes, including support for provincial level communications and television broadcasts to various provinces, as well as providing nationwide commercial phone service. [26]

Weather satellites: Fengyun (FY). In 1988, with the launch of the first FY–1A, China became only the third nation to launch its own meteorological satellites. As of this writing, the PRC has launched four FY–1 weather satellites into polar orbit (one of which is currently operational), and four FY–2 geosynchronous weather satellites (two of which are currently operational).

The FY–1 series operates in the visible, thermal infrared, and near-infrared bands. It has been used to detect forest and grassland fires, as well as to predict areas likely to be affected by droughts or floods.[27] The FY–1 also constituted a major step forward in Chinese efforts to promote international cooperation in space, as it became part of the World Meteorological Organization's constellation of weather satellites.

The first FY–2 series satellite was launched successfully in 1997. The FY–2 series is equipped with three channels for visible light, infrared, and water vapor.[28] It does not appear to have a very long operational life, functioning for only about 3 years (compared with the projected 8-year lifespan of the DFH–3).[29]

The FY–2 series made China one of only three nations with weather satellites operating in both geosynchronous and low Earth orbit at the same time. The FY–2C, launched in October 2004, also marked China's first commercial weather satellite. Chinese writings portray the FY–2C as representing China's entry into civilian aerospace and commercial satellite service.[30]

Recoverable remote sensing satellites: Fanhui Shi Weixing (FSW). The most numerous of China's satellites is the recoverable remote sensing satellite, with 22 launched through August 2005. The satellite drops its payload of either images or experiments back to China by directly firing solid retro-rockets when the craft is over China, descending almost vertically. The successful launch of an FSW series satellite in 1975 made China only the fifth country to be able to retrieve photographs from space.

The nine FSW–0 subseries of missions were apparently aimed at photoreconnaissance. The five FSW–1 subseries appear to have carried a combination of Earth observation and microgravity experiment payloads, in some cases on the same mission. Less clear were the intended tasks for the three FSW–2 subseries or the five FSW–3 subseries of launches.[31]

Chinese analyses note that the FSW series is built upon the idea of evolutionary design and incremental improvements, in order to minimize risk. Nonetheless, over 30 years of service, the FSW has seen a steady increase in capability. According to Chinese writings, for example, the first-generation FSW satellites (apparently encompassing the FSW–0 and FSW–1 subseries) had a lifespan of only 3 to 8 days. By 1992, however, the second generation (apparently encompassing the FSW–2 and FSW–3 subseries) had a lifespan of 15 to 20 days. The data collected by a second-generation FSW was said to be 13 times that of a first-generation craft. Similarly, resolution was said to have improved by a factor of 3. [32]

The FSW series is credited with making major contributions to Chinese agriculture by providing key materials for land use surveys, as well as providing for geodesy, mining surveys, waterworks construction, environmental monitoring, railroad line construction, and urban planning.

Earth imaging/remote sensing satellites: Ziyuan (ZY). While the FSW series of satellites provided China with an initial photoreconnaissance capability, their limited lifespan, coupled with the need to return canisters of film, limited its utility. The PRC in the 1980s began to undertake joint research with Brazil to develop a more capable satellite. The result was the China-Brazil Earth Resources Satellites (CBERS), which is also referred to as the Ziyuan (Resource) Satellite. In October 1999, China launched CBERS–1, also known as ZY–1, from Taiyuan Launch Center.

The ZY series has a design lifespan of approximately 2 years. It uses a set of digital electronic sensors, including a five-channel charge coupled device camera, an infrared multispectral scanner, and a wide-field imager, to gather pictures, which it then transmits to a ground station. [33] The sensors are believed to have a resolution of 20 meters. Interestingly, Chinese writings have noted that some of the ZY–1 series are also equipped with electronic counter-countermeasures for their control systems.

In September 2000, October 2002, and November 2004, three ZY–2 satellites were launched. These are apparently in a lower orbit, with a perigee of 489 kilometers, compared with 773 kilometers for the ZY–1. While Chinese writings indicate that the ZY–2 series is primarily used for Earth resource observation, environmental monitoring and protection, urban planning, agricultural assessments, disaster monitoring, and space science experimentation, some Western writings have characterized the ZY–2 as a military reconnaissance system.

Navigation satellite: Beidou. On May 25, 2003, China's Xichang Satellite Launch Center launched a Long March 3A rocket with the third Beidou satellite into orbit. The successful deployment of its payload made China only the third nation to field its own space-based navigation and positioning system.

The Beidou system, unlike the global positioning system (GPS) or global navigation satellite system (GLONASS), is an active system, built around two geosynchronous satellites (the third is apparently an orbital spare). The user's terminal transmits a signal to the satellites, which in turn signal a separate ground station with the times that they each received the user's signal. The central station calculates the user's two-dimensional position based on the time difference, and then adds information from a digital database to obtain the user's third dimension. All of this is then transmitted back to the user.

While the system is more cumbersome and has an upper limit on the number of users (due to the two-way communications requirements), from Beijing's perspective it also has certain advantages. Most obviously, of course, it is under direct Chinese control. Furthermore, since it requires launching only two satellites (GLONASS involved 21 satellites, GPS requires 24, Galileo will involve 30), compared with global systems, it can be rapidly built and entails relatively low expenditures, yet still provides 10-meter services to a core region. The Beidou system can also serve as a communications system, in addition to satellite navigation and positioning.

In addition to these main systems, the Chinese have also developed other capabilities. For example, in April 2006, China launched the first of what is expected to be a new series of remote sensing satellites, the Yaogan-1. Officially intended for scientific experiments, Earth resource observation, agricultural estimations, and disaster relief, it is part of China's efforts to develop the needed "24-hour, all-weather, all-aspect networked remote sensing capability."[34]

The Chinese have also devoted significant resources into developing small satellites, even developing a dedicated small-satellite launcher, the Kaituozhe. Such satellites would be potentially both cheaper and more resilient than larger satellites. One Chinese analysis concluded that employing larger numbers of much smaller satellites may also reduce overall vulnerability.[35]

The satellite most prominently mentioned in the Chinese press has been the Haiyang-1 ocean surveillance satellite. Launched in May 2002, the Haiyang-1 weighs 368 kilograms and has visible light and infrared capabilities to monitor the ocean surface and observe changes in water temperature. It has a projected lifespan of 2 years. The main aim of this satellite is to provide Chinese scientists with oceanographic information, including data on ocean productivity, fishery stocks, and nutrient levels. It has the ability to examine light and water interaction and monitor algae levels, ocean surface water temperatures, sedimentation, and ocean pollution levels. It is also expected to measure littoral conditions, ocean currents, and ocean surface meteorological conditions.

Manned Space

In addition to satellites, China has launched manned missions into orbit. This was apparently a consideration from the early days of the Chinese space program, specifically with the founding of the Space Flight Medical Research Center by Qian Xuesen in 1968.

While there was reportedly some interest in orbiting a man in a modified FSW capsule in the 1960s, Chinese manned space efforts really began in earnest in the 1990s. As with the rest of China's space program, the original Project 921 proposal for manned spaceflight called for indigenous development of a series of new rockets and new spacecraft over the course of the eighth and ninth Five-Year Plans (1991–1995 and 1996–2000, respectively). Although the program was not approved, construction was nonetheless started at that time on a new flight control center capable of handling manned spacecraft (which eventually became the BADCC).

Then, in 1994, a cash-strapped Russia indicated its willingness to sell space expertise to China, and when Jiang Zemin visited the Russian Flight Control Center in Kaliningrad, he noted that there were broad prospects for cooperation between the two countries in space. In March 1995, a deal was signed to transfer manned spacecraft technology to China, including cosmonaut training, Soyuz spacecraft capsules, life support systems, docking systems, and space suits. In 1996 two Chinese astronauts, Wu Jie and Li Qinglong, began training at the Yuri Gagarin Cosmonaut Training Center in Russia. After training, these men returned to China. It is believed that they have had a hand in the selection, and possibly the training, of the current class of 12 Chinese astronauts.

The Chinese Shenzhou, however, is not simply a copy of the Russian Soyuz. Superficially, the two are similar, both comprised of three separate modules: an orbital module, containing experiments or other payloads; a descent module, which the crew rides into orbit and back to Earth (it is the only part of the system that returns to Earth); and a service module, containing the propulsion systems (which detaches prior to final reentry of the descent module and burns up).

Upon closer examination, however, the Shenzhou is clearly different from the Soyuz. To begin with, the Shenzhou is physically larger than a Soyuz capsule. The Shenzhou is wider, longer, and about half a ton heavier.[36] Furthermore, the Shenzhou has two sets of solar panel arrays, compared with the single set of arrays on the Soyuz. The two arrays together generate approximately 1.2 kilowatts, which is reportedly comparable to that of the entire Mir station, or three times that of an individual Soyuz vessel. [37] This gives the craft more power to run various systems and could give it longer endurance.

One of those solar arrays is on the Shenzhou's orbital modules, which also has its own set of engines. This allows the Shenzhou's orbital module to maneuver and sustain itself on its own, unlike the orbital module on the Soyuz. This ability was demonstrated in the Shenzhou-IV test-flight when the orbital module was boosted to a higher orbit after separating from the descent module and was left in orbit for 9 months on its own. The combination of its own power and propulsion could make the orbital module a potential building block for a Chinese space laboratory.

China has launched six Shenzhou flights as of 2007. Shenzhou-V, launched in October 2003, made China only the third nation to orbit its own astronaut (Yang Liwei). Shenzhou-VI had a two-man crew, Fei Junlong and Nie Haisheng. All three Chinese astronauts are believed to have been fighter pilots in the PLA Air Force.

Lunar Missions

The PRC has also indicated that it plans to undertake lunar missions. The Chang'e program was intended to involve a lunar orbiter mission in 2007 followed by a lunar lander in 2008–2009. The Chang'e program is also expected to involve one or more lunar sample retrieval missions, probably by 2017. All of these missions will be unmanned, robotic missions.

Military Space Programs

The Chinese antisatellite (ASAT) test of January 11, 2007, served as a reminder that the People's Liberation Army plays a significant if little discussed role in China's space efforts. The PRC has been extremely reticent about its military space programs. This is complicated by the dual-use nature of most Chinese satellites, and the avowed interest in using space to improve "comprehensive national power," with its civilian and military components.

Given the confluence of military and civilian bureaucracies, the PLA almost certainly has access to data gathered from civilian space assets. For example, navigation satellites provide the ability to improve navigation and guidance for military and civilian aircraft. Similarly, it is likely that the PLA also has access to meteorological and Earth resources data derived from satellite information.

Little is publicly available, however, regarding China's dedicated military space systems. In the 1970s, the short-lived Technology Experiment Satellite was reputed to have been military in nature. According to some reports, China's initial group of FSW-series satellites launched in the 1970s and early 1980s carried Earth imaging payloads that may have been intended for the PLA.[38] Subsequent FSW satellites may also have conducted military missions.

More recently, reports beginning in 1999 indicated that the PRC was preparing to orbit a military communications satellite. The Zhongxing-22 or Fenghuo-1 was eventually launched in January 2000.[39] That same year, the Chinese orbited a Ziyuan-2 Earth observation satellite. Some reports have indicated that it was actually a military imaging satellite distinct from the Ziyuan-1 named the Jianbing-3.[40]

The Chinese manned program also seems to involve a military component. China's astronaut corps, for example, is apparently drawn from the ranks of PLA Air Force fighter pilots. Some reports have also suggested that the orbital module on the Shenzhou-V mission had a military reconnaissance payload, possibly involving either electronic or photoreconnaissance.

Chinese Views on Spacepower

The PRC defines its national interest in terms of expanding its comprehensive national power: "In the period of our socialist modernization construction, national interest and the general line and principles of the Party focus on increasing social productive forces, revitalizing economy and strengthening comprehensive national power."[41] By *comprehensive national power*, the Chinese are referring to the various capabilities required to provide for the survival and development of the nation, to meet material and ideological demands of its population, and to exert influence on the international scene. The China Institute of Contemporary International Relations, a top Chinese think tank, has defined *comprehensive national power* as the "total of the powers or strengths of a country in economics, military affairs, science and technology, education, resources, and influence."[42]

Space plays a key role in the development of China's comprehensive national power, because it touches on so many of the component elements. As Zhang Qingwei, general manager of the China Aerospace Science and Technology Corporation, has noted, China's space efforts are comprehensively integrated into "the economy, into social development, into scientific advances, and into related industrial areas. It has already become a strategic industry in terms of broadly raising China's real comprehensive power."[43]

Economics

Chinese leadership has consistently supported the development of scientific and technical capabilities as part of their effort to improve the national economy. The general view seems to be that improvements in science and technology will lead to improvements in various Chinese industries, which will in turn raise the overall efficiency and productivity of the Chinese economy. State Councillor Chen Zhili, for example, notes in an article in the influential journal *Qiushi* that development of science and technology, and especially "independent innovative strength," is important in order to "realize a sustainable and healthy economic development."[44]

Hu Jintao, in remarks at the unveiling of China's Mid- and Long-Term National Science and Technology Development Plan in January 1996, emphasized that science and technology represents the first line of production. Consequently, pushing development of S&T is essential for fostering "autonomous innovation" in China.[45] He is echoed by Chen, who notes that science and technology "innovation is rapidly becoming the key force in propelling a country's development."[46] That same phrase is prominently mentioned as a principle underlying the development of China's space program.[47]

More concretely, China's space industry is seen as a major part of the economy. The various corporations under CNSA, for example, employ hundreds of thousands of skilled workers. A prosperous Chinese space industrial base is therefore one that would absorb thousands of engineers. It would also help foster demand for a variety of advanced materials and supporting high technology. Satellite and launcher construction requires advanced electronics, advanced materials such as composites, and improved energy sources. An expanding Chinese space industrial base would therefore promote these other key industries as well.[48]

Along these lines, it is interesting to note that a "Proposal for Development of Our Nation's Lunar Exploration Technology" was incorporated in 1997 into Plan 863. The plan called for a series of unmanned lunar landings. The aim of the plan was to foster China's robotics industry. The plan was reportedly drafted in part by Yang Jiachi, Wang Daheng, and Chen Fangyun, three of the scientists who had approached Deng Xiaoping about creating Plan 863 in the first place.[49]

More broadly, Chinese efforts to develop aerospace technology are seen as an enabler, pushing the development of other essential foundations of the Chinese economy. Work on sophisticated space systems, for example, has the potential to foster improvements in systems integration. [50] This is a significant weakness in Chinese industrial and technological capabilities, and improvements in this area would probably benefit the Chinese economy as a whole as it propagated across industrial sectors.

The development of China's space applications industry in both depth and breadth would also benefit the Chinese economy as a whole. This is one of the major development policies enumerated in the 2006 Chinese space white paper, which called to promote "space application and accelerate the industrialization of space activities."[51]

Indeed, space applications are already generating revenue valued in the billions of renminbi (RMB) and are seen as a major future growth area. China, for example, is already a major user of satellite navigation services. Since 1998, China's market for satellite navigation systems has grown at the rate of 50 percent per year. In 2000, the market was in the area of RMB2 billion/US$256.4 million, with some 150,000 satellite navigation equipment sets sold. By 2003, the market had nearly doubled, to RMB3.95 billion/$506.4 million, of which half involved commercial services, software development, systems integration, and so forth. By 2005, the Chinese satellite navigation market was estimated at RMB12 billion/$1.538 billion. [52]

Another major area of space applications is satellite broadcasting. There are some 50 Chinese television programs currently broadcast by satellite, mostly apparently from the Central China Television system, but there are efforts to expand this by making provincial television programs available to all of China through satellite broadcast as well.[53] Meanwhile, some Chinese analyses foresee major growth in demand for direct-broadcast satellite television. One analysis notes that such growth would help China to develop better software, expand China's domestic consumer electronics market, and promote the construction of satellites, rockets, and associated equipment. [54]

As with space industry, space applications are expected to facilitate growth in national comprehensive power, due not only to the direct benefits, but also from indirect effects. Satellite communications is seen as integral to expanding Chinese commerce, including financial transactions.[55] PRC participation in the global economy, therefore, requires steady improvements in China's communications capacity, including the satellite component. Similarly, improved weather and remote-sensing satellites will likely generate improved agricultural yields and better forestry management. Navigation and positioning satellites help in urban planning and designing transportation networks. Earth imaging satellites provide for more efficient resource and land-use surveys and help warn of natural disasters (such as forest and grasslands fires). As China is still a lesser developed country, the more efficient use of available resources is essential.

Nor is this solely a matter of physical resources. Chinese analyses of future satellite applications often mention the role of distance learning and telemedicine.[56] While this would obviously lead to benefits for more isolated areas (by potentially improving the standards of teaching and medicine), it also leads to a potentially more efficient allocation of resources. The utilization of satellite communications technology to allow expert personnel, in essence, to be in multiple places at once means that scarce, trained human capital can be employed to the maximum extent. Given the ever-growing demand in China for trained personnel, distance learning and telemedicine are powerful means of leveraging scarce human resources.

In this regard, space is also seen as a means of inspiring younger Chinese into a career in the sciences. Creating a cadre of scientific and technical personnel is a key part of the Mid- and Long-Term Plan. Hu Jintao himself has called for seeking out talent and providing international levels of S&T education in order to build a foundation for future economic and technological development. [57] Nurturing human talent is also one of the key points emphasized by CASC director Jun Jiajun, who notes that there must be careful fostering of innovative talent within the space industrial sector.[58]

Finally, by participating in the international space market, China also stands to gain economically. China's entry into the commercial space launch business not only provided orders for Chinese launchers, and therefore jobs, but also constituted a welcome source of hard currency, in the early stages of reform and opening up. Even more lucrative would be the sale of satellites and space services, including navigation and positioning. The Nigeriasat program, for example, is valued at $250 million, including satellite construction, launch, and insurance.[59] The joint effort with Venezuela on the Simon Bolivar satellite is believed to be similarly priced. [60]

Politics

Just as space influences the economic aspects of comprehensive national power, it also affects the political component, including both domestic and foreign elements.

Domestic politics . Politically, space has long been seen as a source of Chinese national pride. The Chinese developed most of their space program solely through their own efforts. This self-reliance, encapsulated in references to the "two bombs, one satellite" efforts of the 1960s, underscored that China's achievements were its own. This mantra is still regularly cited in current Chinese politics. In 1999, for example, there was an awards ceremony for those involved in China's nuclear weapons, missile, and space efforts. Recipients were awarded a "two bombs, one satellite" medal. At the ceremony, Jiang Zemin spoke of the "two bombs, one satellite" spirit. This spirit, he said, embodies five principles, which he characterized as following the leadership of the Chinese Communist Party, maintaining a spirit of self-reliance, focusing efforts on particular goals, respecting the role of science and technology, and maintaining a spirit of scientific management.[61] Jiang called for a continuation of this spirit in ongoing endeavors.

Other Chinese leaders also continue to refer to the "two bombs, one satellite" spirit, specifically linking it with the idea that sophisticated technology was developed from minimal resources, by dint of the Party's leadership. [62] The occasion of the Shenzhou-VI mission, for example, was credited to "the inheritance and elevation of the spirit of 'two bombs, one satellite,' the extension and expansion of the great national spirit, and the powerful spiritual motive force for winning complete success."[63]

Chinese emphasis on autonomous or independent innovation in the space sector would seem to represent an extension of a longstanding theme. Thus, in remarks commemorating the 50th anniversary of the founding of the Fifth Academy, Jun Jiajun noted that China's aerospace industry, and especially CASC, has consistently held to the path of autonomous innovation.[64] This adherence, in turn, is credited with helping make China a more advanced nation. The implication would seem to be that China's rise in stature, marked in part by its improved space capabilities, is not only a reflection of Chinese achievements, but also is emblematic of the correctness of the Chinese Communist Party's decisions and policies.

At a more immediate level, space systems literally help bind the nation together. For example, communications satellites are a key part of China's telecommunications network. One of the objectives has been to utilize satellite communications to improve village-to-village links. Now there is a growing effort to progress to the next step and allow person-to-person links.[65] This is especially important in China, where telephone penetration, while steadily increasing, is by no means universal. Statistics released in 2005 by the Ministry of Information Industry, for example, indicated that fixed-line telephone penetration in China is approximately 24.9 percent, while cell phone penetration is 25.9 percent (although such figures represented 329.5 million and 353.7 million people, respectively). [66]

International politics. From its earliest days, Chinese leadership has seen aerospace technology and developments as a source of prestige and international respect. In 1962, for example, Foreign Minister Chen Yi told Marshal Nie Rongzhen and Chief of the General Staff Luo Ruiqing that "producing atomic bombs, missiles, and supersonic aircraft would put me, the Minister of Foreign Relations, in a better position!"[67] Mao Zedong also noted the importance of such systems in ensuring that China would not be bullied. [68]

This recognition of the importance of international prestige has often been explicit. As China was only the fifth nation to orbit a satellite, Mao himself instructed that said satellite should be larger and more capable than the first American satellite. Similarly, China is only the third nation to orbit an astronaut on its own, but it made sure that its first manned mission was longer than that of either the Soviet Union or the United States. In the case of Shenzhou-VI, the mission was seen as not only showcasing Chinese technological innovation, but also as a means of potentially burnishing the Chinese brand name.[69]

This effort to utilize space to raise China's reputation has extended to its endeavors to engage in international space programs. With the launch of its first Fengyun weather satellite, for example, China offered to provide the resulting data to other nations. Indeed, Chinese descriptions of the Fengyun series of satellites usually mention that the FY–1C was incorporated into the World Meteorological Organization's constellation of weather satellites. Similarly, Chinese analyses of the state of their space industry generally mention space cooperation efforts with Russia, the European Space Agency, and France. The implicit message is that China's space capabilities make it an equal with other, more advanced nations.

While it has sought to leverage more prestige from its space efforts, however, China has also sought to utilize its space capabilities to foster additional diplomatic gains. Beijing was a major impetus behind the creation of the Asia-Pacific Space Cooperation Organization. Beginning in 1992, Thailand, Pakistan, and the PRC sought to form a multinational organization among Asian and Pacific states to facilitate cooperation in the development of space technology and space applications. In 2006, those three states, along with Bangladesh, Indonesia, Iran, Mongolia, and Peru, agreed to form the Asia-Pacific Space Cooperation Organization. They also agreed make the PRC its hosting country and Beijing its headquarters. [70] Soon afterward, Turkey became the ninth member of the organization.

The creation of such an organization marks one step toward diffusing some of the perception in Southeast Asia of a "China threat." It also helps China to forge additional links to states with which it generally seeks to maintain good relations (such as Indonesia and Mongolia). Similar benefits may accrue from other Chinese cooperative efforts, such as those with Brazil.

There have also been more practical gains. China's first overseas facilities, for example, were established as part of the manned space effort. In order to provide constant telemetry and tracking capability, China needed land-based facilities abroad in addition to its domestic sites and four space-observation vessels. As a result, the PRC established facilities in Namibia and Kiribati as support centers for the Shenzhou program. These have since been supplemented by facilities in Pakistan (a longtime Chinese ally) and Kenya, while the Kiribati facility was dismantled.

Diplomacy and economics also interact. While China undoubtedly is interested in the sale of satellites abroad in order to access the global satellite market, the sale of such systems to major oil exporters such as Nigeria and Venezuela may be more than coincidence. Similarly, the desire of the Chinese to cooperate with Europe on space technology almost certainly is affected by the ongoing embargoes on high-technology exports imposed after the events at Tiananmen Square in 1989.

Taiwan. The unique circumstances of cross-Strait relations between China and Taiwan are also affected by China's space program.

On the one hand, the Chinese have sought to use achievements in space to tie Taiwan back to China. Prior to the launch of Shenzhou-V, Chinese officials offered to take seeds from Taiwan into space. The offer was made "to reinforce cooperation with Taiwan on agricultural sciences in a bid to promote the common development of agricultural technology on both sides of the Taiwan Strait." [71] The offer was ultimately accepted, and Shenzhou-V carried flower and vegetable seeds from Taiwan into orbit. Xie Mingbao, director of the China Manned Space Engineering Office, observed that "we are willing to actively promote anything that will benefit Taiwan compatriots."[72]

Similarly, news regarding China's space efforts is often conveyed in a manner to suggest that it reflects upon all Chinese, including those on Taiwan. Fei Junlong, one of the two astronauts on the Shenzhou-VI mission, is quoted as saying, "We're grateful for the deep love and concern by all Chinese people, the Hong Kong, Macao, and Taiwan compatriots," prior to the launch.[73]

At the same time, however, Beijing-Taipei tensions have also been reflected in space affairs. The Chinese facility on Kiribati was closed and the equipment dismantled when the Kiribati government decided to recognize Taiwan. Beijing clearly felt that its efforts to isolate Taiwan outweighed the benefits of any information from that site.

Indeed, there is an implicit message from Beijing to Taiwan that China's space capabilities are intertwined with its military capabilities. Better space-based sensors provide Beijing with the ability to monitor developments on Taiwan. Improved reliability in Chinese space launch vehicles will almost certainly be mirrored by similar improvements in Chinese tactical and strategic missiles. Improvements in optics and controls are likely to lead to not only better space systems, but more lethal and precise weaponry as well.

Military

This message, of course, is not aimed solely at Taiwan. Space is ultimately a dual-use environment. Much of the technology used in space has both military and civilian applications. Therefore, building up China's space capabilities inevitably also will have an impact on China's military capabilities, as it affects the other components of comprehensive national power.

Chinese analyses of recent wars, especially U.S. military operations since the 1991 Gulf War, initially concluded that the key to future warfare was high technology. As Jiang Zemin's 1995 speech on the "Two Transformations" noted, the PLA needed to shift from emphasizing quantity to emphasizing quality, and from preparing to fight local wars under ordinary conditions (industrial age warfare) to preparing to fight local wars under modern, high-tech conditions (in light of information technology and systems of systems).[74]

In the subsequent years, however, and further local wars (such as Afghanistan and Iraq), it became clear to Chinese analysts that the key technologies were those associated with information. The emphasis therefore shifted from local wars under high-tech conditions to local wars under informationalized conditions (LWUIC). This, in turn, has made space a crucial arena for future military operations. According to these analyses:

- Future military operations will be joint in nature. Initially, this simply meant coordinated efforts among operational level service groupings (such as military region air forces or group armies), but increasingly it is assessed as involving integrated operations among more tactical level groupings.

- In order to accomplish joint operations, especially integrated joint operations, there must be the ability to gather, share, and apply information. Indeed, informationalized warfare is seen as the hallmark of the current age, just as mechanized warfare is seen as the hallmark of the industrial age. The objective, then, is to achieve information dominance, which is perceived as the prerequisite for the ability to successfully undertake LWUIC.

- Undertaking informationalized operations necessarily involves the ability to exploit space. According to some Chinese assessments, space dominance is an essential component of information dominance.

This last conclusion is due in large part to the heavy reliance on space systems exhibited by the United States in recent wars. One Chinese article in 2005 noted that:

- in the Gulf War, the United States used 52 military satellites
- in Kosovo, the United States and NATO used 86 satellites
- in the Iraq war, U.S.-UK forces used over 100 satellites.[75]

For the 2003 Iraq war, another Chinese article estimates that the United States relied on satellites for 95 percent of reconnaissance and surveillance information, 90 percent of military communications, 100 percent of navigation and positioning, and 10 percent of meteorological and weather forecasting. It also estimates the Russian military relies on satellites for 70 percent of strategic intelligence and 80 percent of military communications.[76]

It is this steadily escalating reliance upon space for information operations that has led the PLA to conclude that *dominance* of the information domain is predicated on the ability to control space. In the opinions of some PLA analysts, without control of space, any attempt at dominating the information domain, or exercising combat in the electromagnetic spectrum, is made much more difficult, if not outright impossible.[77] Others write that "in modern wars, seizing space dominance has already become a vital part of seizing information dominance, from which one can then retain the active position in the war." [78]

Space, in Chinese writings, represents the new strategic high ground and is described as such. Chinese authors note that the combination of modern information technology and military space systems has created the means of coordinating land, sea, and air forces; control of space (and the advantages thus gained in the information domain) in this view is now crucial for coordinating joint operations. [79] They write that whoever gains space dominance will be able to influence and control other battlefields and will be likely to retain the initiative, while loss of that control is likely to lead to a reactive, passive stance. [80] Space is therefore considered an essential part of joint campaigns, a fundamental method of fighting future wars; conversely, joint campaign coordination will rely upon the ability to exploit space. [81]

To this end, PLA analyses discuss space-related tasks. These include:

- facilitating the transmission of information globally and providing both secure and reliable information channels
- providing essential information regarding weather, which affects military operations
- collecting information regarding an opponent around the clock and providing commanders with the early warning necessary to respond to enemy activities
- undertaking Earth observation, which supports geodesy and general geographic information collection
- providing navigation and positioning information in order to facilitate friendly troop movements with greater certainty as to their own location, as well as provide guidance for modern weapons.[82]

It is probably no accident that each of these mission areas is currently supported by at least part of the Chinese inventory of space assets. The dual-use nature of China's space systems has not prevented it from developing the systems it believes are necessary to sustain military operations.

At the same time, PLA authors have also discussed the importance of denying space to an opponent. Unlike air or naval dominance, space dominance is focused on providing windows of opportunity, establishing control only over certain areas of space for a certain period of time. [83]

It was unclear as of 2007 whether a PLA space doctrine had been formally promulgated. But recent PRC activities suggest that interest is shifting from the theoretical to the physical. Reports in late 2006, for example, indicated that the PRC has fired lasers, possibly several times, at U.S. satellites, apparently in an attempt to blind them.[84] This was then followed by the January 2007 test of a direct-ascent ASAT that destroyed a defunct FY–1C weather satellite.

Although the kinetic kill vehicle test focused attention on Chinese development of hard-kill systems, PLA writings appear to approach the topic from a much broader perspective. Since the objective is attaining information dominance—that is, dominating space is a means, not necessarily an end—the focus is on disrupting the flow of information, rather than necessarily destroying satellites per se.

Consequently, many PLA writings discuss the utility of soft-kill methods against space architectures. Satellite operations rely heavily on the use of computers to transmit and manage the data.[85] Without functioning command, control, communications, computers, and information systems, it would be difficult to employ space systems. This is a major reason why space combat and information combat are so closely linked.[86] As one set of PLA teaching materials notes, an especially effective means to soft-kill space systems may be interference with the computer systems controlling space platforms, both on-board systems as well as those in ground-based control centers.[87]

PLA writings also suggest that there is an important role for passive countering of space systems, which involves various deception and camouflage methods to counter enemy space-based reconnaissance and surveillance systems.[88] Utilizing various deception measures and stealthing techniques in order to forestall detection from space offers the potential for China to suddenly appear where there had been few indications of a PLA presence, thus surprising an opponent. Thus, PLA authors have suggested that "skillful use of technical means to avoid reconnaissance" can be an extremely effective combat style in space-related coordinated activities. [89]

Regardless of whether through soft or hard kill, the key objective seems to be denying opponents access to information by interfering with their space-based systems and thereby retarding their command and control. In short, by denying an opponent the ability to use space freely, the PLA would be denying them the ability to achieve information dominance and therefore make them less able to fight an informationalized war.

Prospects for the Future

Given that China sees improved space capabilities as contributing to the growth of its comprehensive national power, it is hardly surprising that it is interested in strengthening its space capabilities. China's aerospace efforts are likely to focus on undertaking "three transformations." These include:

- shifting from developing civilian goods by the aerospace industry to developing a civilian aerospace industry
- shifting from broad, uncoordinated development of space systems toward a more coordinated, focused development effort
- shifting from management methods inherited from the planned economy toward methods more suited to a market economy. [90]

The overall theme underlying these shifts is that the PRC wishes to make its spacepower more responsive to the needs of the nation and the development of national comprehensive power. This will require a more responsive industrial system, optimized toward considering likely markets and client demands. It will also entail a more focused approach toward research and development.

The 2006 white paper on Chinese space activities enumerates areas in which these transformations will be realized. Certainly, there will be new hardware, including new launchers using more environmentally friendly propellants, as well as a range of new satellite systems, such as improved remote sensing, telecommunications, and navigation satellites. This will require improvements in subsystems, including power sources and materials. In addition, however, the white paper notes that China will develop ground equipment production and operational services, in order to extend itself into the "secondary development of space technology."[91]

Also prominent is the expansion of China's space industry beyond hardware into space applications and space services. This includes improvements in its space applications system, so that the information it does obtain can be better exploited. It also entails the promotion of scientific management and the fostering of talent.[92]

One likely focus will be China's space-based communications systems, including direct broadcast satellite television. This is perceived as an important means of pushing greater domestic political and ideological unity and providing additional cultural development. [93] It is also seen as driving the development of China's software industry, as well as promoting the construction of satellites, rockets, and other associated items. [94]

Another probable focus of development efforts will be satellite navigation and positioning. Satellite navigation will likely be an integral element of the informationalization of China's economy and society. Chinese analyses discuss the merging of wireless communications systems, computer systems, and geographic information systems to create individual mobile, multiuse information service terminals. [95] Not only, then, is the PRC likely to develop its own satellite navigation system (as called for in the space white paper), but also it is likely to try and expand its presence in satellite navigation applications, such as product tracking.

Such efforts will take some time, however, as China's space industries, despite 50 years of development, are still relatively small players. One Chinese analysis, for example, observed that the average working capital for Chinese aerospace firms in 2005 was only about RMB10 million/US$1.3 million, and only 3 percent of Chinese companies have operating capital above RMB20 million/US$2.6 million.[96] By comparison, Boeing Corporation's space-related revenue alone amounted to US$9.1 *billion*. [97]

In the military arena, there probably will be sustained, if not heightened, attention to space operations. PLA authors have increasingly focused on the importance of joint operations, and therefore on the need for information dominance in future local wars under informationalized conditions. This is likely to include additional dedicated military space support systems; it also may result in further testing of offensive and defensive space systems. Just as important, it could include efforts to improve the PLA's ability to interfere with an opponent's overall space architecture while undertaking defensive countermeasures to defend its own.

Conclusion

At the end of the Gulf War, Pierre Joxe, French minister of defense, concluded that the conflict had shown that "the stakes in space go beyond the strict definition of defense. They are national. Not to possess this capacity would affect the very status of the nation." [98] In short, a state seeking to be a major power must be a space power.

The growth of the PRC over the past several decades suggests that China is well on track to becoming a major power. It has seen constant economic growth, greater political standing, and increased influence in world politics. At the same time, however, the PRC is a nation in transition. While parts are rapidly industrializing and developing, the nation as a whole remains relatively poor. There is an omnipresent potential for domestic unrest (often actualized) exacerbated by uneven growth, political corruption, and problematic demographics.

To remedy this situation, the Chinese authorities are intent upon finding and developing those technologies and industries that it can best leverage to maximize national benefits, and increase its comprehensive national power. China's space program would seem to be one of those areas. For the PRC, the development of spacepower may be necessary not only to underscore its great power status, but also to help it attain and retain that status at all.

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Chapter 25:

The European "Spacepower"? A Multifaceted Concept

Xavier Pasco

Is the European Union's (EU's) ambition to manage its own military operations realistic unless it develops satellite networks that can operate independently of America's space assets? Or should Europeans simply rely on U.S. technology? Can Europeans even expect to fight alongside the United States in future wars without increased access to space technology? All of these questions are highly relevant to the EU's hesitant efforts to develop a common European Security and Defense Policy (ESDP). Military commanders and their political leaders are increasingly dependent on space-based technologies for coping with many security challenges—ranging from humanitarian disasters to warfighting. But European governments have been slow to invest in space-based technologies for military purposes.

Considering the growing importance of space technology for military operations, the challenge for Europe is to transform a collection of disparate and relatively modest programs into a European military space architecture. The U.S.-pioneered "revolution in military affairs" (RMA)—a set of new military technologies based on computers and telecommunications—is closely associated with the future development of military space programs. In Europe, however, the RMA has been the subject of mistrust; in particular, there has been uncertainty about the military relevance of such high-technology–oriented thinking. Therefore, Europe has not been prepared to fully support the development of major military space programs.

Today, the United States accounts for perhaps more than 90 percent of the money spent on military programs in space.[1] European investments in space-based military applications amount to less than 5 percent of the global total. The huge disparity between American and European investment in space technology will almost certainly increase the gap between American and European military capabilities. The very notion of *spacepower* can only reflect these global differences, considering that distinct levels of military dependency on these space systems naturally lead to different senses of urgency in protecting militarily the satellites in orbit.

Still, while the United States is already engaged in an unprecedented effort to adapt its armed forces to today's security environment using space-based technologies, European governments also recognize that they will have to adapt their intelligence and information resources to cope with more volatile situations—possibly involving the use of weapons of mass destruction—and more elusive enemies such as international terrorist networks. Space-based technology is a primary element for developing autonomous intelligence tools for Europe. European governments, therefore, should consider what space systems are necessary to both fulfill European military requirements and share more of the military burden with the United States during coalition warfare. But European governments have also agreed to develop their own collective armed forces so as to meet their North Atlantic Treaty Organization (NATO) and EU commitments. At the Helsinki summit in 1999, the EU agreed to work on the creation of a common European Security and Defense Policy. The point of the ESDP is to allow the EU to carry out small-scale "crisis management" operations, when NATO is not involved. The EU has therefore committed itself to a headline goal (a force of 60,000 troops), plus supporting naval, aerial, and civilian capabilities. The EU wants to be able to tackle the so-called Petersberg tasks (humanitarian relief, rescue missions, peacekeeping, and peacemaking) without having to rely on the United States for transport aircraft, intelligence gathering, command and control, and other capabilities.

More concretely, the political green light given to the creation of common European battlegroups has helped define a first format for planning genuine European military capabilities. It is acknowledged that these forces, among which responsibilities will be distributed following a rotating national leadership, will have to rely on shared information capabilities. Their use should be coordinated directly from Brussels by both an operational headquarters and a force headquarters. While still under discussion, these military structures, which have been accepted in principle, may typically appear as primary users of space resources in Europe. While not a revolution in itself, such a command chain using satellite systems for information would perfectly fit the level of development space has attained in Europe, while keeping, at this stage, far behind the United States. Once in service, these structures will mark the first steps in the concrete use of space by Europe for common military purposes.

None of these issues are easy ones. The intrinsic link between space programs and information technologies makes space the key to a new, almost uncharted, world in warfighting techniques. Pursuing very demanding and costly military space programs must not create overdependency on a sector that remains technologically difficult and vulnerable. Europe already possesses a few military space programs that can form the basis for future developments. But the number of these military programs is limited, and their interface with real combat is relatively moderate. European governments, therefore, need to make some decisions now about using space-based technology in the conflicts of tomorrow. Given static European defense budgets, decisions to develop space technology will have to be weighed against other military priorities. More specifically, if European countries are to make the most of their space resources, they should also evaluate the changing uses of military space systems in the United States.

New European Operational Needs: From Theory to Practice

For Europe, the path is somewhat narrow between fulfilling common requirements more efficiently through commercial ventures and needing to protect its autonomy, should military or political circumstances require it. European governments, therefore, need to think about a space strategy in terms of a European architecture. This is necessary for integrating European national programs, whether civilian or military. The key step is to ensure that the different programs can operate together.

Naturally, national programs have reflected the specificity of the national operational requirements. During the Cold War, France justified its production of space-based capabilities—albeit on a much more modest scale than the United States and the Soviet Union—on the grounds that it needed independent intelligence assets. For the French, like their independent nuclear arsenal, access to space and the construction of independent launchers—which gave birth to the Ariane family of space launchers—are viewed as necessary guarantees of strategic independence.

It is also true that common military needs may emerge and tend to rationalize a collective military and/or security use of space. Satellites are also used as a force multiplier—a means of increasing the efficiency and effectiveness of military operations. Information coming from space allows commanders in distant headquarters to see on screen, in real time, the location of their forces and those of their opponents, and to guide weapons precisely to their targets. This means that soldiers need to be equipped with sophisticated personal communications devices. But it also requires the transmission of so-called value-added information: the ability to mix different forms of information sources, to make the information relevant for the user. Strategists bet on compensating for the risk of engaging forces in a badly defined environment with better knowledge and by exerting military action from some distance. The combination of intelligence information with positioning and guidance data gives an inescapable edge to armed forces with access to space technology.

However, the geostrategic landscape is undergoing a total reshaping. Conflicts of diverse nature can break out with almost no warning. This new security environment calls for increasingly adaptable and flexible responses, including such capabilities as peacekeeping operations at the lower end of the combat spectrum. To respond effectively requires complete (multisensor) and intelligent information (data processing and information technology). The diversity of conflicts and the enormous amount of data needed for combat operations require space programs to interoperate increasingly with other intelligence and telecommunications means.

Different pieces of information coming from diverse sensors (space-, air-, sea-, or Earth-based) need to be merged, so that commanders and soldiers have a continuous flow of intelligence data. Space systems would provide strategic information. Indeed, among diverse capabilities, it is recognized that their permanence and the nonintrusive character of their activity reinforce their strategic value. The simple fact that satellites can be used before, during, and after a conflict definitely makes them a distinctive asset that can be used either for general long-term monitoring or for more focused and time-demanding intelligence. Complementary assets such as unmanned aerial vehicles would provide tactical information. Such means would then be devoted to the conduct of military operations with a better information-gathering capability, but on a smaller scale (theater-wide) and for a more limited period.

Moreover, the importance of continuous information flows becomes more acute in a coalition-led war, when partners have to share data coming from their own systems. This requires allies to make their information technology and telecommunications systems fully interoperable. If the partner countries overcome the technical challenges, the strategic nature of the information provided by space systems should increase mutual understanding and trust in a coalition-led war. In addition, military users of space technology increasingly rely on the integration of military space applications with civilian systems. For example, several civil telecommunications projects, consisting of satellites used for mobile or multimedia purposes, fit easily into military telecommunications systems.

In time, space applications may have a more central place in the functioning of the whole military organization. The digitization of the battlefield encourages military officers to think in terms of communications networks that link the air, naval, and ground forces, rather than to focus on traditional platforms such as aircraft, ships, and tanks. This concept of network-centric warfare suggests that space applications may be about to enter a new era, evolving into the role of a military "nervous system."

Still, many military commanders, especially in Europe, fear that excessive use of integrated information technologies during combat operations would lead to a flattening of the chain of command. These concerns do not just reflect the resistance to change usually shown by any social organization. The idea that warfighting can become more like a video game, with buttons pressed on consoles while the enemy is watched on big screens, understandably has made many nervous, leading some to question the usefulness of RMA-inspired technology. That has been the case particularly in Europe, where no full consensus has been reached about the future missions European military forces would have to perform and with awareness of the fact that any military action would be subject to political debate first. While debatable from a purely operational perspective, this reality makes any possibility to shorten the decisionmaking process seem at least as much a flaw as an advantage. New technologies imply major consequences for national military doctrines and warfighting techniques. Different assessments of the usage of information technologies in modern combat also call for cautious approaches toward any telecommunications integration process.

Existing European Space Capabilities

The controversy over the alleged presence of weapons of mass destruction in Iraq has only reinforced the feeling that a fully autonomous intelligence space system must remain at the top of the priority list in Europe.[2] Until today, Europe's space resources have relied mainly on a collection of national assets. These satellites have developed quite dramatically in two main areas: observation and telecommunications.

In the field of observation, recent history has shown how much a collective system can be envisioned considering the complementary approaches under way. The first French military observation satellite launched in the mid-1990s, Helios 1–A, was completed by a second one, Helios 1–B, launched in December 1999. Another Helios 2 series, run solely by France, with a first satellite launched in December 2004, both enlarged the nature of collected intelligence (with a supplementary infrared channel) and increased the transmission rate and volume, thus increasing the flexibility of the system.[3] This effort in optical satellites has remained strongly associated with French industrial know-how. On the civilian side, France has also decided to launch a successor program to the older Spot satellites. This program, called Pleiades, will use a 1-ton platform and will provide 70-centimeter-class imagery for civilian and military purposes. The extreme agility of the satellites increasing the performances of the Pleiades system will possibly complement the Helios data. Other national efforts include those in the United Kingdom to develop domestic capabilities based on microsatellites[4] (with a first experimental TopSat owned by the British Ministry of Defence launched in 2005); and in Sweden with the Svea project equivalent to Seosat in Spain, both offering a 2.5-meter ground resolution and both also raising some military interest.

Germany, Italy, and the United Kingdom have developed some capabilities in the field of radar techniques giving birth to recent programmatic developments. The German military SAR (synthetic aperture radar)-Lupe program led to the launch of the first German Earth observation satellite on December 19, 2006, with four more satellites in line for launch over the next 2 years. In Italy, the program for four SAR satellites, dubbed Cosmo, has also taken shape, with satellites launched over the 2007–2010 period.

While based on specific national orientations and know-how, these systems, having reached some kind of a critical mass, will finally be pooled to form the first European Earth observation architecture. Some examples, still under definition at this stage given the novelty of most of the systems, can be evoked as they have already been the subject of intense discussions and have shown relatively heterogeneous evolutions. Examples include the following:

The French Helios 2 and the German SAR-Lupe do not amount to a collective satellite system. Defense planners envisage only common use of the French and German systems. Data exchange procedures will be organized between the two systems to enrich the information gathered by both programs, and these data exchange arrangements are an important first step in the development of a collective European military space system.

The Pleiades-Cosmo project has been formed as a joint venture between France and Italy, who concluded a bilateral agreement in January 2001. The aim has been to develop a civilian space system for optical and radar imagery that could be used for military purposes. The radar segment has already come on line starting in 2007–2008 (the last of the four Cosmo satellites is expected to be on orbit in 2010), while the optical satellites are to be orbited in 2010. Pleiades-Cosmo may prove to be the real precursor of a collectively designed system at the European level and a test bed for the future replacement of national programs such as the Helios series. The increasing cost of military systems makes the success of such dual-use programs highly desirable.

In the field of telecommunications, the United Kingdom, France, Italy, and Spain have all developed national space capacities, although the scale of these efforts varies. The United Kingdom uses its own Skynet system, a constellation of three dedicated satellites with worldwide coverage for the British armed forces. In August 1998, the British government decided to develop Skynet V, a new generation of military telecommunication satellites.

Skynet V has been developed under the Private Finance Initiative, whereby the system is fully dedicated to the national authorities in times of crisis but the managing organization can commercialize the capability for the rest of the time. The Italian SICRAL–1 and the Spanish Hispasat complete the European picture, thus providing a credible capability as demonstrated by the recent selection of the trinational SICRAL-Skynet-Syracuse III architecture to form the future NATO super-high-frequency space telecommunications system.

Theoretically, other areas (such as early warning, electronic intelligence, and space surveillance) may be regarded as potential candidates for future military space developments in Europe. Nevertheless, approaching more operational issues can only raise the difficulty of squeezing out more detailed common operational requirements at the strategic and the operative levels, leading to Europe's well-known difficulty in creating a consensus for a common defense policy.

From National to European Programs?

Thinking about a European military space program raises the issue of how to incorporate different national and European systems and integrate decisionmaking procedures.

Traditionally, Earth observation is the only field with any European military space cooperation. This cooperation has been materialized since 1991 through the EU satellite center in Torrejon, Spain. Providing satellite imagery interpretation, this center has acted since 2001 as a military intelligence provider directly for the European Security and Defense Policy. The Torrejon center will benefit from any improvement made in the constitution of the European armed forces, adding gradually more military-oriented missions besides its more usual security-related activity. In particular, sensitive issues such as the sharing of intelligence data coming from existing and future national space systems during EU crisis situations involving the newly formed European forces will have to be addressed via the Satellite Center channel.

In addition to this institutional approach, the difficulties that followed for building a French-German optical/radar integrated system (called Helios/Horus at the time) have led to more detailed discussions about the common use (and even development) of military satellites. In this respect, since 1999, the governments of Belgium, France, Germany, Greece, Italy, and Spain have been working on an agreement called the Common Operational Requirements for Global European Earth Observation System by Satellites—more commonly known by its French acronym BOC (*Besoin opérationnel commun*). The aim is to define common requirements for military or dual-use Earth observation systems in the visible, infrared, and radar domains. This document is a first step toward deeper cooperation, with the objective to make future multinational agreements more durable. The BOC approach, by focusing on common requirements, differs radically from the purely financial agreements that traditionally were the essence of European space cooperation. Furthermore, the creation in 2002 of a European military imagery group called the Strategic IMINT (imagery intelligence) Action Group with military representatives from Belgium, France, Germany, Spain, and the United Kingdom led directly to the constitution of European Capability Action Plan groups that have paved the way for common operational thinking with a dedicated space group. The six-nation BOC effort is now transforming into a second step called MUSIS (multinational space-based imaging system for surveillance, reconnaissance, and observation), which is intended to specify a cooperative architecture to be running by the middle of the next decade. [5]

According to figures published in France in October 2001, the total cost of such a development scheme (including observation, telecommunications, early warning, electronic intelligence, space surveillance, and navigation) would amount to around 800 million euros annually for 10 to 15 years.[6] These figures have been contested by an expert group mandated by the European Commission (the so-called Spasec Group Report published in March 2005[7]), which more than doubled the estimate.

Even if no alternative view has been offered, these estimations remain to be confirmed, and some other calculations may certainly diverge from these figures. It will be useful in any case to carefully assess these projections and to begin to think about the total cost for the acquisition and operation of these items. This will be the only way to compare the value of investing in space rather than in other areas, helping European decisionmakers to measure the global cost of any equipment strategy. On the other hand, the cost of maintaining national capabilities will also have to be weighed compared to shared solutions involving several European countries.

A Multifaceted Military and Security Space in Europe: From Dual-use Programs to a Long-term Strategy?

Recent technological trends are making the classical distinction between civilian and military technologies more tenuous. Like most information technologies, the constant improvement of the cost/performance ratio of electronic chips also drives space applications. And progressively more space architectures can mix civilian and military space systems. Most modern military thinkers agree that armed forces are increasingly dependent on using information flows, whatever their source or nature.

The space programs needed by the future European military forces will not only have to adapt to the military national-European interfaces, as just noted, but they will also have to make increasing use of the dual technologies and systems. As can be judged from recent decisions or declarations, this latest evolution may force profound changes in national military thinking.

Two main programs currently on the European agenda—Galileo, the European navigation program by satellite, and Global Monitoring for Environment and Security (GMES), the European environmental and security monitoring program—symbolize the debate around the dual nature of many space applications. On the one hand, the member states of the European Union have a clear understanding that pursuing these projects will make their larger effort to build a coherent European political and military structure more credible. In particular, given the constant reference to "security"-type applications for these programs, including for some military uses, the political authorities will find it increasingly difficult to focus on environmental, industrial, or economic issues only without addressing more focused security issues. But on the other hand, such an evolution toward more security-related space programs may strengthen some of the national reticence to get more involved in their development.

Galileo is quite meaningful in this respect. The navigation and localization satellite program begun in the late 1990s has rapidly imposed itself at the Brussels level in the context of the U.S. global positioning system (GPS) domination. Since the beginning, the objective has always been defined to make Europe part of the precision location–related activities with the ability to master this particular technology to the fullest extent. [8] A number of studies had been published at the time demonstrating the extent to which those systems would become the backbone of a totally new activity with a wide array of possible uses in the market sector. These perspectives clearly showed how important it was for Europe to be a major actor in this area, both for political reasons—depending upon a foreign system for strategic applications was not without political significance if Europe was serious about becoming a major power—and for industrial and commercial reasons.

In its first phase, this program, called the European Global Navigation Overlay System/ Global Navigation Satellite System (EGNOS/GNSS–1), was organized in the framework of the tripartite body composed of the European Space Agency (ESA), the European Commission, and Eurocontrol (the aerial traffic certification institution) with an initial goal to augment the performances and control the integrity of the GPS. From the start, a second stage of GNSS was envisioned, GNSS–2, which was expected to provide Europe with a fully autonomous system based on a satellite constellation that would ultimately become Galileo. From the European perspective, the two principles behind the system proposed to support GNSS–2 were the satisfaction of requirements for precision, availability, and reliability compatible with life-saving activities, and ensuring that the management of the system would be administered by a completely independent civilian and multinational structure with a clear responsibility and liability for any service disruption.

After a number of differences of opinion between its member states were reconciled, Europe confirmed this position through a high-level group position expressed in 1997, while a European Commission document dated January 1998 defined all the action to be undertaken. [9] Initially, the global Galileo system had to be deployed by 2008 and required that Europe would emit experimental signals by 2006 on the various frequency bands used. In order to maintain the frequency allocations granted during the difficult negotiations of the May 2000 International Telecommunication Union World Radiocommunication Conference, it was necessary to deploy the first operational satellite before February 13, 2006. Fulfilling this task, a test bed payload was launched in December 2005, emitting its first signals on January 12, 2006. This objective, widely supported in Brussels, to put in place a complete European constellation of 30 satellites by 2008 has thus reflected a purely European self-assertive approach, with a largely publicized commercial side, besides obvious political interests.

The ambiguity of this public/civilian (even commercial to some extent) arrangement explains the bulk of the financial troubles Galileo has had. A striking feature has to do with the civilian dimension of the project that clearly legitimizes Galileo in the eyes of the Europeans, as it goes beyond the military-only controlled nature of the American GPS. In particular, the enduring possibility of the United States restricting access to users worldwide has been perceived as a severe limitation on the free use of the GPS, as has the potential (even if improbable) voluntary disruption or degradation of the GPS signal. From solely an industrial point of view, these perspectives, even if highly unexpected, were not exactly synonymous with investor trust and easy fundraising. At the European level, such characteristics have been considered a serious limitation in the free use of the GPS, especially as the European institutions had in mind the industrial and commercial applications from the start and desired to make them the primary justification for the program. Then again, two goals can be mentioned: first, to allow the European service industry to expand, and second, to make this industry a crucial part of the building of a new European-wide activity. The massive legal presence of the U.S. firms on the GPS-related services market was viewed in any case as a strongly limiting factor for European industry.[10] The figures at stake and their constant revisions were judged convincing enough to propose an autonomous system that would in return make the industries more willing to invest in it.

In 2002, the European Commission announced that "according to various studies that have been conducted, the equipment and services market resulting from the programme is estimated at around euro 10 billion per annum, with the creation of over 100,000 highly skilled jobs; conversely, if Europe misses out these new developments, many jobs would ultimately disappear in the electronics and aerospace sectors." [11] Lastly and most importantly as far as the desirability of the project for industry was concerned, a study led by the private consulting firm PricewaterhouseCoopers and based on updated projections over a period of 20 years indicated a cost/benefit ratio of 4:6, "which is higher than for any other infrastructure project in Europe," as noted by the European Commission. [12]

As a result, the civilian and commercial aspects of GNSS and Galileo have been increasingly stressed, thereby confirming the implications of the tripartite EU–ESA–Eurocontrol body in the management of the program. Both this early involvement of the European institutions and the ambiguity of the public/private arrangement may explain the bulk of the troubles Galileo has had to face recently from the financing standpoint. The financial scheme (called Public Private Partnership) envisioned by the steering institutions quoted above was based on successive public and private financing phases, implying some degree of return on investment through the commercialization of services by private entities.

At the cost of some adjustments, especially concerning the financial burden put on commercial entities, this system now has to find its balance. Public money would take the form of a European Commission payment of roughly one-third of the amount with private participation covering the other two-thirds. In spring 2001, 15 firms signed a memorandum of understanding aimed at achieving a combined private sector contribution of 200 million euros for the initial development and validation phase ending in 2007. A Galileo Joint Undertaking (GJU) based on article 171 of the European Community Treaty was adopted by the Commission in June 2001 in order to create a single management and financing structure for the program between 2002 and 2006–2007. A few aspects of the arrangements were watched particularly carefully, among which included mechanisms to avoid conflicts of interests that were the condition for the private sector participation.

In July 2004, a new GNSS Supervisory Authority (GSA) was created by the European Union Council. It became active on January 1, 2007, to replace the GJU (which ceased its own activities at the end of 2006) to represent the European public authorities during the preparation and the exploitation phase of the program. The GSA will organize the future relationships between the European Union and the private operator in charge of the actual exploitation of the program, with the particular objective to make sure that the security issues associated with Galileo are fully guaranteed.

Two main industrial groups have been formed and have competed at the European level. One group, Eurely, was composed of British, French, Italian, and Spanish firms around a core team composed by Alcatel Space, Finnmeccanica, and Hispasat, while the other group, INavSat, was built around the giant European electronic firm Thales and the other aerospace giant EADS. Confronted with two highly competitive proposals, the European commission eventually decided to promote the merger of these two groups to form a unique "commercial operator."

For the time being, all the problems related to the Galileo budgeting calendar regarding the rest of the program are not solved. On its side, industry is still considering very cautiously the unusual nature of the early investments it has to make and is urging the European public entities to provide more insurance and more details on the future budgets as well as for the first four satellites and the rest of the space and ground segment. The financing scheme envisioned by the steering institutions quoted above was based on successive public and private financing phases, implying some degree of return on investment through the commercialization of services by private entities.

European ministries of defense have not proved to be the most supportive governmental bodies of the member states. They were hardly in a position to support Galileo directly, as it was conceived as a civilian program from its inception and to its main ultimate goals. From this perspective, the enrollment of Galileo in the "Aerospace" account of the 6th Framework Programme for Research and Development [13] may have had the indirect effect of reinforcing this "civilian only" identification. Galileo could then be merely considered as an element of the global aerospace expenditures, themselves confronted with the competition from other transport budget items. As can be judged by what happened at the end of 2001, this particular position has had negative effects for the program, implying a global, even if implicit, reassessment of the "sovereignty" dimension embedded in it. This reassessment has been highlighted by the hesitations noted in Laeken in December 2001, when the transportation ministers showed themselves unable to agree on the amount of the public financing of Galileo, while its principle had been approved 3 months earlier in Edinburgh during the ESA Summit.

In many respects, this nondecision has highlighted the relative weakness of the member states' political support for the program, much beyond the usual bureaucratic resistance manifested by financially careful ministries toward a program of more than 3 billion euros. High-profile personalities, rather than states' representatives, have had to squeeze out the importance of a positive vote for Galileo and to underscore the damage that could have been caused by Europe's hesitations. Carl Bildt, the former Swedish prime minister, has blamed "the inability of successive Swedish and Belgian presidencies of the European Union to resolve fully the issues around the Galileo Project," summarizing that "the urgent need to begin dialogue with [the] U.S. on this issue, has highlighted Europe's lack of coherent policy and an effective decision making structure." Adding to this severe judgment, Loyola de Palacio, then European Transport and Energy Commissioner, declared at the time that "what we are lacking is a decision by the Governments of the European Union. The problem is not one of cost, but of [politics]."[14]

This need for a "political transcription" of the utility of Galileo for Europe has been somewhat confirmed by the mild position adopted by countries usually judged as the warmest supporters of Galileo. Again, the military side especially expressed a measured approach. European military choices are always made in the context of tight national defense budgets, and space expenditures have never ranked high on their priority list, except in the case of strictly controlled programs related to national sovereignty, such as Helios. It must be noted that the Commission in early communications has always taken care not to put aside the military dimension of Galileo:

And last but not least, Galileo will underpin the common European defense policy that the Member States have decided to establish. There is no question here of coming into conflict with the United States which is and will remain our ally, but simply a question of putting and end to a situation of dependence. If the EU finds it necessary to undertake a security mission that the U.S. does not consider to be in its interest, it will be impotent unless it has the satellite navigation technology that is now indispensable. Although designed primarily for civilian applications, Galileo will also give the EU a military capability.[15]

Obviously, attaining balance on this subject is a delicate matter in the European institutional context. By posing the question of the military use of Galileo at the end of 2001, the United States directly connected the project to the traditional Achilles' heel of the European construction process.

Significantly, the strongest reactions to what were considered as American pressure ~~s~~ to sink the project came from the European institutions. For example, Antonio Rodota, then head of the European Space Agency, affirmed that he was convinced the United States was aiming at destabilizing Galileo in order to keep a monopoly on satellite navigation activity worldwide. On her side, Loyola de Palacio exhorted the governments to keep their objectives clearly defined so they would be ready to definitively set the technical characteristics of the Galileo signal at the World Radiocommunication Conference in 2003.

As far as the U.S. (and NATO[16]) security preoccupations were concerned, they were shared by some European ministries of defense that insisted the military security aspects would obviously have to be taken into account in the management of the European system. In fact, in full compliance with those security requirements at the member states level, the structure of the service brought by Galileo is based on the existence of several types of services. One of these, the public regulated service, will rely on a highly secured and precise signal devoted to an array of governmental activities, including civil security uses or police uses. This means that Galileo will be organized by performance (according to the precision and the reliability required by type of user) rather than the way the GPS is—that is, by nature (along a military/civilian use line). Including the military uses in this wide category of public-only uses, with military standards as minimum requirements, would have to deal with a control and management structure that will be handled directly at the European level. But as mentioned above, the possible military use of Galileo remains a very contentious issue in Europe.

In any case, the global response made to the U.S. authorities about the secure management of the program was hoped to be sufficient to allay their fears in the security management domain and to stop worrying about jamming a future allied asset. Moreover, the technical possibility seems to have been successfully demonstrated that the Galileo signal would not interfere with the GPS. Moreover, the choice of frequencies close to those used by the GPS has even proven to be a prerequisite in the eyes of the ministries of defense of the member states, who insisted at the European level that Galileo would have to be interoperable with the U.S. system.

The increasingly frequent references to enlarged security requirements may help the idea of common European security and military requirements to assert itself, including in the military domain. One may have seen a first sign in this direction in the so-called Baveno Manifesto, which announced this new initiative in 1998 to deal with the need for environmental monitoring.[17] Strictly associated with environment monitoring in the first place, the notion of security contained in the official program label has rapidly been enlarged. A 1999 European Commission document changed the name of the GMES program by transforming it from "Environmental Security" to "Environment and Security." This text insisted on the security of "individuals and nations," underlining "the environment problems . . . [that] could lead to an international conflict."[18] Finally, a 2001 report by the Joint Task Force, a newly created supervising body of the EU and ESA space-related activities, reaffirmed the importance of the security component of GMES: "The security and dual use dimensions of GMES have not been adequately investigated so far [which must lead to] establish an appropriate dialog between the Directorate General of the Commission, the Secretariat of the European CFSP, ESA and relevant authorities in Member States [and] determine the future role of ESA with respect to these issues."[19] In this document, "Joint Task Force Report" refers to the Petersberg tasks, adopted in 1992, which include humanitarian and rescue missions, peacekeeping, and the use of combat force in crisis situations, including peacemaking, and which form the core of the European Security and Defense Policy.

For its promoters, GMES must be considered as a useful tool for civil security, including missions dealing with operational forecasting, hazards mitigation, damage assessment, rescue operations, and health and food problems, with some predicting capabilities. The relationship of these missions with possible military situations under the auspices of the Petersberg tasks naturally makes GMES a potentially relevant tool for the military actors or planners. Beyond the humanitarian dimension, other possible uses of GMES can also be envisioned in the field of security, in particular for a contribution to the verification of some disarmament treaties. Indeed, progress made in the field of the sensors, especially in spectral resolution (hyperspectral techniques), along with constantly improved computing techniques clearly make programs such as GMES better adapted to detect and analyze fine artifacts such as industrial effluents. It must be recalled that analyzing industrial pollution remains one of the program's primary missions related to the Kyoto protocol on global climate change. In any event, the increasing number and variety of sensors on orbit will make GMES a system that, if well supported by an adapted information structure, will contribute to an enhanced European security. Well ahead of the current planning stage of the program, these views give a political content to what remains a scientific endeavor aimed at a better European coherence in the field on the environmental security and that remains financed by the research and development budget at this time.

Considering the political sensitivity of the subject, the potential association of GMES with an ongoing European military destiny has not help to clarify the future of the program. GMES is run by the European Commission, which defined an action plan composed of a 2-year initial period started in 2001, followed in 2003 by a capacity buildup period, with an operational system envisioned for 2008. This process is collectively managed, with a relatively low-profile role for the member states. A joint EU-ESA decision in March 2002 announced the creation of a steering group composed of representatives of each state with the objective to select the national projects sent in response to the first scientific request for proposals issued by the Commission. In its very early stage and rather oriented toward pure research programs, the national answers are coordinated in the member states, which act as coordinators rather than as initiating actors. On its side, the European Space Agency appears as the most proactive institution in this project. One main task of the space agency is to bring services elements to GMES during the final capacity buildup phase, in order to lay the groundwork for receiving the data produced by GMES.

Since November 2005, so-called GMES fast track services have been endorsed at the political level for three areas: land monitoring, global maritime services, and the setting up of a dedicated information infrastructure. The goal is to reach a preoperational stage in the coming years by taking benefit from existing capabilities and resources. In addition, the GMES project also bets on its own Sentinel satellite programs. [20]

The current GMES development process shows how the strategic character of the program has not fully translated into a genuine common political involvement from the European nations in the security and defense policy, despite the efforts made by the European Commission in this direction. Given the expected difficulties to find a consensus on the security aspect of GMES, the scientific and environmental aspects of the program currently monopolize the European activity to develop a common understanding around it. In particular, the European Commission has adopted a relatively cautious approach on the subject to manage a project whose dual aspects are recognized but has not elected yet to make it an instrument of a still-elusive "collective sovereignty" in the European context.

The Path of "European Security"

Both a white paper of the European Commission issued during the autumn 2003[21] and the widely distributed Spasec Group report to the European Commission showed that a proper place should be found for the exiting actors, namely the ESA and the Commission, to allow Europe to develop a reasonable security space capability. While the European advances have definitely followed a pragmatic approach favoring the programs over, for example, collective high-level political and military thinking, it is noticeable that new conceptual efforts have been made by the commission and by the European Space Agency in the field of security since 2004.

As far as the European Commission is concerned, a new program was introduced to budget a "space and security" line for the next 7 years starting from 2007. This effort has already been prepared for 3 years by the Preparatory Action for Security Research (PASR) led by the Commission. This action, supported by a few tens of millions of euros, has identified critical areas where research and development efforts should be concentrated, including in the space area, for improving the security of the European citizen. Not only roadmapping but also real-size experiments (such as the one demonstrated in the case of the ASTRO+ project, one of the PASR projects devoted to the study of the use of space to address security situations) have consolidated views linking space and security in fields like natural and manmade disasters, the protection of critical infrastructures, or maritime surveillance. These topics should be explored more in detail under the European Union 7th Framework Program for R&D that will take place from 2007 to 2013. In total, an average of 200 millions euros should flow annually for space applications devoted to European security only. Such a program should stir new synergies, mobilize dual competencies, and provide a first genuine European political base for a more security-oriented common space program.

It is no surprise that these last years have also been the time for a more active stance from the part of the ESA on security-related issues. In particular, the issue of space surveillance has now reached a high level of priority for the agency. System architecture studies were started in 2007 and led to the adoption in November 2008 of an SSA roadmap with a first 55 million Euros spent over 3 years for preoperational studies. It is expected that a total amount of 620 million Euros will be spent on the European SSA over the next 10 years with the goal to launch the construction of a system early in the next decade. It is clear that such a project relates both to the need for Europe to have a better understanding of the vulnerabilities linked to the use of space systems and to a collective will to better assume the security of Europe at large, possibly enhancing global security by contributing to a better space surveillance system globally.

In these two areas, dramatic steps are being made by transitioning, albeit slowly, from purely national systems to shared systems. These new developments could then be seen as confirming the signs in this direction shown by the two flagship programs mentioned above, with more directly applied political decisions related to the "security of the European citizen." Besides the collective but still hesitant efforts made in the field of European military space, the nascent trend toward a possible "European Space for Security" could well be elected as a more practicable path toward a tangible European spacepower.

Conclusion

Europeans need to decide on their future military space needs. Against a background of U.S. dominance of the international space environment, how does space technology correspond to European security interests? Military space is generally twofold. Space technology comprises, on the one hand, applications directly relevant to the soldier on the ground— intelligence systems, navigation systems, and telecommunications—that can be called force application systems. On the other hand, some space systems aim at defending the orbital domain—space surveillance and antisatellite systems—that can be called space control systems.

Realistically, the "do-it-all" approach of the United States cannot be a template for Europe. Space control systems are irrelevant to the types of peace support missions that the EU aims to undertake. However, it is recognized that developing force application systems should increase the efficiency of European armed forces on the ground. These technologies are increasingly recognized as a prerequisite for future European military operations. First priorities for European space efforts will likely be intelligence and telecommunications systems.

The BOC—the European Earth observation agreement—and NATO's nascent telecommunications satellite infrastructure have shown how much progress has been made in the right direction for the last decade. These multinational initiatives will be pursued and could even extend to sensitive fields such as signals intelligence/electronic intelligence or even early warning, considering an increasing awareness of the need to better assess the ballistic threat. However, this latest issue precisely set the limitations to what may be possible from a collective standpoint in Europe. Differing political and military needs (for example, the different positions existing in Europe related to nuclear deterrence and associated needs) may make these kinds of military programs, if they have to exist, unreachable in Europe.

A second increasing perspective for Europe is to promote innovative ways of using space applications for security in the broadest sense. In this area, current efforts undertaken by the European Space Agency to set up a European architecture for space surveillance and monitoring purposes must be noticed. Such a move is in line with this enlarged security concept where, in this case, monitoring of debris or space traffic will become more crucial for promoting the development of any space activity. It is particularly true as Europe positions itself slowly at the forefront of efforts to integrate military and civilian systems into a global space architecture that would help countries deal with a wider array of security challenges. Indeed, satellites dedicated to monitoring the environment (as envisioned by the GMES program) could also be useful for dealing with other short-term threats that could range from terrorist actions to insufficiently secure industrial or armaments installations in Eastern Europe. In such cases, both civil security and military planners need access to information from more flexible and responsive space systems. The ability to exploit an increasing amount of complex data, and produce relevant information for a wider array of users, should be a priority for European space efforts. The need to integrate space programs with other kinds of sensors and intelligence-collection systems means that Europeans should develop their own system of systems. In other words, military space programs may form part of an all-inclusive European security architecture that integrates both civil and military systems and space-based and non–space-based technologies. This is the only way to make a complete European space system palatable for cash-strapped finance ministries.

Whatever the solution, the two prerequisites for the future of European military space are to make the most of new technologies and to decide how to manage future security needs at the European level. Showing a possible way to enhance security and help Europe be a more capable security partner on the global scene, the notion of a European spacepower that would help solve these larger political issues could then legitimately take shape.

Notes

1. As presented in the most common budget analysis comparing the supposed space military budget in the United States of around $20 billion, as mentioned in Patricia Figliola Moloney, *U.S. Military Space Programs, An Overview of Appropriations and Current Issues* (Washington, DC: Congressional Research Service, August 7, 2006), 2. This U.S. amount is compared to the remaining world budgets comprising the European military space budgets (of around 950 million euros in 2005); see the French Parliamentary Report by Sen. Henri Revol and Rep. Christian Cabal, *Politique spatiale, l'Audace ou le Déclin* (Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques, Assemblée Nationale, Paris, No. 3676, Sénat, No. 223, February 7, 2007), 150, and the estimated Chinese, Indian, and Russian budgets (still kept relatively secret) devoted to this activity, 26–34.
2. This episode has more or less comported with a number of national decisions that were made before, sometimes for the same reasons. In particular, the German decision to develop autonomous military SAR satellites was made in the context of the Kosovo war, with a strong desire to gain a better view on Central Europe by itself. Italy, with its SAR satellite Cosmo series, and the United Kingdom, with a renewed interest in Earth observation satellites, have also fed this trend. The quest for autonomy has spread far beyond the European borders, with Japan getting equipped with its own spy satellite in March 2003: "Japan Questions Reliability of U.S. Security Info," *The New York Times*, July 3, 2002.
3. Another Helios 2 satellite was planned for launch in 2008.
4. See the United Kingdom Future Air and Space Operational Concept, available at <www.raf.mod.uk/downloads/documents/fasoc.pdf>.
5. On this and associated issues, see French Ministry of Defense, "Let U.S. Make More Space for our Defence: Strategic Guidelines for a Space Defence Policy in France and in Europe," Paris, February 2007, available at <www.defense.gouv.fr/defense/focus/donnons_plus_d_espace_a_la_defense__1>.

6. Brigadier Général Daniel Gavoty, *L'espace militaire, un projet fédérateur pour l'Union Européenne* (Paris: Défense Nationale Review, October 2001), 79–96.
7. European Commission, *Report of the Panel of Experts on Space and Security* (Brussels: European Commission, March 2005), available at <http:/europa.eu.int/comm./space/news/article_2262.pdf>.
8. It must be noted that other concurrent efforts were under way in the area of the so-called augmentation system, such as in Japan with the Multifunctional Satellite Augmentation System, or in the United States with the parallel development of the Wide Area Augmentation System for civil aviation use in liaison with Canada.
9. European Commission Communication, *Towards a Trans-European Positioning and Navigation Network*, January 21, 1998. Estimated at the time around 3.2 and 3.4 billion euros, the project was later judged to be the "equivalent to the cost of building 150 km of semi-urban motorway or a main tunnel for the future high-speed rail link between Lyon and Turin—assuming that the tunnel only has one track" as remarked by the European commission in an information note.
10. As a RAND Corporation Report noted in 1995, "The relative breadth with which U.S. GPS inventions are protected around the world provide a competitive advantage to U.S. companies." Giving an example, the RAND Report remarked also that "while Japan has conducted R&D and has exploited GPS internationally, it has not protected its GPS inventions as broadly." RAND Corporation, *The Global Positioning System: Assessing National Policies* (Santa Monica, CA: RAND Corporation, 1995), 117.
11. European Commission, Directorate-General for Energy and Transport, *Galileo: The European Project on Radio Navigation by Satellite*, March 26, 2002.
12. Ibid.
13. The Framework extended through the end of 2006.
14. Carl Bildt and Loyola de Palacio, as quoted in *Satellite News*, January 21, 2002.
15. European Commission, Directorate-General for Energy and Transport, March 26, 2002.
16. Robert Bell, former advisor for strategic negotiations to President Bill Clinton and then NATO Assistant Secretary General for Defence Support, confirmed, "NATO has not taken a position either for or against Galileo. . . . That said, NATO does have a very clear interest in making sure that, if Galileo is eventually deployed, it does not interfere with or impair NATO's access to the significant military advantage afforded NATO forces and that NATO is able, if required, to deny a potential adversary's access to the satellite positioning services available from any *other* satellite navigation services during a conflict." In this respect, and fully in line with the U.S worries, the necessity to be able to jam Galileo stemming from a supposed lack of security guidance due to the "civilian" character of Galileo has been mentioned. R. Bell, "GPS and Galileo—Capabilities and Compatibility," address at European Satellite for Security Conference, Brussels, June 17–18, 2002.
17. *Global Monitoring for Environment and Security: A Manifesto for a European Initiative* (ASI, BNSC, CNES, DLR, EARSC, ESA, Eumetsat, European Commission), 1998.
18. *Global Monitoring for Environment and Security* , *Space Advisory Group 99/3*, European Commission, December 7, 1999.
19. *Joint Task Force Report* , September 2001.
20. These Sentinel satellites will be regrouped in four families: c-band radar satellites (Sentinel-1) to be orbited between 2008 and 2010; high spectral sensitivity satellites (Sentinel-2) also envisioned for launch during the 2008–2010 period; maritime surveillance satellites (Sentinel-3); and atmospheric satellite satellites (Sentinel-4 and -5).
21. Available at <http://europa.eu.int/comm/space/whitepaper/index_en.html>.

Chapter 26:

Emerging Actors

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The world of the 21st century is radically different from that of the previous century. As the new century approached, the world appeared to be a much more uncertain place. The traditional balance of power has been dramatically disturbed. Accelerating technology catalyzed economic change as new nations and international corporations competed in the interconnected global marketplace. The dramatic advances in information technology united and empowered transnational peoples and ideologies beyond the constraint of any single government. Where global powers had faded, new regional powers arose with the potential for influence in the new global economy and information grid.

Spacepower as an Instrument of Global and Regional Influence

As many nations and states reconstitute[1] themselves in this new century, they pursue spacepower to help achieve their economic, political, and cultural objectives. While the traditional powers long ago developed routine space capabilities and operations of vital importance, many nations are now only beginning to add such capabilities to their repertoire of national power. In doing so, they have applied innovative, frugal, and cooperative approaches. Spacepower fits naturally within the goals and ambitions of emerging powers. Economic strength is very dependent on information technologies: this includes collecting information on geography and environment and in communicating information and political messages. Thus, the growing interest in spacepower derives from growing economic aspirations and political influence, and this will unsettle the balance of power of the formerly unchallenged global leaders. Therefore, it is instructive to consider how new and emerging space powers, referred to in this paper simply as *emerging space powers*, are using space to achieve their aims, especially as they build alliances with the established space powers on one hand and, on the other, with neighbors who do not yet have access to spacepower but want to acquire it.

As less developed nations grow in economic, military, and political might, the existing balance of power will be threatened and possibly weakened. Regional rivals will emerge where global superpowers formerly dominated, and new conflicts and tensions will arise. It is quite likely that the increasing activity of spacefaring nations will make space less secure in the near term. Already, certain states and transnational groups have engaged in the jamming and hijacking of satellite communications, intent on blocking or broadcasting propaganda and strategic messages. Yet once the spacepower of these emerging actors is integrated into the security apparatus of strong international partners, the peace and security of the world should be significantly enhanced.

As the United States considers the application and evolution of spacepower as part of its overall strategic influence and leadership, it should beware of challenges to its preeminence in space and should seek opportunities for beneficial cooperation. Many other nations are eager to engage the United States in diplomatic, economic, and cultural affairs, and space is an attractive tool with which to do so.

Higher Aspirations Abroad

The United States primarily thinks of security in terms of threat warning and force projection. These are very important functions, of course, and derive from our Cold War heritage, which is why many of our space systems have been highly classified systems. However, most of the world's spacefaring nations pursued space initially from commercial and civil interests and more recently have been extending their application to meet security needs. This encompasses a much broader spectrum of activities than the U.S. space security community typically addresses and offers many more options for fostering international cooperation, strengthening alliances, and building common interest in foreign affairs.

Space technology, and technology in general, is powerful in effect, but it is not inherently dangerous. [2] More importantly, space technology is now pervasive around the world. Any security strategy that relies on denying an adversary access to technology must be recognized as being unrealistic and doomed to failure. The existing space powers, with the notable exception of the United States,[3,4] openly leverage their spacepower through international cooperation and engagement to further their economic interests and national security. The international space market is a bazaar of opportunities for emerging space powers to buy, sell, and barter important space goods and services to advance their national interest.

To underscore this point, consider the International Space Station project with participants from the United States, Russia, Canada, Japan, and the European Space Agency (ESA). This is by far the most immense international space project, with a cumulative budget approaching $100 billion. Its appeal is prestige on the world stage. China aspires to join, as does recently emerging space power India, but so far continues to be excluded. Emerging space powers are eager to provide an astronaut, who then generally becomes an important icon in their homelands, inspiring their youth to excel in technical studies. Participation in the program represents the cathedral of prestige, not the bazaar of everyday trade where the more pragmatic space applications are quietly being developed and traded within the international community of existing and emerging space powers. [5]

We are beginning to see interesting examples of where emerging space powers are bumping up against established ones and their emerging regional neighbors. Japan, concerned about military developments in North Korea, has launched its own reconnaissance satellites suitable for collecting high-resolution images. This has alarmed the North Korean government, which calls these actions aggressive. On August 31, 1998, North Korea launched what was believed to be a ballistic missile test; Pyongyang later announced it had attempted its first satellite launch. Israel has become rather expert at producing small, lightweight optical imaging systems for satellite missions. The United Arab Emirates is seeking bidders for its own civil-military communications satellite. Iran has been accused of jamming commercial communications satellites that were broadcasting allegedly seditious programming produced by Iranian expatriates in the United States. Canada has become the world's leader in many robotic and autonomous space technologies that could be used in space control satellites. A number of smaller nations have collaborated with Surrey Satellite Technologies of the United Kingdom to learn how to build and operate small satellites. China, Russia, and European nations actively seek out cooperative space projects with each other and with developing nations. India has developed its remote sensing capabilities to such sophisticated levels that it now sells data for environmental monitoring and land management to nations around the globe, including the United States.

What is important in these events is that along with the dangerous ambitions of some developing nations to have nuclear weapons and ballistic missiles, emerging nations also recognize the strategic and pragmatic value of being a space power. North Korea, Iran, and Israel—like many other countries—are interested in exploiting the dual-use nature of space for economic, civil, security, and international affairs.

It is difficult to accurately assess the total spending for national space programs, but table 26–1 estimates the approximate level of investment for the world's space programs.[6] The estimates are based on civil space spending (not including dedicated military space spending by the United States, Russia, and China). For the remaining countries, which have dual-use space programs, the estimates also include spending on security-related applications of their space capabilities. Limited funds mandate that emerging space powers selectively prioritize modest but effective space capabilities to serve their national interests.

Table 26–1. Estimated Budgets of Leading Space Powers

Nation	2008 Budget (USD millions)	Space Launch Capable
United States/National Aeronautics and Space Administration	17,300	Yes
European Space Agency	4,270	Yes
Japan*	3,500	Yes
China	1,700	Yes
Russia	1,540	Yes
France	970	Yes
Italy	910	
India*	860	Yes
Germany	440	

South Korea*	250	In development
Canada*	250	
Brazil*	130	In development
United Kingdom	80	
Israel*	80	Yes

* = emerging space power

It is helpful to consider space powers based on their regional dynamics and based on the level of space capability. Table 26–2 outlines a geographic region versus level-of-capability matrix. The established space superpowers include the United States, Russia, ESA, and China and are shown on the first tier of the matrix. The emerging space powers can roughly be grouped into categories based on level of capability: expanding space powers, emerging space powers, and emerging space users. Finally, the bottom of the matrix shows a tier of space-enabling entities consisting of commercial Internet companies and commercial space companies that are making the rudiments of spacepower products and services affordable and pervasive.

Table 26–2. Space Powers: Geographic Region versus Level of Capability Matrix

	Americas	Europe	East Asia	Middle East/Africa	South Asia
Global and Spacefaring	United States	European Space Agency	Russia China		
Expanding Space Powers			Japan		India
Emerging Regional Space Powers	Canada Brazil		South Korea	Israel Iran	Pakistan
Emerging Space Users	Chile Venezuela		North Korea	Turkey Saudi Arabia Nigeria	
Space Enabling	Google Earth (as a proxy for the commercialization of cyber-space-power)				

What do the emerging space powers have to tell us about spacepower? Through necessity, they pursue innovative approaches that may prove novel or even contradictory to standard practices of the few established space powers, and thus provide interesting case studies in the fuller understanding of spacepower theory.[7] An interesting historical analogy can be used in this regard. The Space Commission report of 2001 referred to the impending threat of a "space Pearl Harbor"[8] where a complacent U.S. space infrastructure was vulnerable to a dramatic first strike by a peer competitor. A different analogy has been suggested: we may be more likely to experience a "space Shays' Rebellion," analogous to the early years of the United States, where dissatisfaction with the Articles of Confederation led to a new Constitution that better fit the diverse needs of the burgeoning national political and economic tableau.[9] A brief survey of the diverse activities of emerging space powers will give us insight into the dynamics of spacepower as they employ it, and at the same time point out opportunities for the established space powers to better engage with emerging competitors in support of national goals and interests.

Emerging Spacepower's Upward Trajectory

The Americas

The dynamic in the Western Hemisphere is dominated by the United States and its space capabilities. North America is stable and technologically advanced, while South America is aspiring to catch up to the modern, high-tech economies of the more developed nations. In North America, Canada has excelled in several niche technologies for space applications. In South America, Brazil leads the way with a fairly mature aeronautics enterprise, but with disappointing progress thus far in space.

Canada. Canada has excelled in remote sensing with its Radarsat program that provides all-weather, day-night imaging capability. With a resolution of about 10 meters, the Radarsat-1 system is applicable for land-use studies, but not for the high-resolution images needed for many intelligence and military functions. In December 2007, Canada's Radarsat-2 follow-on was launched to orbit; it provides an improved 3-meter resolution capability and adds some security-quality applications to commercial and civil uses.

Canada also excels at space robotics, having built the robotic arm for the U.S. space shuttle and the International Space Station. Canadian participation in the September 9, 2006, space shuttle mission to the International Space Station included an astronaut, the deployment of the extension to the Canadarm robotic arm on the International Space Station, the attendance by the Canadian ambassador to the United States at the launch ceremonies, and a significant public relations program broadcast throughout Canada as they enjoyed the national pride of their significant contributions.

Canadian industrial vendors were selected to provide critical robotic technologies for the National Aeronautics and Space Administration's (NASA's) Hubble space telescope repair missions, including the final servicing mission completed in May 2009. They provided robotic manipulators for the Defense Advanced Research Projects Agency's Orbital Express satellite servicing experiment. And they provide a miniaturized laser range finder that the Air Force Research Laboratory used on its XSS–11 space rendezvous and autonomous proximity operations experiment.

That Canadian technical expertise in autonomous space operations and manipulation are best in the world should astound national security specialists. These technologies are critical elements of any potential on-orbit space control system. Such systems are often attributed to alleged U.S. space weapons programs. In fact, these technologies are not only readily available from Canada, but also the premier space organizations of the U.S. Government chose Canadian technology over that provided by U.S. developers.

The Canadian Ministry of Defense also is pursuing a small satellite called SAPPHIRE, a microsatellite weighing approximately 130 kilograms, to scan the skies for space objects and contribute data to the U.S. space object catalog. This would be a contribution under the North American Aerospace Command treaty.

In August 2008, Canada's leading aerospace company, MacDonald, Dettwiler, and Associates (MDA), successfully placed into orbit a constellation of five microsatellites call RapidEye for their customer, RapidEye AG in Germany.[10] RapidEye provides multispectral data suitable for land use assessments, and with the rapid revisit rates of the five microsatellites, the constellation provides extraordinarily large area coverage (up to 4 million square kilometers per day) or provides rapid revisit. This rate makes it quite useful to detect changes in ground coverage, albeit on a 6-square-meter scale, that is useful for security purposes. Indeed, RapidEye AG, has recently signed an agreement with a U.S. company to resell the data in the U.S. market to defense, intelligence, and homeland security customers. RapidEye AG had earlier signed an agreement with Sovzond JSC of Moscow as the distributor of its data to the Russian government. This is an example of innovative collaboration between regional emerging space powers to provide a useful, affordable product to existing global space powers.

The current outlook in the Canadian space program is somewhat ambivalent: while it enjoys participation with the U.S. space program, it also increasingly chafes under U.S. control and interference. Canada's ability to do international business in the space sector is frequently complicated and challenged by U.S. export control regulators. A feeling of frustration is now motivating Canada to pursue stronger collaborative agreements with nations other than the United States.

Recent attempts by U.S. corporations to buy MDA and its Radarsat product line have caused the Canadian government to examine the importance and cost of its spacepower ambitions. This introspection has led to the emphatic declaration that Canadian investment in space capabilities will remain in Canadian hands.

Brazil. Despite having a world-class aeronautics capability with the Embraer corporation,[11] Brazil has struggled to develop its space industry. As early as 1964, Brazil began development of the Sondra series of sounding rockets. Construction of their Alcântara launch site began in 1982. Alcântara is only two degrees south of the equator and provides ideal energy efficiency for launch into geosynchronous orbits. Brazil's first launch from Alcântara occurred on February 21, 1990, with the sounding rocket Sonda 2. Unfortunately, on August 22, 2003 the explosion of the developmental VLS space launcher on the launch pad killed 21 people. In a courageous and determined effort, Brazil was able to follow this disaster with a successful suborbital launch into space in October 2004.

Brazil is looking to leverage its ideal equatorial launch site location by providing commercial launch base services from Alcântara. In 2003, contracts were signed to launch the Ukrainian Tsyklon-4, with discussions under way with Russia, Israel, and China to use the site.

The Brazilian space program was transferred to the newly created Brazilian Space Agency in 1994. While the Alcântara launch site is operated by the military, there are plans to build a neighboring facility specifically for Brazil's civilian space agency. Brazil is also developing an indigenous satellite manufacturing capability, most often working closely with the United States. Difficulties over missile launch technology export controls led the Brazilian space program to expand cooperative activities with the French space program, and additionally, to recognize the benefits of signing on to the Missile Technology Control Regime in 1994.

Brazil's first satellite, an environmental data collecting satellite, was put into space in 1993 using the Orbital Sciences Corporation Pegasus commercial launch vehicle. A second data collecting spacecraft was placed into orbit in 1998, also by a Pegasus. Thus, Brazil is making progress on developing spacecraft manufacturing capability, while its launch vehicle capability has so far made only modest progress.

In the meantime, Brazil has been cooperating with other spacefaring nations to leverage foreign technology. Brazil has been working with China to operate remote sensing satellites for land use and environmental monitoring. The first satellites, China-Brazil Earth Research Satellite (CBERS)–1 in 1999 and CBERS–2 in 2003, were built and launched by China; select data is now shared with Brazil, and operation of the satellite was turned over to Brazil 2 years after initial operations. Subsequent satellites called Earth Resources Satellite-02B and CBERS–3 will be coproduced by Brazil, helping to mature their indigenous satellite manufacturing capability.[12] More recently, Brazil has reached an agreement with the French national space agency, CNES, to codevelop a Brazilian design of a small satellite bus. [13]

Chile. The unique geography of Chile as it drapes along the great length of the Pacific coast of South America is a natural fit with space-delivered capabilities. Chile has pursued cooperative military space projects with the United States for reconnaissance capabilities, but the United States has been reluctant to cooperate. In 2007, the Chilean defense minister was considering a solicitation for Chile's own Earth observation satellite.

Venezuela . Venezuela is most notable as an emerging spacepower user in that its oil resources make it attractive to existing space powers eager to trade space capabilities for access to oil. Venezuela is considering the purchase of a communications satellite from China for indigenous communications services. This agreement is likely part of a portfolio of activities related to China's interest in securing access to Venezuela's oil supplies.

East Asia

There is a new space race developing in Asia between China and India. It is not yet global in scope, as was the first space race between the United States and the Soviet Union, but rather a race for regional influence. For the most part, these programs have been very pragmatic and measured. But there have been recent signs of grander ambitions through space exploration programs. This competition will attract other nations in Asia and around the world to posture for opportunities to cooperate and build common interest with China and India. In East Asia, Japan is a well-developed space power expanding into space security applications, and South Korea is using space to complement its diverse and ambitious push into high-technology infrastructure and commerce.

Japan. A survey of these nations begins with the already established but expanding space power of Japan. It has had indigenous launch capability, has built its own telecommunications satellites, and has participated in international human spaceflight programs. What is emerging is a willingness to deploy space systems to aid its national security.

Japan has continued to develop its space launch capability for commercial and civil purposes. The H–2 launcher and follow-on systems provide significant launch capability. Japan's efforts have been closely tied to participation in civil space exploration with NASA and other civil space agencies. Participation in military space activities is prevented by national law, but the test launch by North Korea in 1998 of a missile that traversed Japanese territory catalyzed the Japanese government to begin a reconnaissance satellite program for national security purposes. Japan first launched its own reconnaissance satellites suitable for collecting high-resolution images for intelligence purposes in March 2003. This has alarmed the North Korean government, which calls these actions aggressive.

Nonetheless, Japanese national security space activities continue. The information gathering satellite K2 was successfully launched September 11, 2006, by an H–2A rocket from the Tanegashima Space Center and will provide 1-meter imaging capability. Japan most recently launched an electro-optical imaging satellite in September 2006 and a radar imaging satellite in February 2007.

Besides remote sensing for reconnaissance purposes, Japan has taken steps to expand the security dimension of its space policy:

> On May 21, 2008, Japan's Basic Law of Outer Space was passed, for the first time allowing the country to use space assets for defensive military purposes. The bill modified the Japanese interpretation of using space "for peaceful purposes only." The new interpretation conforms with policies of other spacefaring nations and will allow Japan's government to develop

> military satellites for defensive purposes. In addition, the new law will place all space-related projects into a unified program for better coordination.[14]

The most recent launch by the North Koreans on April 5, 2009—alleged by their government as a peaceful space launch—managed only to reenter far out in the Pacific Ocean after passing over Japan. Despite widespread international outrage and calls for action against North Korea, none have been taken thus far. In June 2009, Japan approved plans to develop its own missile warning satellites.

Japan, long the sole space power in East Asia, now has rivals. It will be interesting to see how the Japanese realign their cooperative space activities as the Chinese and Indian space programs become prominent in the region.

South Korea. In the aftermath of the Korean war and the treaty that led to the division of Korea into northern and southern states, the Republic of Korea has achieved an amazing transformation from one of the world's poorest countries to one of the leading high-tech economies featuring bullet trains, new superhighways, and extensive broadband network infrastructure.[15] South Korea competes economically with the two dominant regional and global economies of Japan and China. It also has the significant security concern of an unpredictable and sometimes menacing North Korea apparently intent on developing nuclear weapons and ballistic missile delivery systems, along with an asserted space program.

South Korea has invested significantly in space technologies as a means in itself and as a way to inspire a high-tech workforce. [16] The space program is under the purview of the Ministry of Science and Technology and is managed by the Korean Aerospace Research Institute. South Korea plans to increase its space budget from $250 million to $500 million. With a gross domestic product per person about half that of the United States and other leading developed nations, their budget is approaching $1 billion in effective value. South Korea has already built over 10 satellites, mostly microsatellites, but with increasing size and capability as they continue to develop. South Korea soon plans to launch the Arirang-3A, a military and civilian dual-use, high-resolution satellite with optical and infrared imaging capabilities. This follows the launch of the Arirang-2 on July 28, 2006. The Arirang satellite series, also known as the KOMPSAT series, provides images with 1-meter ground resolution or better, suitable for reconnaissance purposes, which is especially important to the South Koreans to provide transparency into military capabilities and operations in North Korea. South Korea previously relied on high-resolution imagery from the United States, but continues to pursue an indigenous capability.

South Korea also has purchased a multipurpose communications, oceanography, and meteorology satellite, COMS–1, from EADS-Astrium in Europe. The spacecraft is intended to be launched to geostationary orbit on an Ariane 5 booster and will provide South Korea with communications connectivity and awareness of ocean environment monitoring that will be useful for commercial fishing and weather forecasting.

To date, the South Koreans have launched their spacecraft on commercial launch vehicles of other countries, most notably Russia. To develop indigenous launch capability, the South Koreans are building a launch complex on an island off the south coast of the mainland. The new Naro Space Center is intended to launch the KSLV–1 launch vehicle beginning in the summer of 2009. The vehicle will be capable of launching 100-kilogram microsatellites into low-Earth orbit. Although of limited capability, it would provide needed reconnaissance and environmental capabilities in an affordable manner.

The South Koreans are also pursuing human spaceflight through cooperation with the Russian space program. South Korean spaceflyer So-yeon Yi arrived at the International Space Station on April 8, 2008. Despite the cost effectiveness of cooperating with the Russian space program, the Koreans have been actively pursuing a closer relationship with the U.S. space program and NASA. The Koreans have designed a number of experiments that could be flown on the International Space Station and have approached NASA in hopes of an agreement to have U.S. astronauts operate the experiment on board.

The South Koreans have recently obtained formal agreements with NASA to explore cooperative activities. Seoul signed an agreement with NASA in late 2008 to boost cooperation in space science and exploration.[17] Although earlier engagements with NASA met with limited results, this recently signed agreement had its impetus in a high level of engagement by South Korean president Lee Myung-bak, who held summit talks with U.S President George W. Bush.[18]

North Korea . For some years now, all eyes have been on North Korea and its development of nuclear weapons and ballistic missile systems. However, on August 31, 1998, something unexpected happened. After the launch of what was at first believed to be a ballistic missile test, North Korea announced the launch of its first satellite. Despite these claims, no foreign observer ever confirmed that North Korea had in fact launched a satellite to orbit. While the success of the alleged space launch is doubtful, the attempt was plausibly real.

Another alleged space launch in April 2009 on a Taepodong-1 missile resulted only in the splashdown of its payload far out into the Pacific after again flying directly over Japan. This event caused quite a bit of alarm in Japan, the United States, and many other nations. Despite calls by many for severe consequences for the antagonistic launch, the international community and the United States have yet to take any action, and it is not clear that they would be fully justified in doing so. It was, after all, according to the North Korean government, a space launch attempt for peaceful purposes.

As international attention focuses on the threat of North Korea's nuclear weapons program, and especially their delivery vehicles, this will likely discourage other nations from cooperating with them on space capabilities. While North Korea appears to be exercising its fledgling spacepower with only a phantom space program, it is not clear that this is a sustainable strategy or how the international community can best address these provocations.

South Asia

India is in many ways the most interesting emerging space power. While its entry into space is not recent, its patient approach has reached a point of critical mass at which it has begun to reshape the regional balance of spacepower in Asia. Pakistan's modest efforts in space are insufficient to challenge India's dominance, but enough to complement Pakistan's nuclear arsenal as a check against Indian hegemony. India also provides some of the most interesting opportunities for space cooperation with the United States. Similarly, partnering with the U.S. space program provides India with opportunities for more ambitious space exploration activities than they could afford on their own. In light of this reciprocal opportunity, the U.S. and Indian space programs take a central place in each other's international space partnerships. [19]

India . India's space research efforts began in the 1960s and were mainly within the Soviet sphere during the 1970s and 1980s. They launched their first satellite in 1975. The overall approach of the Indian space program is very pragmatic and focuses on national communications, enabling educations, and remote sensing for agricultural and environmental concerns. India is beginning to commercialize its launch capability, including a recent agreement to launch an Israeli reconnaissance satellite. It is actively pursuing microsatellite technology for low-cost space missions. A lunar orbiting mission, Chandrayaan, was launched in October 2008 and began India's participation in the new space exploration efforts of the United States and other countries.

While the focus of the Indian space program is to provide benefit to its people, India also intends to use its space program as a tool of foreign policy. In the January 2004 agreement between the United States and India, the presidents of the two countries stated their intentions to strengthen and expand cooperation. This explicitly included participation in civil space cooperation. The new strategic partnership between the United States and India has the potential to be the turning point around which a new geopolitical balance of power might form. A key element in this partnership—U.S.-India space cooperation—will most likely become a defining relationship for space cooperation around which other spacefaring nations will posture their international space cooperation strategies. The central position of India in the Asian continent, its burgeoning economic growth, and its wealth of human capital will be crucial assets in achieving U.S. objectives in space and in broader objectives in global security.

The Indian space program is considered to be the fifth largest, coming in behind the United States, Russia, Europe, and China. Their annual budget is about US $675 million, and given their relatively low-cost workforce, this is equivalent to a multi-billion-dollar program in more developed nations such as the United States, France, or Japan. India's first satellite in 1975 provided communications to remote parts of the country on an experimental basis. Continuing a very pragmatic approach, this was later followed by remote sensing and weather satellites. Through buying foreign technology where needed and pursuing a parallel path of developing indigenous space technology, India's space capability has grown steadily over the years.

The Indian space program is very much a government-executed program, but the government has begun to build a private sector industrial base. In 1992, the Indian Space Research Organization (ISRO) established the Antrix Corporation Limited for the global marketing and sales of Indian remote sensing satellite data. In anticipation of cooperation with the United States and other nations in both civil and commercial space activities, ISRO has made efforts to increase security and access controls at its various facilities to comply with anticipated requirements of export control regimes.

India has developed two primary launch vehicles. The Polar Space Launch Vehicle (PSLV) can launch a 1,500-kilogram payload to 600-kilometer polar orbits. Thus, the PSLV is ideal for launching remote sensing satellites. The PSLV–CA launch of April 2009 marked the twelfth consecutive operational launch of the vehicle. Previous PSLV payloads have included 10 small satellites deployed from one launch in April 2008; the Chandrayaan lunar probe; six Indian remote sensing satellites to polar orbit; a meteorological satellite, KALPANA–1, to geosynchronous orbit; as well as a wide range of small satellites from other states including Germany, South Korea, Belgium, Indonesia, Argentina, Italy, Israel, Japan, Canada, the Netherlands, Norway, Switzerland, Turkey, Singapore, and France.

India has been developing a more powerful launch vehicle configuration for access to geosynchronous orbits. The Geosynchronous Space Launch Vehicle (GSLV) is derived from the PSLV central core with additional liquid-propellant strap-on boosters and a cryogenic upper stage. Following the second successful test flight of the GSLV Mark I in 2003, India is now one of six countries able to launch a 2,000-kilogram satellite into geostationary orbit. To reach geosynchronous orbit, the GSLV relies on an upper stage vehicle powered by a Russian RD56M cryogenic propulsion system.

The joint agreement that enabled the Indians to purchase the formerly Soviet propulsion system was temporarily sidetracked after the dissolution of the Soviet Union in 1991. The GSLV project also ran into problems when the United States imposed sanctions against India over nuclear technology proliferation concerns. In the last few years, cooperation with the Russians has resumed, and U.S. sanctions have been relaxed. In the interim, however, India had entered into a program to develop an indigenous cryogenic upper stage. That work is nearing completion, and the first flight of the new upper stage was expected in July 2009.

The principle focus of the Indian space program has been to provide communications and broadcast capabilities where land-based infrastructure has not yet reached remote regions. The Indian National Satellite System (INSAT) is a series of satellites to deliver satellite communications. The latest of these, INSAT–4A, was launched in December 2005 aboard an Ariane launch vehicle into geosynchronous orbit. India has great interest in using satellite communications to support its national education initiatives:

EDUSAT is the first Indian satellite designed and developed exclusively for serving the educational sector. It is mainly intended to meet the demand for an interactive satellite based distance education system for the country. It strongly reflects India's commitment to use space technology for national development, especially for the development of the population in remote and rural locations. [20]

While developing its indigenous capabilities, India continues to pursue international commercial markets for special capabilities. The Antrix commercial arm of ISRO recently teamed with Astrium Satellites of Europe for small telecom satellites, which in many cases provide affordable capability right-sized for a niche market application. ISRO earlier approached the Boeing Corporation in the United States, but discussions collapsed due to U.S. technology transfer concerns.

India is also exploring means to use satellite communications to augment existing navigation systems. Wide-area augmentation schemes use existing satellite navigation signals, such as from the Global Positioning System or the future Galileo system, and provide corrections based on fixed ground locations. These corrections can then be broadcast over any satellite communications system to provide improved accuracy to satellite navigation users. India is also planning on deploying their own dedicated navigation satellites using rubidium atomic clocks purchased from the French company SpectraTime. These satellites will provide regional augmentation for navigation in conjunction with existing global space-based navigation systems.

The Indian remote sensing satellite system began with the launch of its first satellite in 1988. It consists of a series of remote sensing satellites for imaging, cartography, natural resource mapping, meteorology, and oceanography. This system has been modernized to the present series of satellites. RESOURCESAT–1 was launched into polar orbit in 2003 and carries a suite of multispectral sensors in the visible and near-infrared suitable for land-use and resource studies. The system provides 5-meter-resolution Earth images in 3-color mode and 2.5-meter-resolution Earth images in monochromatic mode. CARTOSAT–1 was launched in May 2005 into a polar orbit and carries two panchromatic imaging cameras, each with 2.5-meter resolution. The stereoscopic imaging by the two cameras facilitates the construction of three-dimensional terrain maps. CARTOSAT–2 was launched in January 2007, and CARTOSAT–2A was launched in April 2008; these satellites feature imaging resolution of less than one meter. ISRO has also developed its first radar imaging satellites to provide the capability to image day or night and through cloud cover; RISAT–2, built with Israeli assistance, was launched in April 2009. Although primarily intended for civil applications, these optical and radar imaging capabilities will provide militarily useful images and could be made available to Indian security and defense forces.

While India has always explored space science as part of its space program, this has definitely been a lower priority than the practical applications of space. Nonetheless, India continues to expand its space science activities as part of the overall expansion of its space program. This area provides a low-cost opportunity for cooperation with other countries to explore space technologies with potential dual-use applications.

The most exciting developments in space over the last few years have been the new initiatives in space exploration announced by the United States, China, the ESA, and

India. In 2004, the United States adopted a new vision for space exploration in the aftermath of the space shuttle Columbia disaster. In 2003, China launched its first manned mission into space and announced plans to eventually explore the Moon.

The Indian lunar mission, Chandrayaan-1, was launched into space on October 22, 2008. This was an historic first for India's space program and marked an important milestone in their space exploration efforts. Chandrayaan-1 provides high-resolution scientific data in the visible, near-infrared, X-ray, and low-energy gamma-ray spectrum that is being used in mapping the constituent materials and potential resources on the Moon and could later be helpful for planning human lunar exploration. The Indians had invited international participation on the Chandrayaan-1 mission and had signed agreements with NASA and ESA to participate by providing scientific payloads on the spacecraft. India has a long-term interest in pursuing lunar exploration and is eager to pursue international cooperation in this field of endeavor.

Oddly, despite establishment of a joint working group on civil space cooperation and other efforts to improve U.S.-India space cooperation, the United States has not taken the initiative to specifically include India in human spaceflight partnership, neither on the International Space Station nor in human missions to the Moon. Understandably, ISRO has obtained a commitment of assistance from the Russian space agency Roskosmos in developing an indigenously built Indian space capsule.[21]

While the focus of the Indian space program is providing benefit to its people, India also intends to use it for foreign policy purposes. This explicitly includes participation in commercial and civil space. India is anxious to commercialize its launch capability, already completing an agreement to launch an Israeli reconnaissance satellite. India has signed up to participate in the European Union Galileo satellite navigation mission. This is in parallel with its efforts to participate with the United States on the Global Positioning System. India would seem to be hedging its interests in the area of global satellite-based navigation. They are also participating in the Global Earth Observation System of Systems, a multinational coalition of over 60 nations established in 2004 to share environmental data. This will allow India to leverage its space-based meteorology, oceanography, and science sensors in order to participate in an international technological forum.

India is also establishing an avenue for cooperative engagement with their regional rival, China, in space activities. In November 2006, Chinese president Hu Jintao visited New Delhi. This visit included the signing of an agreement with Prime Minister Manmohan Singh endorsing their intent to pursue cooperative activities in space for peaceful purposes.

While India has long viewed space capability as a strictly civil function, it is gradually including spacepower more and more in its security and military affairs. "India has established an Integrated Space Cell jointly operated by the three armed forces and the Indian Space Research Organization (ISRO) to protect India's satellites and enhance their capability for both military and civilian use." [22] This expansion into security and military space, along with its success in civil space, shows India's patient pursuit of a space program has established it as a regional space power well on the way to global influence.

Pakistan. Pakistan has pursued its space activities since 1962 with modest success compared to its regional rival, India. The Space and Upper Atmosphere Research Commission (SUPARCO) manages Pakistan's space activities. SUPARCO launched their first suborbital missions of the Rehbar space experiments in 1962. Pakistan's first satellite, Badr A, an experimental communications satellite, was launched into space from a Chinese launch site in 1990. The second satellite, Badr-B, was not launched until a decade later in 2001 from a launch site in Kazakhstan with the assistance of Russia.

Pakistan is undertaking its latest efforts in space through partnership with China.[23] This new agreement on Pakistan-China bilateral cooperation in the space industry could span a broad spectrum, including climate science, clean energy technologies, clean water technologies, cybersecurity, basic space, atmospheric, and Earth sciences, and marine sciences. This latest agreement is an expansion of a 2006 accord for China to launch three Pakistani Earth resource survey satellites.

The Sino-Pakistani cooperation is a logical consequence of several factors. Pakistan seeks to maintain its position regarding India by modernizing its remote sensing and communications through space capabilities. Pakistan also finds itself with limited access to space capabilities driven by U.S. space and missile technology export controls that are supported by U.S. allies and signatories of the Missile Technology Control Regime. China finds the partnership with Pakistan helpful in maintaining a balance of power with India in the region.

The Middle East and Africa

The Middle East is a troubled region, with ongoing strife between Israel and the Arab nations, the growing influence of radical Islam, the predicament in Iraq, and the growing rise of the region's superpower, Iran. Africa is struggling to develop with very little industry and infrastructure. Governments in this region naturally leverage space services as the quickest way to establish communications infrastructure to support commerce, education, and resource monitoring. Satellite communications are especially critical and are in robust demand. [24] But reconnaissance satellites are increasingly becoming a hot commodity in the ongoing effort by all players to obtain strategic and tactical intelligence.

Israel. "Israel has a technologically advanced market economy with substantial, though diminishing, government participation."[25]Its advanced technology is critical to its national security and also one of the key elements in its export portfolio. Security in the region has always been of paramount importance, and thus the Israelis focus their space program on national security. They have two primary applications: the use of space as a force multiplier via communications; and the use of reconnaissance satellites for situational awareness of any massing of forces by adversaries and for up-to-date assessment of military operations.

The rise of Iran's space launch capability, and the pursuit of commercially provided remote sensing systems by regional neighbors, causes Israel concern about maintaining an advantage in the balance of power. Similarly, spacepower is increasingly a part of its economic strategy, as it attempts to develop a self-sustaining economy less reliant on foreign aid.

The Israeli Space Agency was established in 1983. Its budget of approximately US $80 million is only part of the total Israeli spending on space. National security space programs are managed through Israel's Directorate of Defense Research and Development within its ministry of defense. Some authorities estimate Israel's total spending on space at between US $200 million and $300 million. Another important organization in the Israeli space program is the Israeli Air Force. The leadership ranks of Israel's aerospace efforts, including industry, involve a significant number of retired military general officers and admirals. This involves a fairly collegial cohort with its members rotating between positions in government, industry, and academia. This is epitomized by the illustrious career of astronaut Air Force Colonel Ilan Ramon, who died tragically in the space shuttle Columbia accident in 2003. Israel now holds an annual Ilan Ramon Conference on Space to honor his service and to inspire Israeli youth.[26]

Israel has launched 11 satellites in the past 20 years, beginning with the Ofek series in 1988. Despite its modest budget, Israel developed its own space launch capability early on, albeit for very small space missions. The Shavit launcher was used on the initial 1988 space mission to launch the Ofek satellite into orbit. Interestingly, in order to avoid launching over neighboring countries to the east, the Shavit booster takes a westward trajectory to attain orbit. This launching against the rotation of the Earth incurs a 30 percent penalty in mass to orbit capability, but does provide Israel with indigenous launch capability of up to 300 kilograms to low Earth orbit without the sensitivity of launching over neighboring states.

The Ofek series of reconnaissance satellites has grown in size to about 200 to 300 kilograms in mass with primary optics of about 30 centimeters, which provides approximately 1-meter ground resolution. Israel has made strides in leveraging technology to get higher performance out of small satellites. It is developing a follow-on series of reconnaissance satellites, the OPSat series, with larger apertures and correspondingly better image resolution. Plans include a constellation of minisatellites with increasingly sophisticated electro-optical and radar payloads. [27]

Israel first launched an imaging radar satellite, the TecSAR series, to provide critical day-night, all-weather imagery, in January 2008. The TecSAR series, significantly larger than the optical satellites of the Ofek series, could not be launched into orbit by the Shavit rocket. To do so, Israel contracted the launch services of the Indian government's Polar Space Launch Vehicle. Thus, Israel and India have begun to cooperate on space, at this point through commercial launch services, but the full extent of their cooperative activities may not have been publicly revealed. Israel has similarly built a series of communications satellites, the Amos series, being placed into geosynchronous orbit by foreign launch service providers.

Israel has begun launching Earth observation satellites, the EROS system, with 50-centimeter apertures and multispectral capability. This has value for national security and land-use surveys, along with being a viable commercial product. It has also announced a partnership with Northrop Grumman to explore sales of their TecSAR imaging radar satellite in the United States. Likewise, Israel has worked closely with the French on a joint project for a hyperspectral electro-optical satellite, the Vegetation and Environment Monitoring New Micro-Satellite.

Israel tries to leverage commercial sales of its aerospace, electronic, and optical technologies and systems to underwrite its support of national security efforts, somewhat the opposite model of the United States. To compensate for the relatively small amount of funding available for their space program, the Israelis have focused on small, low-cost space systems that deliver adequate capability for their needs. Israel has become rather expert at small, lightweight optical imaging systems for satellite missions. It has worked with European nations such as France to increase its access to technology. With the United States, the Israelis view the Operationally Responsive Space effort as complementary to their efforts in small satellites. Additionally, with the increasing potential of an adversary to block or interfere with their access to space and operation of space systems, they appreciate the value of having rapid launch and deployment capabilities. Thus, Israel is exploring options for airborne launch systems.

Israel is also working hard to develop second-tier suppliers for all of its critical space technologies. It appreciates a healthy, indigenous industrial base, especially with the potential threat of embargos on technology transfer to Israel, and is working hard to establish sustainable technology skills and suppliers.

With respect to the United States, the Israelis enjoyed the prestige garnered by having an astronaut be part of the International Space Station and are looking forward to continue this high-level association.

Israel is looking to export its expertise in exchange for international good will. One in particular is through a contract with the Mexican Ministry of Education to provide 4,400 very small aperture terminals. This will provide wide-band Internet access to 7,700 classrooms using Gilat's Sky Edge network technology. They will be undergoing a similar project in Colombia, teaming with Axesat of Bogata for a 1,500-site SkyEdge 2 broadband service provider.

Israel is using its regional spacepower to meet its immediate security needs and also to generate commercial sales to subsidize its high-tech sector. It works flexibly with other emerging regional space powers such as India to scale up its space systems in affordable ways, and it works with emerging spacepower users for commercial sales and good will. Israel continues to pursue participation on the U.S. human spaceflight for the prestige necessary to inspire its younger generation.

Iran. In the midst of turmoil in Iraq, Afghanistan, and the nearby Middle East, Iran finds itself a regional superpower, but one lacking many modern, high-technology capabilities useful in carrying out this role. Iran is pursuing steps to rectify this through establishment of an embryonic technology sector, pursuit of nuclear power, and pursuit of missile and space technology. With Israel now in possession of its own reconnaissance satellites, the Iranian space program could be considered a response to the Israeli space program. Iran's Sina-1 imaging satellite was launched by the Russians at the Plesetsk facility in October 2005. The satellite can take images with a resolution of about 50 meters—useful only for land-use surveys—but Iran has plans for more capable satellites in the future. In February 2009, Iran announced the launch of its second satellite, its first domestically built satellite, launched on its own Safir-2 launcher.[28]

Iran has also begun a suborbital space research program using the Kavosh-2 sounding rockets. Like all missile technology, space launch and suborbital launch systems help develop the technology for ballistic missiles, and some critics warn that the Iranian government is pursuing such technologies. This is a likely situation, and one that has been previously repeated by spacefaring countries around the world. The technology to do so is well known, and thus is not the limiting factor if Iran chooses to continue developing ballistic missile capability. It only takes the political will and adequate funding to develop operational systems.

Despite possible concern with Israeli activity, however, the Iranians have a more strategic purpose in mind:

> In January [2005], Iran signed a $132 million deal with a Russian firm to build and launch a telecommunications satellite called Zohreh, or Venus. Its launch is planned within the next two years. That satellite will facilitate communications in remote parts of Iran, increase the number of land and mobile telephone lines, boost Internet service and improve radio and television coverage.[29]

Having control of its own space telecommunications capability gives the Iranian government control of critical communications and messaging. Iran has also been accused of participating in the jamming of communications satellites broadcasting in their region that were beaming programming made by Iranian expatriates in southern California. The Telstar-12 satellite broadcasting the programs was being jammed by a transmitter in Cuba, which turned out to be located at the Iranian embassy there. Diplomatic efforts were effective in disarming this Iranian counter-space weapon. Nonetheless, Iran is quite aware of the value of spacepower, is intent on developing its own, and has already taken steps to counter the spacepower it deems to be undermining its domestic stability.

Saudi Arabia. Saudi Arabia does not yet have indigenous space manufacturing capability but has been procuring satellite communications systems from other space powers. The Saudis currently have three orbital slots in the geosynchronous belt that provide them with the most advantageous position in this region of rapidly growing subscribers.[30] The ArabSat series continues its successful growth. Saudi Arabia is also an important voice among its neighboring states, such as the United Arab Emirates, which is also considering the purchase of a commercial-quality reconnaissance satellite. As other Arab states begin to emerge as space users and operators, partnerships with Saudi Arabia will likely increase in number.

Turkey. Turkey has very little indigenous space capability. Its strategy is to develop capability in space applications while procuring systems and services on the commercial market. Although the debate within the European Union continues about whether Turkey is in Europe, Turkey undeniably has an affinity for European technology and space industry.[31]

Turkey has been a user of satellite communications and more recently has added to its satellite remote sensing and imagery to support its security and economic needs. The U.S. company GeoEye announced a deal with the Turkish company INTA Spaceturk, which has the exclusive rights to sell IKONOS and GeoEye-1 imagery in Turkey, Georgia, and Azerbaijan, and has been GeoEye's partner and regional affiliate since 2001. INTA signed an agreement in February 2009 to become an authorized reseller of IKONOS and GeoEye-1 imagery and products.

Turkey is also making efforts to develop and procure indigenously controlled space assets. The Ministry of Defense is working closely with indigenous industry partners, the Turkish Aerospace Industries (TAI) and the International Satellite and Cable Operator. On December 19, 2008, a Franco-Italian team was selected to provide Turkey with a turnkey reconnaissance satellite and ground system. [32] The electro-optical imaging satellite system, named Gokturk, will be operated by Turkey and will provide sub-meter resolution black and white images with 3-meter-resolution multispectral images. The contract, valued at 250 million euros, includes the construction of satellite fabrication facilities for TAI in Ankara to further efforts to establish an indigenous satellite manufacturing capability.

Nigeria. Nigeria, being near the Middle East and supported by petroleum wealth, is making efforts to establish a modern high-technology commercial sector and finds space capabilities a worthwhile and necessary foothold to be made. Nigeria cooperated with Surrey Satellite Technologies to develop and fly its first microsatellite in space, the NigeriaSat-1, launched in September 2003. Similarly, Nigeria worked with China to develop its first communications satellite, NigComSat-1, that was launched by a Long March 3B from Xichang Launch Center in China in May 2007.

Algeria . Algeria is also eager to leverage space programs as a means to jumpstart a high-technology sector. It is working with the French on a collaborative microsatellite effort.[33] Algerian aerospace engineers relocated to France to work with EADS Astrium on the production of two small but 2.5-meter-resolution Earth remote sensing satellites. Called Alsat-2, the satellite will use the French Myriade microsatellites design. Along with procuring the Alsat-2 satellites for the Algerian National Space Technology Centre, the Algerian aerospace engineers will return home to apply their newly acquired experienced to Algeria's indigenous aerospace efforts. This is similar to several contracts for commercial sales by the French aerospace firm, EADS Astrium, to emerging space powers such as South Korea, Malaysia, and South Korea. The French, in the meantime, also gain the good will of investing in the economic development of their former colony, helping to ease longstanding resentments.

Google Earth: The Globalization of Cyber-Space-Power

One of the biggest applications of space capability is the collection and dissemination of information. This makes for a natural fit with the information technology sector and innovative companies such as Google, Microsoft, Yahoo, Cisco, and others. Combine with this the growing number of entrepreneurial space efforts such as SpaceX, Bigelow Aerospace, Virgin Galactic, and others, and what emerges is the synergistic effect of the globalization of *cyber-space-power*, where the neologism conveys the meaning of affordable information collected from space being rapidly disseminated around the globe to anyone with a credit card.

Google has launched its Google Earth project to make a wide variety of imagery, including satellite imagery, available to the public. This has led to more specific cooperative agreements with the United Nations and NASA. The recent partnership between Google Earth and the United Nations Environmental Program (UNEP) has established an environmental monitoring program for UNEP overlays. This project will provide an online reservoir of remote sensing data on more than 100 environmental hotspots that UNEP has identified. Similarly, Google and NASA signed an agreement in 2006 to collaborate in making NASA science and exploration data, including scientific data, images, and video, available to researchers and the general public.

The Google-GeoEye partnership was announced in August 2008. "The combination of GeoEye's high-resolution, map-accurate satellite imagery from GeoEye-1 and Google's search and display capabilities provides users with access to rich, interactive visual image maps of the Earth."" [34] Google already uses imagery collected by another high-resolution GeoEye satellite, IKONOS, as well as imagery from other sources, including GeoEye's main rival, DigitalGlobe. In 2007, DigitalGlobe launched WorldView-1, a high-resolution satellite built by Ball Aerospace that offers half-meter resolution and can collect up to 750,000 square kilometers of imagery each day.

Cisco has teamed up with NASA Ames via a Space Act Agreement to cover the earth with a cyberskin to monitor the global climate. [35] Cisco itself is only providing the architecture and internet router technology to manage and disseminate data from a wide variety of data collected from land, sea, and air by NASA and other organizations. Such a capability would be useful eventually to monitor greenhouse gas emissions under any cap-and-trade system that might be put into place.

One additional impact likely to result from the merging of cyberspace and spacepower will be that increased accessibility to space-collected information will create even more demand for space collection of information. Government leaders, analysts and the general public will expect to have access to the latest information and images related to national and international security and emergency events, and will not be satisfied with excuses that huge financial investments and years of planning would be needed.[36]

Opportunities for Space Cooperation

Guiding Principles

In the early years of spacepower, dominated by the Cold War balance of power and strategic nuclear weapons, spacepower was wielded mainly as a weapon. But 50 years later, space systems are predominantly civil, commercial, and dual-use, with only a few systems dedicated to security applications. In today's world, spacepower is best obtained by skillfully balancing security, civil, and commercial space and using it liberally in the sphere of foreign policy:

> Is there a way to share the benefits of these strategically and tactically important capabilities in a manner that enhances the peace, justice and security of all stakeholders? Many nations around the world are answering "yes" to this question as they enter into agreements on cooperative space projects for the commercial, environmental and military security. More and more they are using their space programs to realign the old balance of power and create new common interests.[37]

At a conference in Bangalore in June of 2004, Lee Morin of the U.S. Department of State emphasized, "The extent of space cooperation currently taking place between India and the United States is quite modest compared to the enormous potential." [38] It is indeed time the United States pursued this greater potential with India and with other emerging space powers.

Civil Space Exploration

Space exploration has always been enormously popular and remains so today. It is a magnet to attract less developed space powers into a cooperative agreement. This great interest creates an opportunity to establish mutually beneficial agreements that advance political, economic, and cultural interests. Once cooperation in civil space is ongoing, it becomes easier to consider expanding into security cooperation.

The U.S. space exploration program is enormously attractive to all the emerging space powers. The United States is in discussion with the traditional global space powers, part of the ongoing legacy of cooperation on the International Space Station, but has made little effort on expanding this to the emerging space powers. These initial activities are just a start. Israel and Brazil have both had astronauts participate with NASA's human spaceflight program. NASA has established an International Lunar Network, an open framework of robotic lunar science missions that allows any interested nation to contribute a node to their system.[39] With very few security issues involved, civil space is an ideal area to begin cooperative engagement.[40]

Space Cooperation Possibilities for Security and Defense

The major security concerns today are nonproliferation, counterterrorism, and stability operations. This is a broad spectrum of security operations not limited to armed conflict. Spacepower provides significant enhancement to military and security operations for the United States and other spacefaring nations, including arms control treaty monitoring. In the case of the 2004 U.S.–India accord, that the strategic partnership identified civil space on one hand and nonproliferation and security on the other hand, it is natural to consider the possibilities for pursuing cooperative efforts in space for defense and security purposes. This is fairly representative of how space is often left out of the top-level strategic thinking. This is attributable to the overly classified and controlled nature of space capabilities in the United States—they are kept hidden as special security tools and not shared as important tools of national interest.

Specifically, the Defense Framework identifies the following objectives: collaborate on multinational operations, promote security and defeat terrorism, promote regional peace and security, combat the proliferation of weapons of mass destruction, expand collaboration on missile defense, support disaster response, support combined operations, support peacekeeping operations, and pursue an increased exchange of intelligence. While these objectives are seemingly straightforward, they will have to be carefully constructed in the context of relations with China, Pakistan, and other powers in the region in order to enhance security and prevent unintended consequences.

In these global security challenges, coalition operations, such as in Iraq and Afghanistan, are now the standard approach necessitated by the geopolitical ramifications of any desired endstate. The difficulties that arise in coalition security operations have led one military planner to argue for Coalition Operational Responsive Space (C–ORS).[41] The responsive space paradigm was developed over the past decade specifically to advocate for simpler, more affordable space solutions that were more responsive to national decisionmakers across a broad spectrum of national security and national interest scenarios.[42] C–ORS specifically addresses the need to implement space solutions constructed as a multinational architecture that is interoperable and extensible by diverse coalition members. As more space powers emerge with indigenous capabilities and procured systems and services, it should easier to undertake C–ORS approaches. More importantly, as more space powers emerge, it will be more necessary to do so to fully integrate coalition operations.

Opportunities in Satellite Communications

The global satellite telecommunications is very mature with government consortia, public-private partnerships, and commercial companies doing a thriving business, with many of the players trying to carve out shares in foreign markets.[43] There are clear opportunities for the United States and its allies to cooperate in satellite communications. Both have an interest in providing strategic messages to populations and communications to forces in the broad land masses of the Gulf, North Africa, Central Asia, and the Indian subcontinent. What is important is that common communications protocols and receiver equipment be fielded so that the capabilities can be used efficiently.

Opportunities in Earth/Ocean Remote Sensing

An important factor in international security is transparency. The nuclear weapons arms control treaties in effect today rely on the ability of signatory nations to verify compliance. Remote satellite imagery has been an important tool for verification and for monitoring impending aggressive actions. The ability of the United States and many of the emerging space powers to share reconnaissance and surveillance data could provide increased capability and build common interest. Going even further, an international reconnaissance system that provides data that is of commercial quality yet of sufficient acuity for verification of security agreements could be operated over central and southern Asia and shared by all cooperating nations in the region. These same reconnaissance systems could be used to support disaster relief operations.

Two important example of this are the Global Earth Observation System of Systems (GEOSS) global coalition and NASA's SERVIR regional coalitions. GEOSS is a partnership of over 70 nations contributing Earth observation data from land, sea, air, and space. "The aim is to provide the right information, in the right format, to the right people, at the right time, to make the right decisions." [44] GEOSS is the right framework, but it is not clear how active and effective the cooperation is. On a much smaller scale, but one that is vibrant and readily extensible, is NASA's SERVIR program, which "integrates satellite observations, ground-based data, and forecast models to monitor and forecast environmental changes and to improve response to natural disasters." [45] Originally established in Central America, the program has been so successful that a second project was established in Africa.

In the future, with global warming and climate change becoming such important issues, it may be necessary for the United States to formally establish a climate change emissions monitoring system. If treaties are agreed to by the nations of the world, then verifiability becomes of utmost importance. This might be done in a manner similar to how nuclear treaty monitoring capability was established early in the Cold War, with space remote sensing capabilities playing an important role.

Opportunities in Space Traffic Control

The recent collision in space of a commercial Iridium satellite and a defunct Russian Cosmos satellite, with its ensuing space debris field, has highlighted the need to address the increasingly crowded outer space. While many in the United States and the international community have argued for more sharing of data on the location of objects in space, it has long been delayed due to concerns about revealing information on critical and classified national security assets. Space situational awareness has a legacy from the Cold War of being critical to all sides in gaining an intelligence advantage. The Iridium-Cosmos collision in February 2009, along with the growing presence of human spaceflight with the International Space Station, the Chinese spaceflight program, and private spaceflight by the commercial sector, argues for the need to spin off a public space traffic control function distinct from the more sensitive space surveillance capabilities.

The U.S. Air Force Space Command has begun a pilot project called the Commercial and Foreign Entities (CFE) initiative. [46] Its transition to U.S. Strategic Command is planned for later in 2009, to begin operational support on space collision hazards to commercial and foreign space users. Uncertainties remain, however, on what level of liability might remain for the U.S. Government while it will be acting essentially in a good Samaritan role. The expansion of a space traffic control network is greatly facilitated by the number of contributors, and the space object data collection systems are relatively inexpensive, thus allowing many emerging space programs to join in a participatory manner.

Opportunities in Science and Technology

Science and technology used to be the one area where international cooperation was easily done. In this era of ever-increasing technology export control, it is becoming harder and harder to do so. Nonetheless, the United States should avidly pursue cooperation with emerging space powers and space information users in space science and technology. Cooperation in science and technology costs less than in operational systems, builds common interest between the technical communities, and provides insight into the aims and objectives of the partner's space program. Most importantly, the benefits flow both ways: U.S. experts will gain significantly from the collaboration with their international peers.

Conclusion

The common theme in all these emerging spacepower efforts is to pursue space and space-related technologies and capabilities that are practical and affordable. While ballistic missiles and missile defense systems are weapons intended to be used only in extremis, spacepower is exercised all the time in support of national and international security needs. A major consideration for these foreign space efforts is developing systems with dual-use capability, providing commercial, civil, and security benefits. Another important trend to observe is that foreign nations earnestly pursue international cooperation and influence through the use of their space programs. These approaches are very responsive to the security needs of the nations involved. While spacepower might provide an irresponsible government with additional military capability, for the most part, the rise of foreign spacepower can be allied with U.S. efforts to ensure international security.

The new and emerging space powers will test the bounds of current spacepower practice and may in the end reconstitute a more vibrant, more interesting milieu of opportunities and challenges in space than previously existed among the former small club of global space powers. The right spacepower leadership will find a host of followers to advance its national and international interests. Without such leadership, the dominant space powers may find their advantage squandered.[47]

Notes

1. Philip Bobbitt, *The Shield of Achilles: War, Peace, and the Course of History* (New York: Alfred A. Knopf, Random House, 2002). Bobbitt analyzes the interrelationship of war and constitutional law throughout history and finds that new forms of constituting sovereign government arise after epochal wars often lasting many decades. He points out that after the long wars of the 20th century (World War I, World War II, and the Cold War), the nations of the world are reconstituting themselves as new "market-states."
2. Some Members of Congress have asserted in public hearings that selling spacecraft components to foreign countries that may in turn transfer them to China is the moral equivalent of European and American industry selling material to Nazi Germany prior to the Second World War. The details of the Congressional hearing where this topic was discussed are available at <http://science.house.gov/publications/hearings_markups_details.aspx?NewsID=2360>. Others have equated the selling of space technology that may one day be used against the United States with profiteering by munitions manufacturers during the First World War. These positions are fallacious in that they argue the extreme. By this logic, buying goods at Wal-Mart that are manufactured in China is morally reprehensible and should similarly be outlawed as the profits are used by the Chinese government for military spending.
3. National Research Council Committee on Science, Security, and Prosperity in a Changing World, "Beyond 'Fortress America': National Security Controls on Science and Technology in a Globalized World," National Research Council, 2009. U.S. technology export control regimes have a long and storied history. Especially unfortunate for space technologies, in 1999 U.S. law placed all space technologies on the controlled munitions list, and thus under strict controls. While this certainly slowed the transfer of U.S. space technologies to countries such as China, Iran, and North Korea, it did not stop the transfer of space technology from other nations. In fact, other nations were catalyzed to develop their own technology to replace the U.S. technology on which they formerly relied but that was now cumbersome to obtain. There is a growing chorus of voices across the U.S. political spectrum calling for a drastic reform of technology export control, but as of yet there is no champion with enough political power or will to challenge the small but powerful national security cult that now dominates U.S. international policy. The "Beyond 'Fortress America'" report is a useful guide to the history and dynamics of U.S. technology export controls. The authors' assessment of the effect of this policy is stated in the opening sentence of the report: "The export controls and visa regulations that were crafted to meet conditions the United States faced over five decades ago now quietly undermine our national security and our national economic well-being."
4. Turner Brinton, "Gen. Chilton: Export Controls Pose Threat to National Security," *Space News*, March 23, 2009, 20. In a written submission to a Congressional committee, General Chilton testified, "I remain concerned that our own civil and commercial space enterprise, which is essential to the military space industrial base, may be unnecessarily constrained by export control legislation and regulation." General Chilton's full testimony is available at <http://armedservices.house.gov/pdfs/SF031709/Chilton_Testimony031709.pdf>.
5. Eric S. Raymond, *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary* (Sebastopal, CA: O'Reilly Media, 1999). The book documents how the open-source software movement became the dominant force in the emergence of the Internet and web infrastructure, economy, and culture much more so than the large established software "cathedrals" of established computing and software corporations. While recognizing that both the cathedral and the bazaar cultures made contributions, most planning and prognosticating overlook the significant and sometimes disruptive innovations that will emerge from the bazaar. In this work on spacepower, the author similarly argues that in fact the more significant changes in the spacepower landscape will arise from the teaming interactions of emerging space powers and established space powers other than the United States.

6. John M. Diamond, ed., *The Space Report 2009* (Colorado Springs: The Space Foundation, 2009), 23.
7. Private communication with Wade L. Huntley regarding the presentation of this author's viewpoint at the Center for Space and Defense Studies Forum panel session, Colorado Springs, CO, January 12, 2007. Huntley pointed out that many influential strategic theorists arose in nations and states during disadvantaged times, that is, when they were not the dominant power.
8. *Report of the Commission to Assess United States National Security Space Management and Organization* , Pursuant to Public Law 106–65, January 11, 2001, accessed on the Internet at <www.dod.mil/pubs/space20010111.html>. This report is often referred to as the Space Commission Report.
9. Wade Huntley, "Perspectives on Small and Emerging Space Powers," remarks given at the Center for Space and Defense Studies Forum panel session, Colorado Springs, CO, January 12, 2007.
10. Press release, "MDA delivers RapidEye information solution," MDA corporate Web site, accessed at <www.sm.mdacorporation.com/what_we_do/rapideye.html>.
11. Embraer Web site, available at <www.embraer.com/english/content/home/>.
12. "Chinese-Brazilian Satellite Slated to Launch this Fall," *Space News*, August 6, 2007, 9.
13. "France to Work with Brazil on Satellite Bus Designs," *Space News*, January 5, 2009.
14. Diamond, 112.
15. Central Intelligence Agency, *The World Factbook 2009*, available at <https://www.cia.gov/library/publications/the-world-factbook/geos/ks.html#Econ >.
16. Private discussion with Dr. Simon P. Worden.
17. Embassy of the Republic of Korea, "Korea, U.S. to sign agreement to bolster cooperation in space exploration," October 2, 2008, available at <http://dynamic-korea.com/news/view_news.php?main=KTD&sub=TCH&uid=200800251780&keyword=>.
18. Ibid.
19. Randall R. Correll, "U.S.-India Space Partnership: the Jewel in the Crown," *Astropolitics* 4 (2006), 159–177. The author argues that space cooperation provides an ideal tool to advance the reinvigorated relationship between the United States and India in the wake of the September 11 terrorist attacks.
20. Official EDUSAT India Web site, available at <http://edusatindia.org/ >.
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32. Andi Nativi and Michael A. Taverna, "Turkish Delight: Telespazio to Supply Gokturk Surveillance Satellite, US MILSATCOM Capability," *Aviation Week and Space Technology*, January 5, 2009, 31.
33. Peter B. de Selding, "Algeria Buys Two Small Remote Sensing Satellites—EADS to Train 25 Algerian Aerospace Engineers," *Space News*, February 6, 2006.
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35. Press release, "NASA, Cisco Partnership on Climate Change Monitoring Platform," March 3, 2009, available at <http://newsroom.cisco.com/dlls/2009/prod_030309b.html>.
36. "Congressman Demands Answers from Google," *Space News*, April 9, 2007, 3. U.S. Representative Brad Miller reportedly demanded to know why images on Google Earth did not show the city of New Orleans ravaged by Hurricane Katrina in 2005. Google Earth and similar Internet-based services do not have an operational mission, and the data, while impressively arrayed, is sparse and stale. Yet government officials at local and national levels around the world are coming to expect ready access to up-to-date information.
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46. Michael A. Taverna, "Traffic Cop," *Aviation Week and Space Technology*, April 20, 2009.
47. Randall R. Correll and Simon P. Worden, "The Demise of U.S. Spacepower: Not with a Bang but a Whimper," *Astropolitics* 3, no. 3 (December 2005), 233–264. The authors argue that staggering cost growth and schedule delays in U.S. space programs are causing national leadership to consider divesting from spacepower in pursuit of other solutions—an ill-advised course of action, but understandably tempting in the face of poor performance by the U.S. military-industrial aerospace complex. A better solution would be to install more competent leadership who could deliver cost-effective spacepower, just as many emerging space actors are doing.

Chapter 27:

Emerging Domestic Structures: Organizing the Presidency for Spacepower

John M. Logsdon

Organizational arrangements are not neutral. Organization is one way of expressing national commitment, influencing program direction, and ordering priorities.

—Harold Seidman[1]

This chapter addresses a single, rather straightforward question: Is there a best organizational structure or approach at the Presidential level if the United States wants to maximize the contributions of its civilian, military, intelligence, and commercial space capabilities to the pursuit of its national goals and purposes?

Developing a sound and comprehensive theory of spacepower is a necessary but insufficient condition for ensuring the full contribution of space capabilities and activities to furthering national interests. To be meaningful, such a theory must be used as a foundation for a spacepower strategy, and it may be that such a strategy cannot be successfully implemented unless that implementation is managed, or at least carefully overseen, by some sort of organizational structure at the national level. There are too many separate interests and centrifugal forces at work in the U.S. space sector to expect an automatic coherence of space actions in pursuit of national objectives; there needs to be some means of coordinating the behavior of various separate space actors to be consistent with national purposes. As Harold Seidman comments:

> A President is not self-sufficient. The Congress can perform its constitutional functions without the executive establishment and the bureaucracy. A President cannot.
>
> It is the agency heads, not the President, who have the men, money, material, and legal powers. . . . To work his will . . . the President must have at his disposal the trade goods controlled by the agencies and be able to enlist the support of their constituencies.
>
> An alliance—which is what the executive branch really is—is by definition a confederation of sovereigns joined together in pursuit of some common goal. . . . Individual purposes and goals are subordinated only to the extent necessary to hold the alliance intact.[2]

The capabilities that form the basis of U.S. spacepower are controlled, not by the President, but by executive branch agencies such as the Department of Defense and its constituent elements, the National Aeronautics and Space Administration (NASA), the

National Oceanic and Atmospheric Administration (NOAA), and the National Reconnaissance Office (NRO). The Department of State relates space capabilities to U.S. foreign policy objectives and oversees the implementation of the International Traffic in Arms Regulations, which influence space technology exports. The Departments of Commerce and Transportation and the Federal Communications Commission also play important regulatory roles vis-à-vis the U.S. commercial space sector. That sector increasingly is developing with private capital and is operating capabilities that are an essential part of U.S. spacepower. Each of these space actors, and subelements within them (for example, NASA's Science Mission Directorate), has its own set of relationships with supportive nongovernmental constituencies. Bringing these separate organizations together in pursuit of common goals is a challenging task.

A President has limited power to pursue national interests as he defines them in the face of this distribution of power with the executive branch. The President can set priorities through policy directives and budget decisions and can appoint people who share his values and perspectives to head the executive agencies, but almost inevitably those individuals find their loyalties divided between White House priorities and their own agency's interests, which only occasionally are the same.

In addition, congressional oversight and funding responsibilities with respect to executive branch space activities are diffused over many committees and subcommittees. They reflect the decentralized organization of the executive branch, and the dispersion of power among congressional committees makes a coherent congressional perspective on any particular space issue, much less a comprehensive approach to U.S. spacepower, almost impossible to achieve. Relationships between executive agencies and Congress may pull agency leaders in directions inconsistent with the President's priorities. Congress and the White House are separate institutions sharing power, and the President must convince Congress to agree with his priorities for U.S. spacepower capabilities if those capabilities are to be maximized. Congress cannot substitute for the President in this regard.

There are also many nongovernmental interests trying to influence the direction taken by one or the other element of the government's space agencies. Each actor in the space industry, labor unions, representatives of state and regional governments, universities, and science and engineering associations, among others, attempts to align the government's space activities with its particular interests.

The U.S. approach to spacepower must also be formulated in a global context, with an increasing number of other spacefaring countries pursuing policies that mix competitive and cooperative elements. The post–Cold War period during which the United States was the unchallenged space superpower is rapidly becoming only a memory, and the United States has to craft an approach to advancing its interests, both in space and through the use of space capabilities, with high sensitivity to its overall relationships with other spacefaring countries and to their differing approaches to the use of their own spacepower.

If there is to be a national strategy for space informed by a comprehensive theory of spacepower, it must come from the center of government: "The bureaucracy is no more equipped to manufacture grand designs for Government programs than carpenters, electricians, and plumbers are to be architects. But if an architect attempted to build a house, the results might well be disastrous."[3] The White House must act as the "architect" for a U.S. space strategy and must persuade the various centers of spacepower within and outside the Federal Government that it is in their mutual interest to work together in turning that strategy into action. How best to achieve Presidential control over executive branch agencies is a classic problem of government organization, and it is basically no different in the space sector than in other areas of government activity.

Recent Organizational Proposals

Recognizing these realities, the Commission to Assess United States National Security Space Management and Organization (the Space Commission) put forth a proposal in January 2001 for dealing with space issues at the White House level. The Space Commission noted that "the United States has a vital national interest in space. . . . [Space] deserves the attention of the national leadership, from the President on down." The commission recognized that "only the President can impress upon the members of the Cabinet . . . the priority to be placed on the success of the national space program." The commission added, "The National Security Council can assist the President with measures to monitor the progress of the national space program toward defined goals."[4]

The Space Commission made detailed recommendations on how best to organize for space within the White House structure, noting that "the present interagency process is inadequate to address the number, range, and complexity of today's space issues, which are expected to increase over time. A standing interagency coordination process is needed." The commission proposed that a Senior Interagency Group (SIG) for Space be established within the National Security Council (NSC) structure. In order to develop the SIG (Space) agenda and to provide coordination at the working level, the Space Commission recognized the need for "dedicated staff support . . . with experience across the four space sectors."[5]

The role of SIG (Space) would be to oversee the activities of the various executive branch space agencies to:

- leverage the collective investments in the commercial, civil, defense, and intelligence sectors to advance U.S. capabilities in each
- advance initiatives in domestic and international fora that preserve and enhance U.S. use of and access to space
- reduce existing impediments to the use of space for national security purposes.

To achieve these objectives, the SIG "would oversee the implementation of national space policy" and "focus on the most critical national security space issues, including those that span the civil and commercial sectors."[6]

The Space Commission also observed that "the President might find it useful to have access to high-level advice in developing a long-term strategy for sustaining the nation's role as the leading space-faring nation." Thus, the commission recommended the creation of a "Presidential Space Advisory Group" that would be "unconstrained in scope and provide recommendations that enable the nation to capitalize on its investment in people, technology, infrastructure and capabilities in all space sectors." Such an independent group could also "identify new technical opportunities that could advance U.S. interests in space."[7]

From the perspective of maximizing and making best use of U.S. spacepower, these organizational recommendations seem to have been particularly well conceived. But when the administration of George W. Bush came to the White House and the chairman of the Space Commission, Donald Rumsfeld, became Secretary of Defense, they were not implemented, and many of the problems pointed out by the Space Commission persisted or even worsened. In 2008, a congressionally mandated "Independent Assessment Panel on the Organization and Management of National Security Space"—more frequently known as the Allard Commission, after its congressional sponsor, Senator Gordon Allard (R–CO), or the Young Committee, after the panel's chair, A. Thomas Young—reached similar conclusions to those of the Space Commission. The group recommended that "the President should establish and lead the execution of a National Space Strategy" and that "to implement the strategy, the President should reestablish the National Space Council, chaired by the National Security Adviser, with the authority to assign roles and responsibilities, and to adjudicate disputes over requirements and resources."[8]

The Executive Office structure for space policy as it existed at the start of the administration of President Barack Obama was thus rather different from that recommended by either the Space Commission or the Allard Commission. And those recommendations with respect to structures at the White House level were only one part of both groups' recommendations for reorganizing the management of national security space. This chapter will conclude with a discussion of whether there is merit in reconsidering these recommendations, if the precepts of a spacepower theory are to be put into practice. But first it would be useful to see if there are lessons that can be learned from a brief review of White House organization for space over the last half-century.

Alternative Organization Approaches: A Historical Perspective

There *has* been some form of White House (including the Executive Office of the President) structure for managing U.S. space efforts since the Eisenhower administration, which was faced with the issue of how to organize the U.S. space effort in response to the October 1957 Soviet launch of Sputnik. A brief review of the various ways in which different Presidents organized their management of U.S. space matters can provide a rather comprehensive catalogue of possible organizational alternatives or elements that might be employed by future Presidents.

EisenhowerAdministration

In the aftermath of the first two Soviet satellite launches, President Dwight D. Eisenhower appointed the President of the Massachusetts Institute of Technology, James Killian, as his advisor on science and technology and gave Killian the responsibility for suggesting an organizational approach for space. In December 1957, Killian recognized that the Department of Defense was "committed to a space program and is in the process of setting one up," but that there was a "broad area of non-military basic research relating to space." He noted that there were several alternatives for the conduct of this nonmilitary space research, including having it managed through the Department of Defense or through an existing or new civilian agency. Whatever approach the President chose, suggested Killian, "there should be some mechanism . . . which gives coherence to the broad program."[9] From the very beginnings of the U.S. space program, the need for a central coordinating mechanism was thus recognized.

Eisenhower at first did not see the need for a new, separate space agency; his initial inclination was to keep all U.S. space activities within the Department of Defense. But he soon became persuaded that space science and exploration should be under civilian control. That decision spread U.S. Government space capabilities between two agencies, the Department of Defense and a new National Aeronautics and Space Administration. By assigning control over the initial U.S. reconnaissance satellite program Corona to a separate mechanism outside of both the Department of Defense and the Central Intelligence Agency in February 1958, Eisenhower also laid the foundation for a separate intelligence space organization. As he sent his proposals for a civilian space agency to Congress in April 1958, Eisenhower did not include a mechanism for coordinating the national space effort.

However, as Congress debated the administration's proposal, both the House of Representatives and the Senate came to the view that some such mechanism was necessary. The House suggested an Aeronautics and Space Advisory Committee that would be comprised of individuals outside the government and would meet only four times a year. This position was also favored by Killian. The Senate, under Majority Leader Lyndon B. Johnson, favored a high-level policy board along the lines of the NSC to exercise centralized policymaking authority for a coordinated national space program and to ensure that questions of broad national strategy were considered in formulating that program. The Senate position prevailed, and the 1958 Space Act established a nine-person National Aeronautics and Space Council in the Executive Office of the President. The council would be chaired by the President and would include as members the Secretaries of State and Defense, the administrator of NASA, the chairman of the Atomic Energy Commission, one other senior government official, and three private citizens.[10]

Although he had agreed to establish the council at Johnson's urging, Eisenhower did not fully implement the intent of Congress. Rather, he added a few people to the NSC staff to deal with space matters and handled space policy issues through the National Security Council process, adding the NASA administrator to those in attendance when space issues were to be discussed and declaring such an occasion a meeting of the Space Council. By 1960, Eisenhower had concluded that the idea that there could be a comprehensive, integrated U.S. space program was incorrect, and thus called for a revision of the 1958 Space Act that would eliminate "those provisions which reflect the concept of a single program embracing military as well as non-military space activities," since "in actual practice, a single civil-military program does not exist and in fact is unattainable." Given this conclusion, Eisenhower judged that he did not need a separate council for space matters and proposed that it be abolished.

Both NASA and the House of Representatives supported Eisenhower's proposal, but it was blocked in the Senate by Lyndon Johnson, who observed that there would be a Presidential election in a few months and that "the next President could well have different views as to organization and function of the military and civilian space programs." By the time he made this comment on August 31, 1960, Johnson knew that John F. Kennedy and not he was the Democratic nominee for the Presidency, but he still believed in the strategic importance of space and the need to deal with space issues at the national level.[11]

A broad 21-page statement of national space policy was developed during the Eisenhower administration and issued inside the government (but not made public) as a National Aeronautics and Space Council document in January 1960. The statement noted that "although the full potentialities and significance remain largely to be explored, it is already clear that there are important scientific, civil, military, and political implications for the national security."[12] This was to be the last Presidentially approved statement on national space policy for 18 years.

Kennedy Administration

As he prepared to enter the White House after his 1960 election, John F. Kennedy was advised that there was a need for policy coordination between the civilian and military space programs and that a revitalized National Aeronautics and Space Council, with fewer members (none from outside the government) and with the Vice President rather than the President as its chair, might be a useful means of achieving such coordination with respect to "high priority policy issues."[13] Kennedy accepted this advice and submitted the legislation needed to amend the 1958 Space Act to create a National Aeronautics and Space Council along these lines.

An opportunity to use the council mechanism arose early in the new administration. In the wake of the April 12, 1961, launch of the first human, Soviet cosmonaut Yuri Gagarin, into space, President Kennedy asked his Vice President, Lyndon Johnson, "as Chairman of the Space Council to be in charge of making an overall survey of where we stand in space."[14] At this point, the Space Council had only one staff person, a former congressional staff member named Edward Welsh. Together, he and Johnson organized hurried consultations involving NASA, the Department of Defense, the Atomic Energy Commission, NASA official Wernher von Braun, Air Force General Bernard Schriever, several businessmen, and senior members of the Senate. Then NASA and Department of Defense staff (without Welsh's involvement) prepared a lengthy memorandum titled "Recommendations for Our National Space Program: Changes, Policies, and Goals." This memorandum was sent to the Vice President on May 8. Johnson endorsed it and forwarded it to the President on the same day. The memorandum called for an across-the-board acceleration of the U.S. space effort and increased integration of the civilian and military space programs, which Dwight Eisenhower a few months earlier said was impossible. It also recommended setting a manned lunar landing as a national goal.[15]

The Space Council acquired a small staff of its own in 1961–1962 and was active on other space issues, in particular on how best to organize the government for the development and operation of communications satellites. The Space Council principals met a number of times as a body during the Kennedy administration. However, the council never again was the primary source of space policy advice to the President, who relied on those with whom he had a personal relationship, such as his science advisor Jerome Weisner and his staff, and on NASA Administrator James Webb for counsel on space matters. (Webb was never happy to find the Space Council and its staff between himself and the President.) Attempts by the Space Council to develop a comprehensive statement on national space policy were not successful, and there is no indication that the council staff was able to exert any influence on defense and national security space issues.

Johnson Administration

Lyndon Johnson once remarked that he had spent much more time on space matters as Vice President than he did as President. This is not surprising, given that issues such as the war in Southeast Asia and the demands of his Great Society programs were high-priority issues during his time in the White House. Vice President Hubert Humphrey, who became chairman of the Space Council in 1965, had shown little interest in space matters as a member of the Senate, and there is no indication that the council was particularly active between 1964 and 1968. Edward Welsh stayed on as executive secretary, but the White House depended more on James Webb, its science advisory apparatus, and budget director Charles Schultze for space policy advice. Vice President Humphrey did try to use the Space Council mechanism to stimulate discussions on how better to use the space program as an instrument of foreign policy, but with little apparent impact. By the end of the Johnson administration, the Space Council was basically a moribund structure. Welsh stayed on as executive secretary until Johnson left office in January 1969.

NixonAdministration

As he assumed office in January 1969, President Richard M. Nixon was advised that, with the first landing on the Moon in the near future, there was a need for a comprehensive review of the national space program. Nixon asked his Vice President, Spiro Agnew, to head up a Space Task Group to carry out such a review. The review did not use the formal mechanism of the National Aeronautics and Space Council, which in 1969 was without a dedicated staff, to carry out this review. Staff support for the Space Task Group came instead from the White House Office of Science and Technology.

In June 1969, toward the end of the Space Task Group review, Apollo 8 astronaut William Anders was appointed executive secretary of the Space Council, with a mandate to revitalize the organization. Over the next 3½ years, Anders and his small staff were active participants in the White House discussions on the content of the post-Apollo space program, on a new approach to international cooperation in space, and on whether to approve development of the space shuttle. They had little apparent involvement with the military or national security space programs. But the Space Council never met at the principals level, and its staff was only one of several sources of space policy advice within the Executive Office. The Science Advisor and his Office of Science and Technology and what in 1970 became the Office of Management and Budget had more weight in most White House policy debates.

As he began his second term in January 1973, Richard Nixon announced that he was abolishing the National Aeronautics and Space Council (and the Office of Science and Technology). His message to Congress announcing this action said that:

> basic policy issues in the United States space effort have been resolved, and the necessary interagency relationships have been established. I have therefore concluded, with the Vice President's concurrence, that the Council can be discontinued. Needed policy coordination can now be achieved through the resources of the executive departments and agencies, such as the National Aeronautics and Space Administration, augmented by some of the former Council staff.[16]

Ford Administration

During most of the administration of President Gerald R. Ford, there was no Executive Office unit with specific responsibilities for space policy. General science and technology advice was provided by the director of the National Science Foundation, who was also designated as the President's science advisor. In 1976, Congress passed a bill reestablishing a White House Office of Science and Technology Policy (OSTP) to provide advice to the President on the full range of science and technology policy issues, including space. Defining space as a science and technology policy issue, rather than as an issue of broad national policy, had the effect of limiting the influence of OSTP on non–research and development space matters.

Carter Administration

Space policy remained the responsibility of OSTP during the 4 years that Jimmy Carter was President. Given the broad purview of OSTP responsibilities and its small staff, only one or two staff members worked on space issues. With OSTP leadership, for the first time since the end of the Eisenhower administration, a broad statement of national space policy was developed. The senior OSTP staff member with space responsibilities was dual-hatted as a National Security Council staff member, establishing a pattern of close cooperation on space matters between the two organizations that has persisted for most of the time since. This arrangement also allowed this staff person access to highly classified programs and intelligence information. As the Carter administration began talks on space arms control with the Soviet Union in 1978, OSTP was very much involved.

Reagan Administration

For the first 18 months of Ronald Reagan's Presidency, OSTP remained the lead White House organization for space policy; its staff managed the development of the first Reagan statement on national space policy, which was issued on July 4, 1982. That policy stated that:

Normal interagency coordinating mechanisms will be employed to the maximum extent possible to implement the policies enunciated in this directive. To provide a forum to all Federal agencies for their policy views, to review and advise on proposed changes to national space policy, and to provide for orderly and rapid referral of space policy issues to the President for decision as necessary, a Senior Interagency Group (SIG) on Space shall be established. The SIG (Space) will be chaired by the Assistant to the President for National Security Affairs and will include the Deputy or Under Secretary of State, Deputy or Under Secretary of Defense, Deputy or Under Secretary of Commerce, Director of Central Intelligence, Chairman of the Joint Chiefs of Staff, Director of the Arms Control and Disarmament Agency, and the Administrator of the National Aeronautics and Space Administration.[17]

The National Security Council, using the SIG (Space) mechanism, held the White House lead for space policy for the remainder of the Reagan administration and issued a number of space policy statements with associated public "fact sheets."[18] There was usually only one NSC staff member with specific space responsibility who worked closely with one or two colleagues from OSTP.

George H.W. Bush Administration

The Democratic leadership in Congress was not happy with the shift of space policy jurisdiction to the NSC. This meant that space decisions would be made in the secretive style characteristic of NSC operations and that Congress could not force the NSC director, who was also assistant to the President for national security affairs, to testify at congressional hearings, since he was not a Senate-approved Presidential nominee. There were several attempts in the 1980s to reestablish a separate space council through legislation; doing so would mean that the Senate had to approve the nomination of an individual to be Space Council executive secretary and could compel that individual to testify before Congress. The White House opposed such a congressional initiative until 1988, when the measure was incorporated in the NASA fiscal year 1989 authorization bill. In its revised form, the Space Council executive secretary was not a Presidential nominee requiring Senate confirmation. That bill was signed by the President.

A new National Space Council came into being on February 1, 1989; it was chaired by Vice President J. Danforth Quayle. The law establishing the council was silent on membership but did provide for up to six council staff members in addition to an executive secretary.

For the next 4 years, the Space Council staff played an extremely activist role in attempting to revitalize what it judged to be a stagnant civilian space program. The staff was the primary mover behind what became known as the Space Exploration Initiative, announced by President Bush on July 20, 1989. This initiative called for a return to the Moon and then human journeys to Mars. In December 1989, the council assembled a blue ribbon commission for a 2-day meeting to comment on what was perceived as NASA's disappointing response to that initiative, and then convened a synthesis group to examine alternative approaches to human space exploration. In 1990, the council staff initiated another high-level examination of the civilian space program, chaired by Lockheed Martin executive Norm Augustine; this review took place over several months and went into great depth. In 1991, council staff convinced the Vice President and the President that NASA administrator Richard Truly should be replaced and played a key role in selecting his successor, Daniel Goldin. After the collapse of the Soviet Union, the council took the lead in outreach to the new Russian government with respect to both commercial and government-to-government space cooperation. In mid-1992, the National Space Council finally established a 12-person Vice President's Space Policy Advisory Board that had been called for in the legislation establishing the council. The board was composed of nongovernmental members with long experience in the various sectors of U.S. space activity, and it issued three reports on space issues during the second half of 1992.

There is no evidence that the council staff played an equally activist role with respect to the national security space program, and its interventions into the day-by-day management of NASA's efforts were strongly resented by senior NASA officials. The Vice President convened occasional meetings of senior executive branch officials involved in space matters, and there were several statements of national space policy issued under the council's auspices, but the National Space Council was primarily a staff-intensive activity rather than a forum for top-level policy discussions. Given the council's central role in space policy, neither OSTP nor NSC played a major role with respect to space policy during the Bush administration.

ClintonAdministration

One of Bill Clinton's campaign promises was to reduce the size of the institutional Presidency by 25 percent. As part of this effort, the National Space Council and the Vice President's Space Policy Advisory Board were abolished soon after Clinton took office in January 1993. Jurisdiction over civil space policy matters was assigned to OSTP as part of the portfolio of its associate director for technology, with national security space being assigned to the associate OSTP director for national security and international affairs. For most of the 8 years of the Clinton administration, there were two or three OSTP staff members with specific space policy responsibilities, and for the most part they limited their activities to the civilian space sector. The administration also established a National Science and Technology Council as the inside-the-government mechanism for policy review. That council had several standing committees in various areas of science and technology, but none for space. President Clinton in 1993 established the President's Council of Advisors on Science and Technology as a source of external advice on science and technology; space policy was not among the topics that came before that body during the Clinton administration.

There were a number of space policy statements generated through an interagency process coordinated by OSTP, with a new statement of national space policy issued in September 1996. Vice President Al Gore and his staff also paid particular attention to space issues and had a major role in the decision to invite Russia to join the space station program and in several other space initiatives. Staff cooperation between OSTP and NSC continued. The National Security Council lead for space matters was its director for space, who reported to the NSC senior director for defense policy and arms control and who worked closely with the OSTP staff on space issues.

George W. Bush Administration

At the outset of his administration, President Bush created a number of policy coordinating committees (PCCs) that were to be the main day-to-day fora for interagency coordination of national security policy, rather than establishing separate senior interagency groups for high-priority issues. The PCCs were to provide policy analysis for consideration by more senior committees of the NSC system, such as the Deputies Committee, the Principals Committee, and the NSC itself, and to ensure timely responses to decisions made by the President.[19] Space policy was not originally a focus of one of the PCCs, but a Space Policy Coordinating Committee, chaired by the National Security Council, was soon established and in June 2002 was assigned the responsibility for carrying out a comprehensive review of national space policy.

Members of the Space Policy Coordinating Committee are mid-level political appointees (for example, assistant secretaries) of the executive agencies dealing with space matters. Staff support is provided by the NSC Director for Space, the Assistant Director for Space and Aeronautics of the White House OSTP, and a senior OSTP analyst. These three individuals are thus the only people (except for Office of Management and Budget staff) with a primary responsibility for space policy in the Executive Office structure.

A National Defense University review of the work of the PCCs suggests that "PCC planning is focused more on advance planning at the political and strategic level. . . . An effective interagency process reduces the complexity of the policy decisions and focuses the planning on mission success." The review added: "Collaboration is central to a PCC's success, but teamwork and unity is [sic] vulnerable to political risks, bureaucratic equities, and personal relationships. . . . Policy disagreements and turf battles are inevitable because of divergent political philosophies, different departmental objectives and priorities, disagreements about the dynamics or implications of developing situations, or because departments are seeking to evolve or formulate new roles and missions." In addition, "hard problems do not lend themselves to easy solutions, and frequently there are genuine differences between departments over the best ways, means, and objectives for dealing with a national security problem. . . . As one former NSC staff member observed, the easiest outcome to produce in the interagency process is to *prevent* policy from being made." For the PCC process to work, "the wide range of issues, the different policy perspectives of various departments, the nature of bureaucratic politics, contests over turf and responsibilities, disagreements over which department has the lead, and the clash of personalities and egos all place a premium on ensuring that the equities of all involved agencies are considered, and on building an informal policy consensus amongst the players."[20] This recent description of the relationship between the President's policymaking apparatus and various executive agencies is strikingly similar to the more general observations made by Harold Seidman 38 years ago.

These general observations also appear to reflect the recent experience in the space policy sector. Reportedly, interagency disagreements slowed the progress of the space policy review ordered in June 2002 and required multiple drafts of a national space policy statement before it could be sent to the President for approval in August 2006. In the space sector, "an informal policy consensus" seemingly proved very elusive, and the distribution of power between the Executive Office and the disagreeing agencies made it almost impossible to force agreement from the White House.

Lessons Learned

One clear observation that follows from the above review is that many approaches to organizing White House space policy management have been tried in the last half-century. Thus, any structure that might emerge in the future is likely to resemble a prior structure or include elements of prior structures that had previously been tried.

A second observation is that a separate White House space policy organization, such as a space council, has not been successful in demonstrating its superiority as an organizational approach. Although the National Aeronautics and Space Council existed from 1958 to 1973, it never became the major, much less the sole, means for developing a national approach to what would now be called spacepower. With only a few exceptions, other Executive Office organizations, particularly the Office of Science and Technology Policy and the National Security Council, not to mention the White House budget office, and the heads of the executive branch space agencies were not willing to defer to the council as the primary forum for developing space policy options for the President. Reestablishing the National Space Council in 1989 was an initiative forced on a reluctant White House by Congress. In its 4 years of operation, an activist council staff managed to alienate most executive agencies. Its major policy proposal, the Space Exploration Initiative, was stillborn; the council did not prove an effective mechanism for rallying broad support for a Presidential space initiative or for convincing the NASA leadership that the initiative was the proper course of action to follow. One possible reason for the space council's lack of influence is that it has been headed during most of its history by a Vice President who was not a close ally of the President, who had no strong Washington political base of his own, and thus could not call on either the President's or his own power to back up the guidance provided by the council and its staff. In addition, by operating outside of the National Security Council structure, the space council found it very difficult to exert influence on national security space issues.

On the positive side, the National Space Council between 1989 and 1992 did commission two high-level external reviews of space issues and did create a well-qualified external Space Policy Advisory Board that was able to produce three insightful reports in a short period of time, demonstrating that there could be value in such an advisory body. As a Presidential appointee, the executive secretary of the National Space Council could serve as a spokesman for the White House on space policy matters. But the Space Council mechanism did not demonstrate sufficient value to be maintained in existence as the administration changed in 1993.

Giving the Office of Science and Technology Policy and the National Science and Technology Council the lead responsibility in space policy, as was the case during the Clinton administration, is likely to have biased the policy debate toward treating space as a research and development issue. Approaching space issues from this perspective is not likely to fully capture all dimensions of a spacepower approach to national space policy. The reality is that the OSTP and NSC staffs have worked closely together, whichever parent organization has lead responsibility, but at the more senior levels of decisionmaking, OSTP leaders come from different backgrounds than their NSC counterparts, and as space issues have worked their way up the OSTP chain of command they were viewed differently than if they had been considered issues of broad national security policy.

A persistent problem for White House control over the totality of the Nation's space effort has been the diffuse structure and strongly entrenched position of the various elements of the national security space sector. It has been extremely difficult for the Executive Office staff to penetrate and then influence the inner workings of that sector. The 2001 recommendations of the Space Commission and the 2008 recommendations of the Allard Commission were intended to provide a more integrated national security space sector, more amenable to central management within the Department of Defense (and by implication, the White House).

It seems that only the National Security Council within the White House structure brings to bear the requisite perspectives and institutional position to have a reasonable chance to be effective in advancing U.S. spacepower and linking it to U.S. scientific, economic, and national security interests. As the most recent statement of national space policy notes:

In this new century, those who effectively utilize space will enjoy added prosperity and security and will hold a substantial advantage over those who do not. Freedom of action in space is as important to the United States as air power and sea power. In order to increase knowledge, discovery, economic prosperity, and to enhance the national security, the United States must have robust, effective, and efficient space capabilities.[21]

Is the Present Structure Working?

Saying that in principle the National Security Council is the appropriate venue for managing U.S. space activities in ways most likely to maximize the contributions of spacepower to broad national objectives does not mean that in practice it now has either the mandate or the organizational capabilities to carry out that role. As noted earlier, in January 2001, the Space Commission concluded that "the present interagency process is inadequate to address the number, range, and complexity of today's space issues, which are expected to increase over time." Would an objective review of the management of national space policy since the Space Commission submitted its report reach a similar conclusion today? It seems as if the answer is "yes," given how close the conclusions and recommendations of the 2008 Allard Commission were to those of the 2001 Space Commission.

There were a number of changes in the White House and interagency management of the U.S. space program during the Presidency of George W. Bush. As has already been discussed, in 2001 the lead in space policy at the Presidential level was switched from OSTP to the NSC, and an NSC official chaired the Space Policy Coordinating Committee. The NSC staff (working with the OSTP) drafted the initial versions of the five new space policy statements that were issued between 2002 and 2006, which in a bureaucratic context provide an important point of leverage. However, space matters have been dealt with at a relatively junior level within the NSC structure, including the membership of the PCC, and there is still only one NSC staff person with primary responsibility for space matters.

The August 2006 national space policy identifies key areas for top-level attention:

- developing space professionals
- improving space system development and procurement
- strengthening and maintaining the U.S. space-related science, technology, and industrial base
- increasing and strengthening interagency partnerships.

Indeed, innovative interagency mechanisms in specific areas of space activity have recently emerged as complements to the central management of space policy and programs. These include (dating from 1994) the Integrated Program Office for the troubled National Polar Orbiting Environmental Satellite System and, since 2004, a National Space-based Positioning, Navigation, and Timing (PNT) Executive Committee chaired by Deputy Secretaries of Defense and Transportation, supported by a dedicated staff, and with an external Space-based PNT Advisory Board. These two structures are intended to provide a national perspective in their areas of focus; they operate under the guidance provided by White House space policy statements.

In addition, since 1997, NASA and the national security space community have jointly worked through a Partnership Council to discuss issues of mutual interest. Current members of the Partnership Council include NASA, U.S. Strategic Command, the Air Force Space Command, Defense Research and Engineering, the Office of the Undersecretary of the Air Force for Space, the NRO, and the Central Intelligence

Agency. The council meets at least twice a year at the principals level. This mechanism, operating at the interagency level, could be a particularly useful tool if it were linked to a broad national perspective on the development and use of spacepower.

Even so, significant problems in the integration of U.S. space efforts across the four sectors of activity remain. A "Committee on U.S. Space Leadership" in March 2009 noted that "there are serious and systemic problems which portend a broad erosion of U.S. leadership and advantage in space." The committee called for establishing a "White House focal point and mechanism" for establishing strategic direction and priorities, for providing management oversight, and for coordinating decisions and actions across departments and agencies.[22]

Modest Proposals for Change

Two of the various recent recommendations seem to have continuing merit for the Obama administration:

- Creating within the National Security Council context (perhaps with OSTP involvement as well) some sort of standing interagency body for space involving more senior officials than has been the case for the Space Policy Coordinating Committee. This would provide for the White House a continuing focus on the condition of the Nation's spacepower capabilities and on their use to achieve various national objectives. Such a body would need to go beyond the traditional National Security Council focus to reflect the interests and perspectives of the civilian and commercial space sectors.
- Providing this body with adequate staff support with experience in all space sectors. A separate small space office could be created with one senior director for space and two or three other staff members, with one or two coming from outside the national security community. Rather than depend on only OSTP staff for support, this would mean that the NSC staff would have all the capabilities needed to manage the development of space policies and oversee their implementation.

In essence, what could be done is creating a mini-Space Council, but within the overall National Security Council structure rather than separate from it. The National Security Council historically has had good links to U.S. foreign policy and international interests. However, it has more limited experience in dealing with science and technology and commercial issues. Creating a National Security Council staff element with officials experienced in such issues could provide a comprehensive perspective on spacepower issues for the Senior Interagency Group for Space and ultimately for the President.

The benefits of creating a Presidential Space Advisory Group are not as clear. There is limited precedent for the NSC staffing a standing external advisory committee, which would have to be the case if the NSC became the central focal point for national space issues. (One important exception to this statement is the President's Foreign Intelligence Advisory Board.) Given the sensitivity of most issues that are considered in the NSC context, there might be issues of adequate clearances and confidentiality of such a group's deliberations; and an advisory committee operating under the guidelines of the Federal Advisory Committee Act is somewhat at odds with the character of National Security Council activities. The Vice President's Space Policy Advisory Board was active for only 6 months in 1992 at the end of the first Bush administration, so it is difficult to assess its value to space policymaking. On the other hand, that board did produce four useful reports in its brief existence, suggesting that there could be value in an external advisory group operating under rules that allowed access to classified information and confidential advice to the Executive Office and the President.

Most fundamental, however, is convincing the President that the Space Commission was correct in its 2001 assessment that "the United States has a vital national interest in space. . . . [Space] deserves the attention of the national leadership, from the President on down." Providing a structure for effective Presidential space leadership will have limited impact if that leadership itself is missing. To enable full value from the Nation's spacepower, "sustained leadership must emerge, as it did early in the first [space] age, to guide and direct transformation of U.S. space efforts toward realizing their potential to serve the national interest."[23]

During his Presidential campaign, Barack Obama issued a lengthy statement of his views on space that seemed to reflect such a perspective. In addition, he called for reestablishing a National Space Council, reporting to him as President. Such a council, he suggested, would "oversee and coordinate civilian, military, commercial, and national security space activities." It would "solicit public participation, engage the international community, and work toward a 21st-century vision of space."[24] As this essay is written, the Obama administration is still considering how best to organize itself for space policy. But there are strong indications that President Obama recognizes the important contributions that space leadership can make to advancing U.S. interests. That realization is more important than whatever organizational scheme is ultimately adopted, but its translation into policy and actions can certainly be facilitated by an effective White House structure for space.

Notes

1. Harold Seidman, *Politics, Position, and Power: The Dynamics of Federal Organization* (New York: Oxford University Press, 1970).
2. Ibid., 73–74.
3. Ibid., 76.
4. Report of the Commission to Assess United States National Security Space Management and Organization, January 11, 2001, 82–83.
5. Ibid., 84–85.
6. Ibid., 84.
7. Ibid., 83–84.
8. Institute for Defense Analyses, *Leadership, Management and Organization for National Security Space*, July 2008, ES–4.

9. John M. Logsdon et al., eds., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. I, *Organizing for Exploration* (Washington, DC: NASA Special Publication 4407, 1995), 629–630.
10. See John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge: MIT Press, 1970), 23–24, for an account of these organizational steps.
11. Ibid., 27.
12. The statement can be found in Logsdon, *Exploring the Unknown*, 362–373. The quoted material is from page 362.
13. Ibid., 415.
14. Ibid., 424.
15. Ibid. See 439–452 for a copy of the memorandum.
16. White House, Reorganization Plan 1, January 26, 1973, available at <www.washingtonwatchdog.org/documents/usc/ttl5/app/0167/0167/index.html>.
17. Logsdon, *Exploring the Unknown*, 593.
18. However, the SIG (Space) mechanism was bypassed as the question of whether to approve development of a space station was considered by President Reagan in favor of a Cabinet Council on Commerce.
19. The White House, National Security Policy Directive 1, "Organization of the National Security Council System," February 13, 2001, available at <www.fas.org/irp/offdocs/nspd/nspd-1.htm>.
20. Alan G. Whittaker, Frederick C. Smith, and Elizabeth McKune, *The National Security Policy Process: The National Security Council and Interagency System* (Washington, DC: Industrial College of the Armed Forces, National Defense University, August 2005), 25–26.
21. The text of the fact sheet summarizing the unclassified version of the policy is available at <www.ostp.gov/html/US%20National%20Space%20Policy.pdf>.
22. Committee on U.S. Space Leadership, Memorandum for the President, "America's Leadership in Space," March 10, 2009.
23. Joseph Fuller, Jr., "It's Time for a New Space Age," *Aviation Week and Space Technology* 166, no. 2 (January 8, 2007), 7.
24. Barack Obama, "Advancing the Frontiers of Space Exploration," August 17, 2008.

Chapter 28:

Space Law and the Advancement of Spacepower

Peter L. Hays

Space law has and should continue to play an essential role in the evolution of spacepower. Testing the principle of "freedom of space" and helping establish the legality of satellite overflight were primary objectives of National Security Council Directive 5520, the first U.S. space policy, approved by President Dwight D. Eisenhower in May 1955;[1] during the 1960s, the superpowers and other emerging spacefaring states negotiated a far-reaching and forward-thinking Outer Space Treaty (OST);[2] and today, a variety of transparency and confidence-building measures (TCBMs) for space are being discussed and debated in a number of fora.[3] Law can be perhaps the single most important means of providing structure and predictability to humanity's interactions with the cosmos. Justice, reason, and law are nowhere more needed than in the boundless, anarchic, and self-help environment of the final frontier. The topics that space law is designed to address, the precedents from which it is drawn, and the pathways ahead that it illuminates will be critical determinants of the future development of spacepower.

Although there is some substance to arguments that the OST only precludes those military activities that were of little interest to the superpowers and does not bring much clarity or direction to many of the most important potential space activities, the treaty nonetheless provides a solid and comprehensive foundation upon which to build additional legal structures needed to advance spacepower. Spacefaring actors can most effectively improve on this foundation through a number of actions including further developing and refining the OST regime, adapting the most useful parts of analogous regimes such as the Law of the Sea and Seabed Authority mechanisms, and rejecting standards that stifle innovation, inadequately address threats to humanity's survival, or do not provide opportunities for rewards commensurate with risks undertaken. In the three sections below, this chapter explores other specific ways improvements in space law may contribute to furthering the quest for sustainable space security, enabling more direct creation of wealth in and from space, and ultimately improving the odds for humanity's survival by helping to protect the Earth and space environments. Without clearer and better developed space law, humanity may squander opportunities and investments, making it more difficult for spacepower to enable these and other critical contributions to our future.

While desires for better refined space law to advance spacepower may be clear, progress toward developing and implementing improvements is not likely to be fast or easy. Terrestrial law evolved fairly steadily and has operated over millennia. Space law, by contrast, is a relatively novel concept that rapidly emerged within a few years of the opening of the space age and thereafter greatly slowed. The objectives of space law must include not just aspirational goals such as structuring competition between humans and helping define and refine fundamental interactions between humanity and the cosmos but also more mundane issues such as property rights and commercial interests. It is likely there will be growing pressure for space law to provide greater predictability and structure in many areas despite the fact that it can be very difficult to establish foundational legal elements for the cosmic realm such as evidence, causality, attribution, and precedence. Moreover, any movement toward improving space law is likely to be slowed by discouraging attributes associated with spacepower that include very long timelines and prospects for only potential or intangible benefits. These factors can erode acceptance of and support for improving space law at both the personal and political levels, but they also point to the need for an incremental approach and reinforce the long-term value of law in providing stability and predictability.

Other impediments to further developing space law are exacerbated by a lack of acceptance in some quarters that sustained, cooperative efforts are often the best and sometimes the only way in which humanity can address our most pressing survival challenges. Cosmic threats to humanity's survival exist and include the depletion of resources and fouling of our only current habitat, threats in the space environment such as large objects that could strike Earth and cause cataclysmic damage, and the eventual exhaustion and destruction of the Sun. The message is clear: environmental degradation and space phenomena can threaten our existence, but humanity can improve our odds for survival *if* we can cooperate in grasping and exploiting survival opportunities. Law can provide one of the most effective ways to structure and use these opportunities. Sustained dialogue of the type this volume seeks to foster can help raise awareness, generate support for better space law, and ultimately nurture the spacepower needed to improve our odds for survival.

The Quest for Sustainable Security

In examining space law, spacepower, and humanity's quest for sustainable security, it is prudent for spacefaring actors to transcend traditional categories and approaches by considering resources in novel, broad, and multidimensional ways. This chapter attempts to employ the spirit of this unrestrained approach but is not suggesting that everything discussed would necessarily turn out to be useful or implementable in the real world. In addition, it is often not practical or even possible to examine space law developments in discrete ways by delineating between legal, technical, and policy considerations or between terrestrial and space security concerns. Over the long run, however, an expansive approach will undoubtedly reveal and help create the most opportunities to advance space law and spacepower in the most significant and lasting ways. Nonetheless, when beginning the journey, small, incremental steps are the most pragmatic way to develop and implement more effective space law, and the process should first focus on improving and refining the foundation provided by the OST regime.

Most spacefaring actors understand the merits and overall value of the OST regime; they are much more interested in building upon this foundation than in creating a new structure. As the most important first steps toward further developing space law, the international community needs to find better ways to achieve more universal adherence to the regime's foundational norms and embed all important spacefaring actors more completely within the regime. Beginning work to include major non-state actors in more explicit ways could prove to be a difficult undertaking that would require substantial expansion of the regime and probably should be approached incrementally. Fortunately, the security dimensions of the regime have opened windows of opportunity and important precedents have been set by expanding participation in the United Nations Committee on the Peaceful Uses of Outer Space and the World Radio Conferences of the International Telecommunications Union (ITU) to include nonstate actors as observers or associate members. Some form of two-tiered participation structure within the OST regime might be appropriate for a number of years and it may prove impractical to include nonstate actors in a formal treaty, but steps toward expanded participation should begin now, both to capture the growing spacepower of nonstate actors and to harness their energy in helping achieve more universal adherence to the regime. Perhaps most importantly, these initial steps should help promote a sense of stewardship for space among more actors and increase attention on those parties that fail to join or comply with these norms. Of course, these first steps alone would be insufficient to make large improvements or assure compliance with the regime, yet they might be among the most easily undertaken and significant ways to advance space law in the near term. Other specific areas within the OST regime that should be better developed, perhaps through creation of a standing body with implementation responsibilities, include the article VI obligations for signatories to authorize and exercise continuing supervision over space activities and the article IX responsibilities for signatories to undertake or request appropriate international consultations before proceeding with any activity or experiment that would cause potentially harmful interference.

One key way the United States could help better define OST implementation obligations and demonstrate leadership in fostering cooperative spacepower would be to share space situational awareness (SSA) data globally in more effective ways through the Commercial and Foreign Entities (CFE) program or some other approach. Congress has extended the CFE Pilot Program through September 2010 and, following the February 2009 collision between the Iridium and Cosmos satellites, there is more worldwide attention focused on space debris and spaceflight safety as well as considerable motivation for the United States to improve the program by providing SSA data to more users in more timely and consistent ways. A most useful specific goal for the CFE program would be development of a U.S. Government–operated data center for ephemeris, propagation data, and premaneuver notifications for all active satellites; consideration should also be given to the utility and modalities of creating or transitioning such a data center to international auspices.[4] Users would voluntarily contribute data to the center, perhaps through a Global Positioning System (GPS) transponder on each satellite, and the data would be constantly updated, freely available, and readily accessible so that it could be used by satellite operators to plan for and avoid conjunctions.[5] Difficult legal, technical, and policy issues that inhibit progress on sharing SSA data include bureaucratic inertia, liability, and proprietary concerns; nonuniform data formatting standards and incompatibility between propagators and other cataloguing tools; and security concerns over exclusion of certain satellites from any public data. Some of these legal concerns could be addressed by working toward better cradle-tograve tracking of all catalogued objects to help establish the launching state and liability; using opaque processes to exclude proprietary information from public databases to the maximum extent feasible; and indemnifying program operators, even if they provide faulty data that results in a collision, so long as they operate in good faith, exercise reasonable care, and follow established procedures.

History suggests there is a very important role for militaries both in setting the stage for the emergence of international legal regimes and in enforcing the norms of those regimes once they are in place. Development of any TCBMs for space, such as rules of the road or codes of conduct, should draw closely from the development and operation of such measures in other domains such as sea or air. The international community should consider the most appropriate means of separating military activities from civil and commercial activities in the building of these measures because advocating a single standard for how all space activities ought to be regulated or controlled is inappropriately ambitious and not likely to be helpful. The U.S. Department of Defense requires safe and responsible operations by warships and military aircraft but they are not legally required to follow all the same rules as commercial traffic and sometimes operate within specially protected zones that separate them from other traffic. Full and open dialogue about these ideas and others will help develop space rules that draw from years of experience in operating in these other domains and make the most sense for the unique operational characteristics of space. Other concerns surround the implications of various organizational structures and rules of engagement for potential military operations in space. Should such forces operate under national or only international authority, who should decide when certain activities constitute a threat, and how should such forces be authorized to engage threats, especially if such engagements might create other threats or potentially cause harm to humans or space systems? Clearly, these and a number of other questions are very difficult to address and require careful international vetting well before actual operation of such forces in space. Finally, consider the historic role of the Royal and U.S. Navies in fighting piracy, promoting free trade, and enforcing global norms against slave trading. Should there be analogous roles in space for the U.S. military and other military forces today and in the future? What would be the space component of the Proliferation Security Initiative and how might the United States and others encourage like-minded actors to cooperate on such an initiative? Attempts to create legal regimes or enforcement norms that do not specifically include and build upon military capabilities are likely to be divorced from pragmatic realities and ultimately be frustrating efforts.[6]

Seemingly new U.S. focus and direction on space TCBMs initially was provided by a statement that appeared on the Obama administration White House Web site on January 20, 2009: "Ensure Freedom of Space: The Obama-Biden administration will restore American leadership on space issues, seeking a worldwide ban on weapons that interfere with military and commercial satellites."[7] The language about seeking a worldwide ban on space weapons was similar to position papers issued during the Obama-Biden campaign but much less detailed and nuanced; it drew considerable attention and some criticism.[8] By May 2009, the "Space" part of the Defense Issues section on the White House Web site had been changed to read:

Space: The full spectrum of U.S. military capabilities depends on our space systems. To maintain our technological edge and protect assets in this domain, we will continue to invest in next-generation capabilities such as operationally responsive space and global positioning systems. We will cooperate with our allies and the private sector to identify and protect against intentional and unintentional threats to U.S. and allied space capabilities.

Ongoing space policy reviews including a congressionally directed Space Posture Review and Presidential Study Directives on National Space Policy are likely to encourage policies that are more supportive of pursuing TCBMs as well as greater reliance on commercial and international partners.[9] Consideration is also being given to the best ways to reconcile any new approaches with the 2006 U.S. National Space Policy language about opposing "development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space" while encouraging "international cooperation with foreign nations and/ or consortia on space activities that are of mutual benefit."[10] Spacepower actors can expect to continue making progress in developing effective, sustainable, and cooperative approaches to space security by building on the ongoing thoughtful dialogue between all major space actors in several venues that emphasizes a number of mainly incremental, pragmatic, technical, and bottom-up steps. Prime examples of this approach include the February 2008 adoption by the United Nations General Assembly of the Inter-Agency Debris Coordination Committee (IADC) voluntary guidelines for mitigating space debris and the December 2008 release from the Council of the European Union of a draft Code of Conduct for outer space activities.[11]

Beyond the OST, efforts to craft comprehensive, formal, top-down space arms control or regulation continue to face the same significant problems that have overwhelmed attempts to develop such mechanisms in the past. The most serious of these problems include disagreements over the proper forum, scope, and object for negotiations; basic definitional issues about what is a "space weapon" and how they might be categorized as offensive or defensive and stabilizing or destabilizing; and daunting concerns about whether adequate monitoring and verification mechanisms can be found for any comprehensive and formalized TCBMs. These problems relate to a number of thorny specific issues such as whether the negotiations should be primarily among only major spacefaring actors or more multilateral, what satellites and other terrestrial systems should be covered, and whether the object should be control of space weapons or TCBMs for space; the types of TCBMs that might be most useful (for example, rules of the road or keep-out zones) and how these approaches might be reconciled with the existing space law regime; and verification problems such as how to address the latent or residual antisatellite (ASAT) capabilities possessed by many dual-use and military systems or how to deal with the significant military potential of even a small number of covert ASAT systems.

New space system technologies, continuing growth of the commercial space sector, and new verification and monitoring methods interact with these existing problems in complex ways. Some of the changes would seem to favor TCBMs, such as better radars and optical systems for improved SSA, attribution, and verification capabilities;

technologies for better space system diagnostics; and the stabilizing potential of redundant and distributed space architectures that create many nodes by employing larger numbers of smaller and less expensive satellites. Many other trends, however, would seem to make space arms control and regulation even more difficult. For example, micro- or nanosatellites might be used as virtually undetectable active ASATs or passive space mines; proliferation of space technology has radically increased the number of significant space actors to include a number of nonstate actors that have developed or are developing sophisticated dual-use technologies such as autonomous rendezvous and docking capabilities; satellite communications technology can easily be used to jam rather than communicate; and growth in the commercial space sector raises issues such as how quasi-military systems could be protected or negated and the unclear security implications of global markets for dual-use space capabilities and products.

There is disagreement about the relative utility of top-down versus bottom-up approaches to developing space TCBMs and formal arms control but, following creation of the OST regime, the United States and many other major spacefaring actors have tended to favor bottom-up approaches, a point strongly emphasized by U.S. Ambassador Donald Mahley in February 2008: "Since the 1970s, five consecutive U.S. administrations have concluded it is impossible to achieve an effectively verifiable and militarily meaningful space arms control agreement."[12] Yet this assessment may be somewhat myopic since strategists need to consider not only the well-known difficulties with top-down approaches but also the potential opportunity costs of inaction and to recognize when they may need to trade some loss of sovereignty and flexibility for stability and restraints on others. Since the United States has not tested a kinetic energy ASAT since September 1985 and has no program to develop such capabilities, would it have been better to foreclose this option in order to purse a global ban on testing kinetic energy ASATs, and would such an effort have produced a restraining effect on Chinese development and testing of ASAT capabilities? This may have been a lost opportunity to pursue legal approaches but is a complex, multidimensional, and interdependent issue shaped by a variety of other factors such as inabilities to distinguish between ballistic missile defense and ASAT technologies, reluctance to limit technical options after the end of the Cold War, emergence of new and less easily deterred threats, and the demise of the Anti-Ballistic Missile Treaty.

Moreover, the Chinese, in particular, apparently disagree with pursuing only bottom-up approaches and, in ways that seem both shrewd and hypocritical, are currently developing significant counterspace capabilities while simultaneously advancing various top-down proposals in support of prevention of an arms race in outer space initiatives and moving ahead with the joint Chinese-Russian draft treaty on Prevention of Placement of Weapons in Outer Space (PPWT) introduced at the Conference on Disarmament in February 2008. If the Chinese are attempting to pursue a two-track approach to space arms control, they need to present that argument to the international community much more explicitly. The current draft PPWT goes to considerable lengths in attempting to define space, space objects, weapons in space, placement in space, and the use or threat of force, but there are still very considerable definitional issues with respect to how specific capabilities would be classified. An even more significant problem relates to all the terrestrial capabilities that are able to eliminate, damage, or disrupt the normal function of objects in outer space, such as the Chinese direct ascent ASAT. One must question the utility of a proposed agreement that does not address the significant security implications of current space system support for network enabled terrestrial warfare, does not deal with dual-use space capabilities, seems to be focused on a class of weapons that does not exist or at least is not deployed in space, is silent about all the terrestrial capabilities that are able to produce weapons effects in space, and would not even ban development and testing of space weapons, only their use.[13] Given these weaknesses in the PPWT, it seems plausible that it is designed as much to continue political pressure on the United States and derail U.S. missile defense efforts as it is to promote sustainable space security.

Since Sino-American relations in general and space relations in particular are likely to play a dominant role in shaping the quest for space-power and sustainable security during this century, other proposed Sino-American cooperative space ventures or TCBMs are worthy of further consideration, including inviting a taikonaut to fly on one of the remaining space shuttle missions and making specific, repeated, and public invitations for the Chinese to join the International Space Station program and other major cooperative international space efforts. The United States and China could also work toward developing nonoffensive defenses of the type advocated by Philip Baines.[14] Kevin Pollpeter explains how China and the United States could cooperate in promoting the safety of human spaceflight and "coordinate space science missions to derive scientific benefits and to share costs. Coordinating space science missions with separately developed, but complementary space assets, removes the chance of sensitive technology transfer and allows the two countries to combine their resources to achieve the same effects as jointly developed missions."[15] Michael Pillsbury outlined six other areas where U.S. experts could profitably exchange views with Chinese specialists in a dialogue about space weapons issues: "reducing Chinese misperceptions of U.S. Space Policy, increasing Chinese transparency on space weapons, probing Chinese interest in verifiable agreements, multilateral versus bilateral approaches, economic consequences of use of space weapons, and reconsideration of U.S. high-tech exports to China."[16] Finally, Bruce MacDonald's report for the Council on Foreign Relations, "China, Space Weapons, and U.S. Security," offers a number of noteworthy additional specific recommendations for both the United States and China. For the United States, MacDonald recommends assessing the impact of different U.S. and Chinese offensive space postures and policies through intensified analysis and "crisis games" in addition to wargames; evaluating the desirability of a "no first use" pledge for offensive counterspace weapons that have irreversible effects; pursuing selected offensive capabilities meeting important criteria—including effectiveness, reversible effects, and survivability—in a deterrence context to be able to negate adversary space capabilities on a temporary and reversible basis; refraining from further direct ascent ASAT tests and demonstrations as long as China does, unless there is a substantial risk to human health and safety from uncontrolled space object reentry; and entering negotiations on a kinetic energy ASAT testing ban. MacDonald's recommendations for China include providing more transparency into its military space programs; refraining from further direct ascent ASAT tests as long as the United States does; establishing a senior national security coordinating body, equivalent to a Chinese National Security Council; strengthening its leadership's foreign policy understanding by increasing the international affairs training of senior officer candidates and establishing an international security affairs office within the People's Liberation Army; providing a clear and credible policy and doctrinal context for its 2007 ASAT test and counterspace programs more generally, and addressing foreign concerns over China's ASAT test; and offering to engage in dialogue with the United States on mutual space concerns and become actively involved in discussions on establishing international space codes of conduct and confidence-building measures.[17]

Harvesting Energy and Creating Wealth in and from Space

Spacefaring actors should again consider revising and further developing the OST regime as a key first step when seeking better ways to harvest energy and create wealth in and from space. Expanding participation in the OST as recommended above would also be helpful, but other steps such as reducing liability concerns and clarifying legal issues with respect to harvesting energy and generating wealth are likely to be more effective in furthering commercial development of space. Of course, as with security, a range of objectives and values are in tension and require considerable effort to change or keep properly balanced. The OST has been extremely successful thus far with respect to its primary objective of precluding replication of the colonial exploitation that plagued much of Earth's history. The international community should now consider whether the dangers posed by potential cosmic land grabs continue to warrant OST interpretations that may be stifling development of spacepower, and, if these values are found to have become imbalanced, how impediments might best be reduced. Spacefaring actors should again use an expansive approach to consider how perceived OST restrictions and the commercial space sector have evolved and might be further advanced in a variety of ways including reinterpreting the OST regime itself, becoming more intentional about developing spacepower, creating space-based solar power capabilities, and improving export controls.

While the OST has thus far been unambiguous and successful in foreclosing sovereignty claims and the ills of colonization, it has been less clear and effective with respect to de facto property rights and other liability and commercialization issues. OST language, negotiating history, and subsequent practice do not preclude some level of commercial activity in space and on celestial bodies, but various articles of the OST support different interpretations about the potential scope of and limitations on this activity. The treaty most clearly allows those commercial activities that would be performed to support exploration or scientific efforts. It is far more problematic with respect to commercial space activity that would result in private gain or not somehow equitably distribute gains among all states. Even if it were found that commercial activities would not "appropriate" space resources, however that might be defined, it would be difficult to reconcile such activity with the spirit of the OST regime, especially since the regime provides no guidance on how private or unequal gains might be distributed. In addition to clarifying potential property rights and wealth distribution mechanisms, consideration should be given to reevaluating liability standards. The OST and 1972 Liability Convention establish two distinct liability structures: launching states are absolutely liable to pay compensation for any damages caused by space objects on Earth or to aircraft in flight but are only liable for damages caused in space by space objects if found to be negligent. A challenge for the international community is how best to evolve the existing space law regime based on either absolute liability or fault/negligence, depending upon the location of the incident, into a structure that might provide enough clarity to help establish liability for damages in space and perhaps provide better incentives for commercial development.[18]

Additional interpretation issues stem from the fact that OST is embedded within a larger body of international law and that broad regime is evolving, sometimes in ambiguous and contradictory ways. Elements within this large regime are of unclear and unequal weight: the Moon Agreement with its Common Heritage of Mankind (CHM) approach to communal property rights and equally shared rewards undoubtedly has some effect in advancing the CHM principle in both formal and customary international law. At the level of formal international law, however, the Moon Treaty falls well short of the OST due to its lack of parties, especially among major spacefaring states, particularly in contrast to the OST, a treaty that has been ratified by some 94 states and in force for over 40 years.

Most fundamentally, however, the current lack of clarity within space law about property rights and commercial interests is the result of both space law and space technology being underdeveloped and immature. Of course, there is also a "chicken-and-egg" factor at work since actors are discouraged from undertaking the test cases needed to develop and mature the regime because of the immaturity of the regime and their unwillingness to develop and employ improved technologies and processes as guinea pigs in whatever legal processes would be used to resolve property rights and reward structures. The most effective way to move past this significant hurdle would be to create more clear mechanisms for establishing property rights and processes by which all actors, especially commercial actors, could receive rewards commensurate with the risks they undertake. In addition, any comprehensive reevaluation of space property rights and liability concerns should also consider how these factors are addressed in analogous regimes such as the Seabed Authority in the Law of the Sea Treaty. Unfortunately, however, there are also several problems with attempting to draw from these precedents. First, several of the analogous regimes like the Law of the Sea build from CMH premises in several ways and it is not clear this approach is entirely applicable or helpful when attempting to sort through how the OST should apply to issues like property rights and reward structures. Second, while these analogous regimes are undoubtedly better developed than the OST and have a significant potential role in providing precedents, today they are still somewhat underdeveloped and immature with respect to their application in difficult areas such as property rights and reward structures, again limiting the current utility of attempting to draw from these precedents.

Provisions of the OST regime are probably the most important factors in shaping commercial space activity, but they are clearly not the only noteworthy legal and policy factors at work influencing developments within this sector. Legacy legal and policy structures developed during the Cold War were probably adequate for the amount of commercial space activity during that period, but it is far from clear they will be sufficient to address the significant and sustained increase in such activity since that time. In the 1960s, the United States was the first to begin developing space services such as communications, remote sensing, and launch capabilities but did so within the government sector. This approach began to change in the 1980s, first with the November 1984 Presidential Determination to allow some commercial communication services to compete with Intelsat and continuing with subsequent policies designed to foster development of a commercial space sector. By the late 1990s, commercial space activity worldwide had outpaced government activity, and although government space investments remain very important, they are likely to become increasingly overshadowed by commercial activity. It would be helpful if governments, and the U.S. Government in particular, could more explicitly develop and consistently implement legal structures and long-term policies that would better define and delineate between those space activities that ought to be pursued by the private and public sectors as well as more intentionally and consistently develop the desired degree of international cooperation in pursuing these objectives.

Other clear commercial and economic distinctions with the Cold War era have even more significant implications for the future of space-power: whereas the Soviet Union was only a military superpower, China is a major U.S. trading partner and an economic superpower that recently passed Germany to became the world's third largest economy, is poised to pass Japan soon, and is on a path to become larger than the U.S. economy, perhaps within only about 10 years. Because of its economic muscle, China can afford to devote commensurately more resources to its military capabilities and will play a more significant role in structuring the global economic system. For example, China holds an estimated $1.4 trillion in foreign assets (mainly U.S. treasury notes), an amount that gives it great leverage in the structure of the system.[19]

The United States and other major spacefaring actors lack, but undoubtedly need, much more open and comprehensive visions for how to develop spacepower. This study is one attempt to foster more dialogue about these issues, but the process should continue, become more intentional and formalized, and be supported by an enduring organizational structure that includes the most important stakeholders in the future of spacepower. Legal structures should be a foundational part of creating and implementing the vision to develop spacepower, but a broader approach should be:

> focused on opening space as a medium for the full spectrum of human activity and commercial enterprise, and those actions which government can take to promote and enable it, through surveys, infrastructure development, pre-competitive technology, and encouraging incentive structures (prizes, anchor-customer contracts, and property/exclusivity rights), regulatory regimes (port authorities, spacecraft licensing, public-private partnerships) and supporting services (open interface standards, RDT&E [research, development, test, and evaluation] facilities, rescue, etc.).[20]

In addition, consideration should be given to using other innovative mechanisms and nontraditional routes to space development, including a much wider range of Federal Government organizations and the growing number of state spaceport authorities and other organizations developing needed infrastructure. Finally, the United States should make comprehensive and careful exploration of the potential of space-based solar power its leading pathfinder in creating a vision for developing spacepower. Working toward harvesting this unlimited power source in economically viable ways will require development of appropriate supporting legal structures, particularly with respect to indemnification and potential public-private partnerships.

Global licensing and export controls for space technology have often been developed and implemented in inconsistent and counterproductive ways. It is understandable that many states view space technology as a key strategic resource and are very concerned about developing, protecting, and preventing the proliferation of this technology, but the international community, and the United States in particular, needs to find better legal mechanisms to balance and advance objectives in this area. Many current problems with U.S. export controls began after Hughes and Loral worked with insurance companies to analyze Chinese launch failures in January 1995 and February 1996. A congressional review completed in 1998 (Cox Report) determined these analyses violated the International Traffic in Arms Regulations (ITAR) by communicating technical information to the Chinese. The 1999 National Defense Authorization Act transferred export controls for all satellites and related items from the Commerce Department to the Munitions List administered by the State Department.[21] The stringent Munitions List controls contributed to a severe downturn in U.S. satellite exports.[22] To avoid these restrictions, foreign satellite manufacturers, beginning in 2002 with Alcatel Space (now Thales) and followed by European Aeronautic Defense and Space, Surrey Satellite Company, and others replaced all U.S.-built components on their satellites to make them "ITAR-free."[23]

There are two key reasons why the United States should move away from the priorities in its current space export control regime. First, an overly broad approach that tries to guard too many things dilutes monitoring resources and actually results in less protection for "crown jewels" than does a focused approach, and second, a more open approach is more likely to foster innovation, spur development of sectors of comparative advantage, and improve efficiency and overall economic growth. Congress and the Obama administration should make it a priority to reevaluate current U.S. export controls and adjust laws and policies accordingly. Excellent starting points are the recently released recommendations for rebalancing overall U.S. export control priorities in the congressionally mandated National Academies of Science study.[24] In addition, the United States should implement key recommendations from the Center for Strategic and International Studies study on the space industrial base such as removing from the Munitions List commercial communications satellite systems, dedicated subsystems, and components specifically designed for commercial use.[25]

Environmental Sustainability and Survival

Work toward developing space law to advance spacepower and improve environmental sustainability and humanity's odds for survival faces a number of daunting challenges, including a high "giggle factor," long timelines that can be beyond our political and personal awareness, and potential returns that are uncertain and intangible. While difficult, work in this area is absolutely critical since it may hold the key to humanity's survival, and it must be pursued with all the resources, consistency, and seriousness it deserves. The quest to improve space law to support environmental and survival objectives should focus on three areas: space debris, environmental monitoring, and planetary defense.

Human space activity produces many orbital objects; when these objects no longer serve a useful function, they are classified as space debris. Over time, human activity has generated an increasing amount of debris; the number of catalogued debris objects has gone from about 8,000 to over 18,000 during the past 20 years.[26] The most serious cause of debris is deliberate hypervelocity impacts between large objects at high orbital altitudes such as the Chinese direct ascent kinetic energy ASAT weapon test of January 2007, which now accounts for more than 25 percent of all catalogued objects in low Earth orbit (LEO).[27] If current trends continue, there is growing risk that space, and LEO in particular, will become increasingly unusable. Fortunately, there is also growing awareness and earnestness across the international community in addressing this threat. Overall goals for spacefaring actors with respect to space debris include minimizing its creation while mitigating and remediating its effects—space law can play an important role in all these areas. Key approaches to minimizing creation of debris are commercial best practices and evolving regimes such as the IADC voluntary guidelines adopted by the United Nations General Assembly in February 2008. Spacefaring actors also need to consider mechanisms to transition these voluntary guidelines into more binding standards and ways to impose specific costs such as sanctions or fines on actors that negligently or deliberately create long-lived debris. Fines could be applied toward efforts to further develop and educate spacefaring actors about the debris mitigation regime as well as to create and implement remediation techniques. An additional potential source of funding for mitigation and remediation would be establishing auctions for the radio frequency spectrum controlled by the ITU that would be analogous to the spectrum auctions conducted at the national level by organizations like the Federal Communications Commission. Finally, it must be emphasized that techniques for remediating debris using lasers or other methods are likely to have significant potential as ASAT weapons, and careful international consideration should be given to how and by whom such systems are operated.

Space provides a unique location to monitor and potentially remediate Earth's climate. It is the only location from which simultaneous in situ observations of Earth's climate activity can be conducted, and such observations are essential to developing a long-term understanding of potential changes in our biosphere. Because so much is riding on our understanding of the global climate and our potential responses to perceived changes, it is particularly important to apply apolitical standards in getting the science right and controlling for known space effects such as solar cycles when making these observations. If fears about global warming are correct and the global community wishes to take active measures to remediate these effects, space also provides a unique location to operate remediation options such as orbital solar shades.

It is also imperative that the United States and all spacefaring actors think more creatively about using spacepower to transcend traditional and emerging threats to our survival. Parts of space law can help to illuminate paths toward and develop incentives for creating a better future. Space, perhaps more than any other medium, is inherently linked to humanity's future and survival. We need to link these ideas and better articulate ways spacepower can light a path toward genuinely cooperative approaches for protecting the Earth and space environments from cataclysmic events such as large objects that may collide with Earth or gamma ray bursts that may have the potential to render huge swaths of space uninhabitable. Better knowledge about known threats such as near Earth objects (NEOs) is being acquired but more urgency is needed. All predicted near approaches and possible NEO impacts such as that of the asteroid Apophis, predicted for April 13, 2029, ought to be seen as opportunities since they provide critical real-world tests for our ability to be proactive in developing effective precision tracking and NEO mitigation capabilities. In the near term, it is most important for national and international organizations to be specifically charged with and resourced to develop better understanding of NEO threats and mitigation techniques that can be effectively applied against likely impacts. Ultimately, however, we cannot know of or effectively plan for all potential threats to Earth but should pursue a multidimensional approach to develop capabilities to improve our odds for survival and one day perhaps become a multiplanetary species.

There will be inevitable missteps, setbacks, and unintended consequences as we refine space law to improve our quest for sustainable space security, generate wealth in and from space, and protect the Earth and space environments. The inexorable laws of physics and of human interaction indicate that we will create the best opportunities for success in improving space law by beginning long-term, patient work now rather than crash programs later. This patient approach will allow the best prospects for space law to provide a solid foundation for the peaceful advancement of spacepower.

Notes

1. The best and most comprehensive analysis of the complex maneuvering by the superpowers at the opening of the space age remains Walter A. McDougall's Pulitzer Prize–winning . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985). National Security Council Directive 5520 is reprinted in John M. Logsdon, ed. *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. I, *Organizing for Exploration* (Washington, DC: NASA History Office, 1995), 308–313. McDougall in *Heavens and Earth* and R. Cargill Hall's introductory essay, "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring the Unknown* masterfully develop the context and purposes of the directive. Hall uses the term *stalking horse* to describe the purpose of the IGY satellite in relation to the WS–117L (America's first reconnaissance satellite program). *Peaceful purposes* for space activity are often referenced and cited but never authoritatively defined.

2. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (General Assembly resolution 2222 [XXI], annex), adopted December 19, 1966, opened for signature January 27, 1967, and entered into force October 10, 1967.
3. The term *transparency* apparently connotes espionage when translated into Chinese and since the Chinese are a key party that spacefaring actors wish to engage, consideration should be given to finding an alternative term, perhaps *clarity of intensions*.
4. For an outstanding and detailed analysis of the benefits and challenges associated with creation of an international data center, see Lee-Volker Cox, "Avoiding Collisions in Space: Is It Time for an International Space Integration Center?" research paper, U.S. Army War College, March 30, 2007, available at <www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA469676&Location=U2&doc=GetTRDoc.pdf>.
5. Space situational awareness (SSA) issues are framed by specialized concepts and jargon. *Conjunctions* are close approaches, or potential collisions, between objects in orbit. *Propagators* are complex modeling tools used to predict the future location of orbital objects. Satellite operators currently use a number of different propagators and have different standards for evaluating and potentially maneuvering away from conjunctions. Maneuvering requires fuel and shortens the operational life of satellites. Orbital paths are described by a set of variables known as ephemeris data; two-line element sets are the most commonly used ephemeris data. Much of this data is contained in the form of a satellite catalog. The United States maintains a public catalog at <www.space-track. org>. Other entities maintain their own catalogs. Orbital paths constantly are perturbed by a number a factors including Earth's inconsistent gravity gradient, solar activity, and the gravitational pull of other orbital objects. Perturbations cause propagation of orbital paths to become increasingly inaccurate over time; beyond approximately 4 days into the future, predictions about the location of orbital objects can be significantly inaccurate. For more about SSA concepts, see Brian Weeden, "The Numbers Game," *The Space Review*, July 13, 2009, available at <www.thespacereview.com/article/1417/1>. For discussion about ways to share SSA data and other space security ideas fostered by meetings between the Department of Defense Executive Agent for Space and the Chief Executive Officers of commercial satellite operators, see David McGlade, "Commentary: Preserving the Orbital Environment," *Space News*, February 19, 2007, 27.
6. On the role of militaries in enforcing legal norms and analogies between the law of the sea and space law, see R. Joseph DeSutter, "Space Control, Diplomacy, and Strategic Integration," *Space and Defense* 1, no. 1 (Fall 2006), 29–51.
7. The statement appeared on the Defense Agenda section of the White House Web site, available at <www.whitehouse.gov>.
8. See in particular, the *Space News* editorial for February 2, 2009, "Banning Space Weapons— and Reality."
9. Section 913 of the Fiscal Year 2009 National Defense Authorization Act (P.L. 110–417) directs the Secretary of Defense and Director of National Intelligence to submit a Space Posture Review to Congress by December 1, 2009. In addition, the Obama administration has ongoing Presidential Study Directives that are examining the need for changes to current National Space Policy; see Amy Klamper, "White House Orders Sweeping U.S. Space Policy Review," *Space News*, July 15, 2009.
10. The unclassified version of current National Space Policy was posted on the Office of Science and Technology Policy Web site on October 14, 2006.
11. United Nations General Assembly Resolution 62/217, "International Cooperation in the Peaceful Uses of Outer Space," February 1, 2008, and Council of the European Union, "Council Conclusions and Draft Code of Conduct for Outer Space Activity," December 3, 2008.
12. Ambassador Donald A. Mahley, remarks at the State of Space Security Workshop, Space Policy Institute, George Washington University, Washington, DC, February 1, 2008.
13. Fact sheet, "Preventing the Placement of Weapons in Outer Space: A Backgrounder on the Draft Treaty by Russia and China," ReachingCriticalWill.org, available at <www.reachingcriticalwill.org/legal/paros/wgroup/PAROS-PPWT-factsheet.pdf>. For an outstanding analysis of trigger events for space weaponization and why space-basing is not necessarily the most important consideration, see Barry D. Watts, *The Military Use of Space: A Diagnostic Assessment*

(Washington, DC: Center for Strategic and Budgetary Assessments, February 2001), 97–106. Watts argues: There are at least two paths by which orbital space might become a battleground for human conflict. One consists of dramatic, hard-to-miss trigger events such as the use of nuclear weapons to attack orbital assets. The other class involves more gradual changes such as a series of small, seemingly innocuous steps over a period of years that would, only in hindsight, be recognized as having crossed the boundary from force enhancement to force application. For reasons stemming from the railroad analogy . . . the slippery slope of halting, incremental steps toward force application may be the most likely path of the two. Watts discusses high-altitude nuclear detonations, failure of nuclear deterrence, and threats to use nuclear ballistic missiles during a crisis as the most likely of the dramatic trigger events.

14. Philip J. Baines, "The Prospects for 'Non-Offensive' Defenses in Space," in *New Challenges in Missile Proliferation, Missile Defense, and Space Security*, ed. James Clay Moltz (Monterey: Center for Nonproliferation Studies Occasional Paper no. 12, Monterey Institute of International Studies, July 2003), 31–48.
15. Kevin Pollpeter, *Building for the Future: China's Progress in Space Technology during the 10th 5-year Plan and the U.S. Response* (Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2008), 48–50.
16. Michael P. Pillsbury, "An Assessment of China's Anti-Satellite and Space Warfare Programs, Policies, and Doctrines," report prepared for the U.S.-China Economic and Security Review Commission, January 19, 2007, 48.
17. Bruce W. MacDonald, *China, Space Weapons, and U.S. Security* (New York: Council on Foreign Relations, September 2008), 34–38.
18. Although article VII of the Outer Space Treaty discusses liability, that article was further implemented in the Convention on International Liability for Damage Caused by Space Objects, commonly referred to as the Liability Convention. Under the Liability Convention, article II, a launching state is absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight. However, under articles III and IV, in the event of damage being caused other than on the surface of the Earth by a space object, the launching state is liable only if the damage is due to its fault or the fault of persons for whom it is responsible (that is, commercial companies) under a negligence standard. Convention on International Liability for Damage Caused by Space Objects (resolution 2777 [XXVI] annex), adopted November 29, 1971, opened for signature March 29, 1972, and entered into force September 1, 1972.
19. James Fallows, "The $1.4 Trillion Question," *The Atlantic* (January–February 2008).
20. Peter Garretson, "Elements of a 21st-century Space Policy," *The Space Review*, August 3, 2009, available at <www.thespacereview.com/article/1433/1>.
21. The January 1995 failure was a Long March 2E rocket carrying Hughes-built Apstar 2 spacecraft, and the February 1996 failure was a Long March 3B rocket carrying Space Systems/Loral-built Intelsat 708 spacecraft. Representative Christopher Cox (R–CA) led a 6-month long House Select Committee investigation that produced the "U.S. National Security and Military/Commercial Concerns with the People's Republic of China" report released on May 25, 1999 (available at <www.house.gov/coxreport>). In January 2002, Loral agreed to pay the U.S. Government $20 million to settle the charges of the illegal technology transfer and in March 2003, Boeing agreed to pay $32 million for the role of Hughes (which Boeing acquired in 2000). Requirements for transferring controls back to the State Department are in Sections 1513 and 1516 of the Fiscal Year 1999 National Defense Authorization Act. Related items are defined as "satellite fuel, ground support equipment, test equipment, payload adapter or interface hardware, replacement parts, and non-embedded solid propellant orbit transfer engines."
22. Satellite builders claim that their exports dropped 59 percent in 2000 and that since March 1999 their share of the global market declined sharply (from 75 percent to 45 percent). Evelyn Iritani and Peter Pae, "U.S. Satellite Industry Reeling Under New Export Controls," *The Los Angeles Times*, December 11, 2000, 1. According to *Space News,* 2000 marked the first time that U.S. firms were awarded fewer contracts for geostationary communications satellites than their European competitors (the Europeans were ahead 15 to 13). Peter B. de Selding and Sam Silverstein, "Europe Bests U.S. in Satellite Contracts in 2000," *Space News*, January 15, 2001, 1, 20.

23. Peter B. de Selding, "European Satellite Component Maker Says it is Dropping U.S. Components Because of ITAR," *Space News Business Report*, June 13, 2005; and Douglas Barrie and Michael A. Taverna, "Specious Relationship," *Aviation Week & Space Technology*, July 17, 2006, 93–96.
24. National Research Council, *Beyond "Fortress America:" National Security Controls on Science and Technology in a Globalized World* (Washington, DC: National Academies Press, 2009). With the new administration and Congress as well as former Congresswoman Ellen Tauscher confirmed in the key position of Under Secretary of State for Arms Control and International Security, conditions for changing the space export control law are the most favorable they have been for the last decade.
25. *Briefing of the Working Group on the Health of the U.S. Space Industrial Base and the Impact of Export Controls* (Washington: Center for Strategic and International Studies, February 2008).
26. Comprehensive and current information about orbital debris is provided by NASA and the European Space Agency at <www.orbitaldebris.jsc.nasa.gov> and <www.esa.int/esaMI/Space_Debris/ index.html>.
27. "Fengyun 1–C Debris: Two Years Later," *Orbital Debris Quarterly News* 13, no. 1 (January 2009), 2. As a result of the January 11, 2007, Chinese ASAT test, the U.S. Space Surveillance Network has catalogued 2,378 pieces of debris with diameters greater than 5 centimeters, is tracking 400 additional debris objects that are not yet catalogued, and estimates the test created more that 150,000 pieces of debris larger than 1 square centimeter. Unfortunately, less than 2 percent of this debris has reentered the atmosphere so far and it is estimated that many pieces will remain in orbit for decades and some for more than a century. By contrast, destruction of the inoperative USA–193 satellite on February 21, 2008, occurred at a much lower altitude and did not produce long-lived debris; the last piece of catalogued debris from this intercept reentered on October 9, 2008. On the engagement of USA–193 see, in particular, James Oberg, "OPERATION BURNT FROST: Five Myths about the Satellite Smashup," NBC News Analysis, February 27, 2008, and James E. Oberg, "Down in Flames: Media ‘Space Experts' Flub the Shoot-Down Story," *The New Atlantis*, no. 24 (Spring 2009), 120–129.

Chapter 29:
Affordable and Responsive Space Systems

Martin Sweeting

This chapter discusses the principal issues influencing affordable and responsive space systems, and the application of low-cost, small satellites to the military and civil space domains. It establishes the proposition that small, affordable satellites will be employed mainly to extend space capabilities to regions of the "performance envelope" that large satellite systems simply cannot populate in an affordable fashion. It also discusses the technological advances that will provide opportunities to employ affordable systems in more traditional space application areas (such as strategic surveillance).

The chapter commences with discussions of the military and civilian drivers that will influence the design of responsive space systems. It describes some of the desirable characteristics of responsive and affordable systems and the capabilities that they will offer to the warfighter. It then addresses specific design approaches that lead to affordable satellite systems that can be delivered in a responsive timeframe (since the development timescales are a facet of responsiveness just as much as the launch and operations). The concluding remarks consider the high-level issues that are likely to arise as space systems become increasingly responsive, with particular emphasis on the topic of space control.

Military and Civil Drivers

The concept of responsive space has been addressed mainly in the military domain, but there are analogous drivers in the civil domain that will also support the development of such systems in the future. Indeed, applications such as monitoring water and food resources are generally treated as civilian tasks at present, but it is widely believed that as population pressures increase in the next two decades, access to clean water and fertile land will increasingly become the catalyst for conflict. As a result, the need for timely surveillance will grow, and the line between military and civil monitoring will blur.

In the military domain, since the conflict in Kuwait in 1991 (which has been described as the first space war), space has been recognized as the new high ground in military operations. The growing desire for the affordable and responsive space systems that are the subject of this chapter arises from the subsequent recognition that existing strategic space assets are relatively ill suited to supporting operational and tactical requirements.

The procurement process for traditional space systems has for many years been in a negative spiral of increased costs, aversion to risk, long development timescales, and reduced numbers of launch opportunities. This stands in stark contrast to two of the principal drivers on the military today: reducing budgets and accelerating the tempo of operations to stay within an opponent's decision cycle.

By contrast, small satellite systems are on a positive spiral of reducing costs, pragmatic risk management, short development timescales, and frequent launch opportunities. For these reasons, they can be used to address the future needs of warfighters in diverse locations around the globe.

Other significant drivers in the military domain, all of which have implications for the design of affordable and responsive space systems, include:

- a reluctance to put the lives of military personnel (on both sides) and civilians at risk. Military interest in capabilities such as unmanned surveillance platforms and precision weapons systems, utilizing high precision surveillance capability, is therefore on the increase.
- an interest in employing network enabled technologies. The aim is to integrate the various elements of existing military capability, enhancing the efficiency of military campaigns and reducing the time for their completion. Improved communications capability, especially to mobile users, is central to this objective.
- the desire to counter enemy camouflage, concealment, and deception techniques. The nature of the threat has changed, and military targets are generally becoming harder to distinguish. There is thus a significant reluctance to rely on a single surveillance capability, and indeed, the rules of engagement typically mandate target confirmation from a second sensor prior to engagement. Enemy awareness of satellite surveillance systems also leads to concealment operations during satellite passes.
- the need for an effective Identification Friend or Foe (IFF) capability. The need to perform effective discrimination between friend and foe in a maneuver warfare environment in which the battle lines are far more fluid is a further driver for surveillance and communication systems.
- the ability to conduct operations at extended range as the capabilities of weapons systems improve. With the advent of extremely capable surface-to-air missile systems and the proliferation of long-range ballistic weapons, the challenge to perform effective surveillance of regions deep within enemy territory from which a viable threat could nevertheless arise is becoming ever more acute.
- a greater diversity of locations for potential conflict. Following the Cold War, the need for more agile forces capable of deployment to locations around the globe has increased. This includes the need to support more than one deployment in different locations on the globe at any given time.

In the civil domain, much has been written concerning the National Aeronautics and Space Administration (NASA) mantra of "faster, better, cheaper." Improving space system performance simultaneously in all these areas has proved challenging (to say the least), but they remain three of the key performance metrics for any space system. Perhaps NASA's vision has been most closely approached in the realm of small satellites, where the scale of the systems makes it possible for them to be faster and cheaper, and where the use of modern commercial-off-the-shelf technologies has allowed them to close the performance gap on some of their larger cousins, which typically have much earlier "technology freeze dates."

Among the principal civil drivers for responsive and affordable satellites systems are:

- the push for newsworthiness. Despite the proliferation of satellites among many new space players in recent years, it is still comparatively rare to see satellite images in the news media. The reason is that the typical 2- to 3-day life of a news story represents a significant timeliness challenge to large space systems, where the access times to the region of interest are usually long, and the need for comparatively high-resolution imagery has until recently precluded the use of constellations of small satellites.
- the goal of disaster mitigation. Some forms of natural disaster, such as hurricanes, can be tracked by existing space assets, but there are many others, such as earthquakes and floods, where timely access to warning data would be of extreme utility to the people attempting to respond to the crisis. As our understanding of the physical processes behind earthquakes improves, it may even be possible to use constellations of responsive spacecraft to move from disaster monitoring to disaster mitigation.
- data continuity. Although the military has requirements for multiple surveillance data sets to perform short-term change detection, the need for data continuity in the civil domain is crucial to the maintenance of a wide variety of monitoring services. At the current time, for example, the Landsat community of users who are exploiting that system for long-term environmental modeling faces a potential data gap as the on-orbit assets reach the end of their lives. Here the driver is to find an affordable way to maintain access to data over long periods of time, but there is also a need to replace assets in a timely fashion should one of the existing sensors fail unexpectedly. Another element of responsiveness is the desire to monitor some phenomena at specific times of day or during particular seasons. With a limited number of space assets available, such monitoring becomes something of a statistical lottery. By contrast, responsive constellations provide sufficient collection opportunities to overcome the vagaries of the weather.
- integrity and reliability. As we rely increasingly on space assets in a variety of subtle ways—for example, mobile phone networks and national power grids use the precision timing signal provided by global positioning systems (GPS) for switching coordination—it is important that our space systems can monitor their own state of health and respond accordingly if one of the elements in the system becomes unavailable for some reason. However, these high levels of integrity and reliability quickly become cost drivers unless significant levels of autonomy are included in the system.

Characteristics of Responsive and Affordable Space Systems

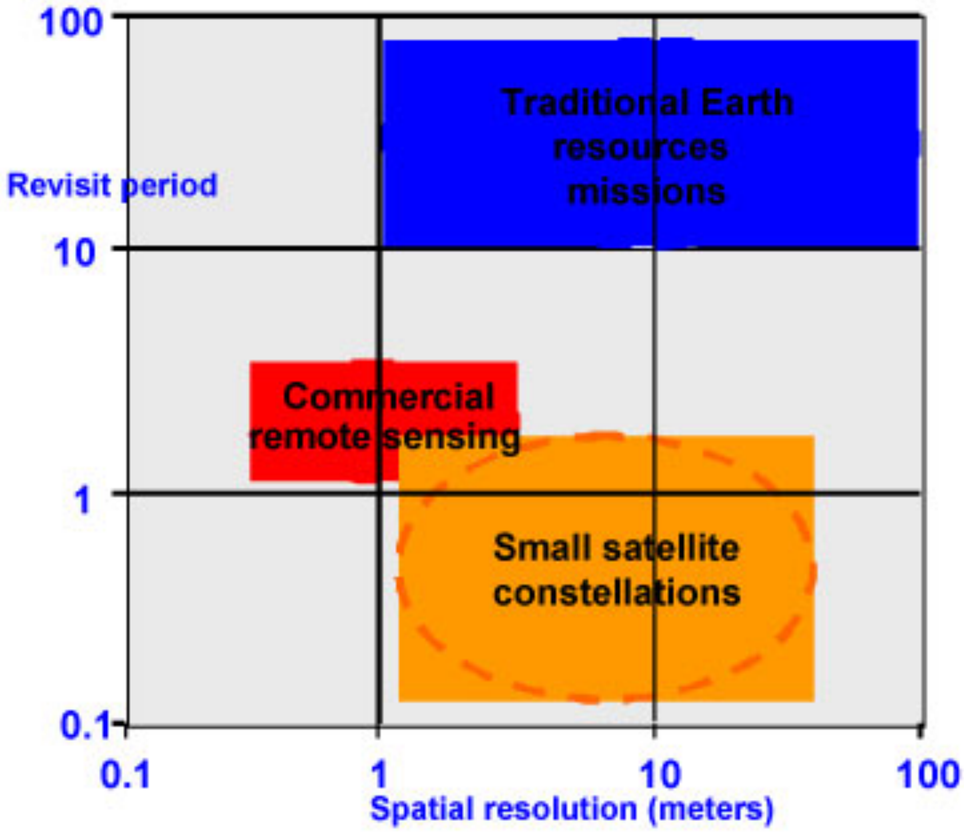
There is a pressing need to keep the costs associated with space systems to a minimum. The budgets available to the military have decreased in real terms since the end of the

Cold War, but at the same time, the number of military tasks that satellites are able to support has grown significantly, to the point where effective military operations are now infeasible without the surveillance, communications, navigation, and meteorological capabilities provided from space. In the civil domain, it is becoming increasingly common for commercial organizations rather than governmental institutions to commission constellations of satellites. In the commercial domain, there is always a focus on providing a return to investors in the shortest possible time. In order to be responsive, future space systems will thus need to provide significantly greater capacity to meet this increasing demand. However, it is simply not feasible to proliferate large satellite systems to achieve this; the costs and timescales are prohibitive. It is thus axiomatic that to be affordable and responsive, future responsive space systems must be designed around constellations and clusters of small satellites.

This process of evolution to multiple satellite systems has already begun. Examples in the surveillance domain include the international Disaster Monitoring Constellation (DMC) and the forthcoming RapidEye constellation, both of which comprise five satellites in Sun-synchronous orbits. Even more numerous in terms of satellites are the low Earth orbit (LEO) communication constellations, such as Orbcomm and Iridium; these are clearly starting to enter the realm of mass production, where the costs of the initial design can be amortized through the production of multiple platforms, thereby enhancing the affordability of the system as whole. The broad coverage offered by these systems leads to some of the most interesting possibilities for the future, with every likelihood that space systems will be used to support individual users/operators equipped with network-enabled Blackberry-class terminals (discussed in more detail below).

Figure 29–1 illustrates the regions of the surveillance performance envelope that are occupied by different classes of satellite. Satellites for traditional Earth resources missions, such as Landsat and Spot, are large and expensive, are launched infrequently, and have 2-week orbital revisit cycles. It is a measure of the increasing capability of small satellites (which employ far more modern detector technology) that similar resolutions can now be achieved with much smaller and cheaper space hardware. Uniquely, as a result of the lower costs associated with small satellites, they can be proliferated in constellations, such as DMC and RapidEye. As a result of having five satellites, these constellations offer daily global imaging capability, moving their performance envelope significantly lower in the diagram. By contrast, existing military satellites are located somewhere to the left of the red region representing the capabilities of commercial remote sensing satellites such as Quickbird and Ikonos.

Figure 29–1. Revisit Period versus Spatial Resolution for Imaging Surveillance Satellites



In the future, the operational and tactical requirements that drive the design of responsive satellite systems will be located near the bottom of the 1-meter (m) resolution line on this diagram; that is, the spatial resolutions required will be less exacting than for strategic intelligence assessments, but the data will need to be delivered in near real time. It is apparent that the journey from the existing capabilities to this target location on the diagram is far shorter, and hence far more feasible, for small satellites.

This is just one example of the need for different metrics to measure the performance of responsive satellite systems. The increasing need to conduct operations at extended range means that area coverage rate, rather than spatial resolution, will be one of the primary performance metrics. The 600-square-kilometer (km) images generated by the wide area cameras on the first-generation DMC satellites are approximately 10 times the size of a comparable resolution Landsat image and take just 80 seconds to collect, rather than the weeks demanded by the Landsat orbit cycle. The pan-sharpened multispectral data available from the second-generation DMC satellites are arguably the best quality (4 m resolution) per dollar (a total mission cost of less than $20 million) of any satellite ever launched.

The next generation of small surveillance satellites will offer even more interesting tradeoffs between resolution and area coverage by exploiting the agility of small satellite platforms. Because large satellites frequently have deployed appendages, such as solar arrays and antennas, settling time is required following maneuvers to allow the highest resolution imagery to be collected. By contrast, small satellites have relatively few dynamic modes and hence can be pitched and rolled to collect multiple images of a specific theater in a given pass. In consequence, 2–2.5 m resolution imagery over regions covering 60 km^2 will be available before the end of the decade.

For affordable space systems, the value-for-money metric is also of crucial importance. This metric is typically assessed by comparing the spatial resolution of the imagery provided by the system with the costs incurred in building and launching the satellite. It is also conventional to extend this performance metric to consider the value provided by the system as the total number of images at a given resolution over the satellite lifetime. This is a valid calculation, but it can be seen that attempting to maximize this particular measure of the value can sometimes come into opposition with the need for affordability and responsiveness. The value provided from a satellite in this case clearly increases if the lifetime is extended (since the satellite will have the opportunity to collect more imagery), but the costs associated with extending the satellite's lifetime (higher specification components, additional functional redundancy of the satellite hardware, far more extensive and time-consuming testing programs) can start to compromise the goal of affordability; that is, the value of the system increases, but the value for money is not necessarily enhanced because the costs also rise. The need for a more sophisticated approach becomes more apparent when the temporal aspects of the problem are considered—a complex satellite with a long design lifetime is a concept that stands in direct contrast to the responsiveness that is increasingly desired. As will be discussed, there are distinct advantages to designing "responsive" satellites with a 5- to 7-year lifetime.

The need for greater accuracy to support precision-guided long-range weapons systems means that future responsive satellite systems also need to emphasize geolocation accuracy among their design criteria. In part, this can be achieved by improved orbit knowledge (on-board GPS receivers already deliver better orbit determinations than ground-based radars). In addition, the use of enhanced star cameras will permit attitude determinations to very high precision on the next generation of small satellites. These missions should thus be capable of providing geolocation values of better than 50 m without the need for ground control points. The agility of this generation of small satellites will also permit the collection of in-pass stereo data to further improve the quality of the geospatial information available from the system. A direct comparison with large satellite design helps to emphasize this point. Most large satellites cannot collect in-pass stereo because they have large deployed antennas and solar panels, which are excited into dynamic modes by any maneuvering of the satellite. Hence, pitching a large satellite at the angular rates necessary to achieve a suitable stereo pair would lead to unacceptable perturbations of the sensor and seriously degraded image quality. One solution to this problem has been implemented on Spot 5, where the satellite carries two cameras, one pointed forward and one pointed aft, so that the satellite can collect two images without changing its attitude. Clearly, though, a small, agile satellite that can capture two images using a single camera makes a significant saving relative to this approach.

Improving Future System Responsiveness

The responsiveness of future systems can be improved in a number of ways, some of which are enumerated below.

Orbital heights and inclinations. The satellite system can be designed to operate at a greater variety of orbital heights and inclinations. This has the advantage that, upon launch, an orbit can be chosen that maximizes the coverage of a particular theater of interest, wherever it is located on the globe. The increase in the number of passes per day potentially compensates for the reduction in the satellite's duty cycle that may result from having less than optimal power generation conditions. (However, note that an operational duty cycle as low as 2 percent per orbit will still be sufficient to provide coverage of most theaters of interest.) As the sizes of militarily relevant satellites reduce, it becomes increasingly feasible to envisage a flexible concept of operations in which the satellite is able to perform on-orbit maneuvers to establish a repeating ground trace. The advantage of such an orbital maneuver for a surveillance satellite is that the imaging geometry generally can be duplicated on successive days, with the result that relatively straightforward (and hence timely) change-detection algorithms can be applied to extract the relevant military information from the raw data.

It is also interesting to consider the extent to which lower orbits (traditionally avoided by long-lived satellites since the propellant loads become prohibitive) can be exploited by satellite systems that have shorter design lives. This potential extension into the near space domain can offer higher resolutions (the sensor is closer to a target at nadir); improved sensitivity/signal to noise ratios (for the same reason); and, surprisingly, greater area coverage rates (for a sensor with a maximum slant range of operation, the instantaneously accessible region on the surface of the Earth actually increases if the satellite flies at a lower altitude).

Time of operation. The system can be designed to operate at different local times of day. Many surveillance systems are constrained by lighting or power considerations to operate in specific orbits, from which they provide coverage at particular times of day. This not only limits the operational flexibility of allied commanders, but also introduces a degree of predictability that an opponent can exploit to avoid being detected. The agility of small optical surveillance satellites can be exploited in the form of a pitching motion that reduces the effective ground speed of the satellite's sensor, as demonstrated by the current TopSat mission. The effect of this pitching motion is that more light enters the camera, producing a better quality image. It follows, therefore, that by increasing the pitching rate, more ground-motion compensation is possible. Enough light can then be collected to generate usable imagery even when the satellite is comparatively close to the terminator. Optical surveillance is thus freed from its traditional time slots either side of local noon and (with some caveats) is also freed from its traditional dependence (in the West at least) on Sun-synchronous orbits. Orbits that are not Sun-synchronous will pass over specific locations on the ground at different times of day. This lack of predictability in terms of orbital pass times will make it more difficult for an opponent to implement concealment measures, a difficulty that will be compounded as satellites become smaller and thus more difficult to track. Again, the agility of small satellites can be seen to be delivering capabilities that large satellites would find it extremely difficult to match.

Adding intersatellite links. Current LEO communications systems include Iridium, which is equipped with intersatellite links (ISLs) to expedite the delivery of messages within the system. Iridium allows communications with much smaller mobile terminals on the ground, but it is also possible to envisage using systems of this sort to communicate with other satellites in LEO. In the near future, satellites equipped with ISLs are anticipated to be permanently in contact with their control stations for the purposes of receiving thin-route command data. Some existing LEO surveillance assets are equipped with complex low Earth/geosynchronous orbit links via broadband data relay satellites to allow them to return their data in near real time. At present, the data volumes that can be supported by the LEO communications networks are insufficient to allow imagery data to be passed in a responsive timeframe, but future data delivery concepts, such as the Cascade satellite program, may allow this.

Onboard processing. Exploiting the rapid development of miniaturized, high-capacity terrestrial processors, small satellites are increasingly able to outperform their much larger cousins in terms of onboard processing. As an example, the 6.5-kilogram Snap-1 nanosatellite launched in 2000 had twice the processing capability of the entire 8-ton Envisat platform that was launched in 2003. This ability to exploit novel technologies means that small satellites will increasingly be able to preprocess their data and return their information at a much reduced data rate, either via the LEO communications networks or to transportable, in-theater command and data reception terminals.

In-theater control. Placing the command authority in the theater of operations will significantly improve the responsiveness of the system to the commander's needs. Networking such capabilities through a network-centric architecture has already been demonstrated by the Virtual Mission Operations Centre experiment, in which a router carried by the United Kingdom's DMC satellite was used to create an in-orbit point of presence on the Internet that is able to respond to requests for imagery data from the satellite's memory. At present, the logistical impact of in-theater payload control and data reception is that a 2.5-meter-diameter tracking dish needs to be fielded, alongside a vehicle equipped with the processing capabilities to turn the raw data into exploitable imagery. The United Kingdom's TopSat mission has already demonstrated the feasibility of in-theater data reception direct from the satellite on the same pass that the imagery was collected. Future experiments are planned with TopSat that will additionally demonstrate the ability to command the satellite on the same pass as the planned imagery collection, with the result that the tasking, collection, and processing elements of the imagery intelligence process can be completed in less than 15 minutes.

In the future, technological developments—including greater satellite power generation capacities achieved through improved solar cell design, better use of satellite power resources through the employment of intelligent, steerable antennas, improved on-board processing, enhanced coding schemes, and improved ground terminal designs derived from mobile phone technologies—will significantly reduce the logistical impact on the ground stations, to the extent that a relatively noncooperative handset, potentially comparable to an Iridium mobile phone, will be all that is required to interact effectively with the space segment. These technical improvements should also help to address one of the other military drivers discussed earlier: the need for more effective IFF capabilities to protect troops at all levels of command, some of which would otherwise find it difficult to carry terminals with adequate performance to interact reliably with a satellite.

Sensor diversification . The speed with which a target of interest will be detected and discriminated from friendly forces will depend on the range of sensors that can be brought to bear on the task. In the past, the lack of coordination between different sensor systems (imagery and signals intelligence, for example) has made the fusion of their data difficult, if not impossible. In the future, responsive constellations of multiple satellites will greatly enhance the number of opportunities to collect collocated, contemporaneous surveillance data, and so address the problems posed by camouflage, concealment, and deception, and IFF. This may be implemented on multicapability missions (such as TACSAT–2) or on cooperative constellations of satellites with single sensing systems. The range of fusion techniques that can be applied will be further enhanced by the variety of surveillance modes on offer from future sensors. Hyperspectral imagers and synthetic aperture radar (SAR) instruments are responsive in the sense that they can vary their number of sensing bands, spatial resolutions, and surveillance footprints in order to tailor their collection to the intelligence task at hand. The compact hyperspectral imaging spectrometer instrument carried by the Proba satellite has already demonstrated some of this flexibility in the hyperspectral arena, and multimode, multi-polarimetric SAR collection is the objective of the United Kingdom's proposed AstroSAR satellite.

Clearly, this move toward active sensing using small satellite radars will progressively escape the constraints of lighting conditions and cloud cover, which will forever limit the responsiveness of optical surveillance assets. However, the performance of an optical sensing system depends in no small part on the extent to which it can be provided with cueing information about cloud cover. In a sparse network consisting of just a few surveillance assets, only limited near-real-time information is available to target the collection through the gaps in the cloud cover. A more densely populated constellation of satellites potentially can be used much more efficiently if the data from one satellite can be exploited in a timely fashion to update the commanding for the next asset that will make a pass over the theater of interest.

A further advantage of having multiple sensors that are capable of viewing a region simultaneously is the increased possibility of novel sensing techniques. In the hyperspectral domain, for example, the power of such sensors to discriminate different materials on the ground depends in part on the ability to measure the bidirectional reflectance distribution function (BRDF), which is essentially the extent to which the color of a surface changes depending on the angle between the direction of illumination and the direction of the sensor. A small, agile satellite can potentially make a number of samples of the BRDF as it passes over a target, but these are necessarily separated somewhat in time. An even more attractive and responsive possibility is that a number of satellites with similar sensors could be trained on a given target at the same time to get an immediate readout of its BRDF, since this would allow instantaneous measurements of the signatures of moving targets as well as static ones. It is hard to imagine large satellites that are either agile enough or cheap enough to be proliferated sufficiently to match these capabilities.

Radar satellites also offer a greater range of sensing mechanisms when used collaboratively. Traditional monostatic imagery collection can be enhanced by bistatic collection modes, and the simultaneous collection of multipolar imagery can further enhance the discrimination capabilities of the system if required. The range of different illumination angles available from a constellation reduces the impact of "radar shadows" that would otherwise affect the responsiveness of the system (since, to be useful, the imagery products need to include data on a significant percentage of the terrain below). As an example, terrain information can be generated by two radar satellites working in tandem using inverse synthetic aperture processing techniques. The digital terrain elevation data products resulting from this process must include a high percentage of the terrain in order to meet the established criteria for such products. Terrain shadowing often prohibits this level of coverage from a single imaging pass, resulting in the need for several orbital passes at different geometries in order to build up a suitable mosaic. The problem of terrain shadowing becomes even more acute in the case of moving target information (MTI) systems. In hilly terrain, the areas most likely to be shadowed are those at the bottoms of valleys. For practical reasons, most of the lines of communication (roads, railways, and rivers), and hence most of the moving targets of interest, are also at the bottoms of valleys. This statistical bias is likely to make MTI ineffective unless a constellation of assets providing a range of surveillance geometries is available.

Some of the examples discussed above assume the use of small satellites operating in widely separated constellations, where the timeliness and responsiveness of the system on a global basis will be maximized by distributing the passes of the satellites in time. Some of the later examples of simultaneous multiple-satellite coverage assume the use of formation-flying techniques, where the assets are operated in a cluster, providing contemporaneous coverage of a specific region of interest. Assuming that at least some of the satellites in a constellation operate in common orbital planes, it is possible to envisage a situation in which relatively small propulsive maneuvers could reconfigure a "constellation" into a formation-flying "cluster" over a period of time via in-plane velocity changes. This is a higher, system-level aspect of responsiveness that will allow space systems to be configured most appropriately for the military tasks at hand.

When configured as a cluster, the elements of a satellite system can operate in a comparatively independent fashion to generate data sets that can later be combined. It is, however, also possible to envisage clusters of satellites with the ability to combine their data interferometrically, and thus create a sparse aperture that could synthesize the capabilities of much larger satellites. In order to preserve the signal phase information required to achieve this, the intersatellite links would need to provide not only the relatively coarse positional information required to maintain acceptable baselines between the satellites, but also the much finer metrology necessary to measure the intersatellite separations to small fractions (perhaps 10 percent) of the operational wavelength of the system. In the near term, this implies that such systems will be constrained to operate at radio and microwave frequencies, but the long-term ambition would be to create clusters of satellites that could avoid the expense of having to launch a satellite with a massive, deployable instrument.

In response to a future conflict scenario, the operation of a cluster of orbiting assets could be varied progressively depending on the user need. A cluster of assets operating as an interferometer over comparatively small regions on the ground (to generate high-resolution imagery, for instance) could be switched almost immediately to more independent modes covering somewhat larger regions within the same theater (for example, using the separate apertures within a cluster to collect data on a given region sequentially, rather than simultaneously, for change detection purposes), and could then be maneuvered physically around their orbit plane to change the pattern of passes over the theater to maximize the area coverage rate and timeliness of revisit. Physical reconfigurations offer the additional advantage that an opponent will find it harder to predict surveillance overflights and hence will have more difficulty implementing countersurveillance operations.

Achieving Responsive and Affordable Capabilities

To provide the most cost-effective, responsive space capabilities, there is a need to change procurement strategies to exploit terrestrial technologies, which now often exceed military capabilities. Following World War II, the Western militaries had access to the highest technology levels across a wide range of disciplines. The huge sums of research money now being invested by commercial industry in areas such as telecommunications, computing, cameras, and so forth mean that, in these areas especially, the former military supremacy is no longer the case.

Experience with small satellites suggests that some very specific techniques can be implemented to exploit novel technologies and thus increase both affordability and responsiveness.

Modular design. A standardized approach to the design of core satellite elements such as electronics trays allows specific elements to be incorporated in the design with a minimum of overhead.

Maximize use of heritage hardware. In small satellite design, in order to keep costs down, it is generally considered good practice to ignore blank sheets of paper. It is also inadvisable to use lists of components that have been designed before. The approved approach is to use a change management process to adapt an existing design for a new mission. This approach can also be used for software to keep the launch and early orbit phase shorter.

Evolve capability using experiments. An approach that has been successfully employed over a series of satellite missions is to fly experiments in orbit to prove their viability before baselining them for operational missions. A current example is the GPS reflectometry experiment flying on the DMC satellite, where GPS satellite signals that have been reflected into space by the ocean surface are collected by an orbiting receiver. In the process of reflection, the GPS signals are modulated by the waves. By comparing the reflected signal with the direct-path original, it is possible to derive information on the prevailing sea state.

Design for launch on any vehicle. Having a satellite design that will withstand the loads imposed by any launch vehicle avoids potential delays due to launch vehicle failures (potentially imposing a program hiatus while the problem is resolved or while the satellite is redesigned for an alternative launch platform). This approach allows design effort to be concentrated on elements of mission that are unique. Satellites will thus not be mass-optimized, but rather time- and cost-optimized.

Selecting appropriate technologies . Some terrestrial technologies are more suitable than others for exploitation in space. For example, the use of a controller area network to link the various components of a satellite can be seen as an appropriate choice when it is recalled that this technology was developed for use in the automobile industry, where the temperature and vibration environment is extreme. When considering placing a technology on a rocket and launching it into a vacuum, it is clearly desirable if it comes "pre-ruggedized."

Avoid requirements creep . The most responsive approach normally is to work with a customer in advance to agree on satellite design specifications (sometimes accepting slightly lower performance for a major discount on cost), and then sign a fixed-price contract—a major disincentive to requirements creep and contract change notices. Satellite builders have to learn to "just say no" when design modifications are mooted.

Mass produce . As in any other branch of manufacturing, there are significant cost savings to be made through mass production. In the case of the automobile industry, more than 99 percent of the prototype costs can be saved via the implementation of a mass production process. It is unrealistic to assume that figures as optimistic as this would be possible for space in the short term, but the successes of the Russian space program over an extended period would appear to be largely based on long production runs of essentially identical satellites, which kept the costs to an affordable level.

Automate. A significant component of any mission's costs is operations. This is an area where responsiveness and affordability can be competing drivers, but it remains a major advantage to take the human out of the loop wherever possible. This is only partly because computers are cheaper to employ. They are also able to perform calculations faster than human beings and, if programmed correctly, do not make the sort of errors that can add delays and costs to a program.

Conclusion

Small satellite systems now have the ability to provide affordable support in the responsive timescales associated with the operational military domain, with the result that military planners (especially in the United States) view space as the new military high ground. As small satellites provide this operational support, they will increasingly become targets for hostile enemy action, causing space situation awareness and the control of space to move up the agenda of military priorities. Responsive satellite assets have a role to play in creating the "recognized space picture" that will underpin all military operations in the future.

Improved affordability means that military space capabilities based on small satellite systems will continue to spread to a variety of nations that have not previously had access to such systems. While these systems will not match the performance levels of large satellites in terms of spatial resolution, they will offer a degree of timeliness and responsiveness that will level the playing field to some degree.

It is likely that this expansion of capabilities will extend into the radar remote sensing domain, with the result that the National Reconnaissance Office assertion, "We own the night," will be challenged. Previously, this would have required access to a very capable launch system, as well as significant radar satellite hardware, but the change in scale of the on-orbit hardware will diversify the available launch options, and the use of commercially available terrestrial technologies that can be sourced from anywhere on the globe means that export controls are likely to prove ineffective. It is thus unrealistic to suppose that it will be possible to prevent the deployment of novel in-orbit capabilities.

Increasingly, the opportunities for satellites to collaborate in multinational constellations, such as DMC, will make the ownership of certain capabilities a more complex issue. For example, it is clear who owns each of the individual satellites in the DMC constellation, but the emergent responsiveness of the constellation as a whole is "owned" by a multinational consortium. It is not difficult to imagine circumstances where such multinational arrangements could be compromised by political considerations in the future. Increasingly, though, the advantages of such international constellations will be perceived not only by the satellite owners, but also by the other nations that benefit from their existence. (For example, although not a part of the DMC constellation, the United States was supplied with wide-area disaster relief imagery by Nigeria in the wake of Hurricane Katrina.) In this sense, satellites become a form of public good, and decisions on space control operations will need to be influenced by the potential costs associated with the denial of capability in certain circumstances. The recent proposal for a coalition operationally responsive space capability is thus widely regarded as the sharpest space idea to emerge from the United States this millennium.

The U.S. navigation warfare strategy recognizes a similar issue by mandating that the various public good missions supported by the satellite assets will be unaffected outside the immediate theater of operations. If—as now appears likely following the successful launch of the first low-cost Galileo demonstrator satellite—the European equivalent of the GPS constellation can be implemented affordably, similar navigation warfare issues will arise.

The desire to avoid collateral damage to uninvolved civilians means that, in some senses, the objective of exercising space control will require the ability to control not the whole of space, but specifically the region of space above and adjacent to the theater of operations. Clearly, this has implications for the systems that may be used to conduct surveillance of this localized region and for the ones that may subsequently utilize this localized surveillance information to exercise space control: both are likely to require an in-theater component. If some of the surveillance assets are in-theater, adequate secure communications will be required to convey their data to the locations in home territory from which the launches of any responsive space assets would presumably be coordinated. This would probably be true even if some of the launches themselves occurred from mobile platforms located in places that would either deliver an element of surprise to the enemy or allow easier access to orbits tailored to the particular theater of operations. (In the case of the United States, for example, sea-launch platforms located close to the Equator would allow greater payload masses to be delivered to low inclination orbits than would be possible using similar launch vehicles from fixed sites within the continental United States.)

It should also be borne in mind that the space surveillance task, whether in-theater or not, is likely to become more challenging in the coming years. At present, all operational satellites are large enough to be tracked by the existing radar network, but "cubesats," with dimensions of about 10 centimeters, are already starting to push the limits of detectability. In the future, an increasing proportion of the on-orbit assets will be small responsive systems that present these sorts of problems to the tracking networks. (Incidentally, the risk here is not simply that an enemy might deploy undetectably small platforms, but also that maintaining knowledge of small responsive allied assets will become harder for the traditional sensors.) But it is not just size that is the problem. In the future, the sort of stealth technologies that have been applied to aircraft and other military platforms inevitably will also be applied to satellites, reducing their signatures and making them harder to see. Clearly, though, small, responsive satellites start out with an advantage in the stealth arena in the sense that their signatures are smaller.

The space situation awareness task will be further complicated by the proliferation of assets that are likely to be launched (in part to convey robustness through proliferation). This will be especially true in time of crisis (in a responsive, constellation-dominated future, there will simply be more satellites to detect, characterize, and track). Responsive systems also require a responsive concept of operations, a consequence of which is that satellites are likely to maneuver frequently, either to optimize their number of passes over a theater; to create specific viewing geometries; or to make it harder for enemy forces to target counterspace operations against them. In the last of these instances, it is axiomatic that such maneuvers would take place out of sight of the opposing forces, such that the satellite would make its next transit over the theater on a novel trajectory. This emphasizes the need for robust in-theater tracking capabilities, especially since there is an element of statistical uncertainty in all satellite maneuvers. A satellite's postmaneuver orbit may successfully confuse the opposition, but for its subsequent passes to be used effectively, its new orbit will need to be determined quickly by its owners, as small timing errors can lead to large miss distances at orbital velocities close to 7.5 kilometers per second.

The opportunity cost associated with having responsive satellites on hand awaiting launch is only viable if costs are very low and launches are frequent. In the small satellite domain particularly, satellite lifetimes are short because of rapid technology evolution. Just as for personal computers, 5 years is the typical "obsolescence timeframe" for a small satellite, since at this point its performance will be superseded by new technologies. It is thus not a viable strategy to use up a significant fraction of this lifetime with the satellite hardware on the ground. A more credible approach would appear to be to design satellites with a flexible concept of operations, allowing the configuration of the constellations and clusters to be modified on-orbit in response to changing situations on the ground.

If small satellites are "the PCs of space," then the interconnection of small satellites using intersatellite links (initially exploiting the existing LEO mobile communications networks) will create a responsive and affordable "space Internet" offering a wide range of exciting possibilities and emergent capabilities. The protection of this multiply interlinked, international network could become one of the highest priorities for any space control system in the future.

The contributions that various nations make to this international network will be one dimension of the soft power projection that they will be able to exercise in this timeframe. In light of the stated aspirations of China to launch more than 100 small satellites over the next decade or so, producing affordable and responsive space systems may not be something the West chooses to do in order to create an advantage and exert influence in the future, but rather something that it needs to do simply to maintain parity.

Chapter 30:

Future Strategy and Professional Development: A Roadmap

Simon P. Worden

Once upon a time there was a dear little chicken named Chicken Little. One morning as she was scratching in her garden, a pebble fell off the roof and hit her on the head. "Oh, dear me!" she cried, "The sky is falling. I must go and tell the King," and away she ran down the road.

The fable of Chicken Little has many versions. In some, she is saved by the King or another altruistic entity. In most, she and her colleagues are eaten by the evil Foxy Loxy. In my fable, however, the sky is not falling on Chicken Little—but that sky is receding at an ever increasing pace.

In the 1980s and 1990s, space capabilities, and in particular their security-related aspects, were all the rage. In the 1980s, the United States was mounting a major missile defense program based largely on space capabilities. The Strategic Defense Initiative promised to lead to the end of the Cold War, and many experts believe it did. Our civil space program was beginning to fly the space shuttle, a reusable space transportation system that was heralded as ushering in a new era of space access and expansion. In the 1990s, commercial space programs such as the global space communications system Iridium were touted as the first step toward explosive growth for commercial space endeavors. Perhaps most significant was the apparent realization of the central role that space would play in national security. The bipartisan 1999 Commission to Assess National Security Space Management and Organization (the Rumsfeld Commission, named after its chairman, Donald Rumsfeld) resulted in huge growth in national security space spending and sweeping reorganization and centralization of national security space endeavors.[1]

Alas, none of the ambitious prospects for space appear to have been met. Our missile defense systems have little to do with space capabilities; indeed, the entire program has effectively been transferred to the U.S. Army's ground-oriented management. The space shuttle has not met its promise and is being phased out in favor of the older Apollo approach. Most communications systems now rely on global fiber connections and not commercial space capabilities. And practically all of the Rumsfeld Commission's space recommendations have been abandoned.

Of growing concern is what is going on outside the United States. Several states have expressed alarm over an alleged U.S. space weapons program. While these nations, particularly China and Russia, know that little is going on in this area, they have enjoyed stirring up international outrage for their own purposes. While this may seem harmless enough in the short term, it could itself be an impetus or perhaps an excuse for others to mount a counterspace effort of their own. In the past, such challenges to U.S. space utilization might have seemed laughable, but that is not so today.

Many nations are mounting impressive programs in space technology and utilization. Key to these efforts has been the development of so-called microsatellites and low-cost means of getting them into space. The pioneer in this technology has been Surrey Satellite Technology, Ltd. (SSTL) at the University of Surrey.[2] Part of SSTL's success has been its programs to assist other nations develop small (100-kilogram-class) space systems. Over a dozen nations have benefited from SSTL collaborations. Today, for less than $20 million, just about any nation can build and launch a satellite capable of significant security-related functions such as 1-meter-class imagery.

While the rest of the world aggressively develops these low-cost systems, the United States is increasingly mired in cost overruns and failed space systems. Practically every major U.S. security-related system is grossly overrun and significantly behind schedule. Moreover, with some exceptions (mostly driven by congressional insistence), the U.S. security community has shown little interest in small, fast-paced space systems.

Part of the U.S. malaise stems from rather uninspired leadership in military space system development and operation. Most military space discussions begin with something along the lines of "support to the war fighter." This attitude has led to the perspective that space capabilities, and correspondingly military space leaders, are secondary to "warfighters." The U.S. Air Force highlights its combat pilots, not its space engineers. This is not the type of environment that will attract aggressive, creative leaders.[3] The first premise of this chapter is that the primary value of space capabilities is not their support to warfighters; rather, it is that they are the primary means for war prevention through the forging of collaborative international security arrangements.

Interestingly, SSTL has developed an impressive prototype for future use of space systems for security purposes: cooperative international space security measures based on small satellites. The SSTL-inspired and -led Disaster Monitoring Constellation consists of five microsatellites built and launched by Algeria, China, Nigeria, Turkey, and the United Kingdom.[4] Each satellite obtains wide-area 36-meter imagery with planned improvements to 4-meter resolution. The member states get frequent revisit imagery suitable for detecting and managing responses to natural disasters such as floods and earthquakes. Key for the purposes of this discussion is the postulate that such systems represent a broader meaning of security and a new means to link diverse states in a common security endeavor. The United States would do well to learn from this success and find ways to involve itself in and lead such future cooperative ventures.

One such possibility for cooperative international leverage is the new U.S. "Vision for Space Exploration." As with the Apollo program of the 1960s, the new space exploration initiative, involving the goal of permanent international settlements on other worlds, has considerable security-related possibilities.

Significantly, space capabilities such as precision positioning, navigation, and timing through such systems as the global positioning system (GPS) have become true global utilities. Protecting and expanding these capabilities, which are critical elements in global economic lynchpins such as transportation and communication, are in the global interest. A new security regime based on shared global utilities, including long-term goals such as space exploration and settlement, offers the United States a new opportunity to lead international security regimes. Aggressive U.S. development of technology—for example, distributed small space systems such as microsatellites—is key.

The Problem

Foreign Progress

The United States prides itself on its space leadership, particularly in the security use of space. Indeed, it regards space as critical to its overall national security stature. The National Space Policy reiterates this importance when it states, "United States national security is critically dependent upon space capabilities, and this dependence will grow."[5]

The United States also recognizes that its space stature is being challenged by many nations. The Rumsfeld Commission noted:

> The relative dependence of the U.S. on space makes its space systems potentially attractive targets. Many foreign nations and non-state entities are pursuing space-related activities. Those hostile to the U.S. possess, or can acquire on the global market, the means to deny, disrupt or destroy U.S. space systems by attacking satellites in space, communications links to and from the ground or ground stations that command the satellites and process their data. Therefore, the U.S. must develop and maintain intelligence collection capabilities and an analysis approach that will enable it to better understand the intentions and motivations as well as the capabilities of potentially hostile states and entities.[6]

This concern is translated in many minds, particularly those of national security space professionals, as a direct military challenge. However it does not appear that direct threats are the only, or perhaps even the most severe, ones.

Many nations are developing significant dual-use capabilities that meet both security and other, often commercial and scientific, purposes. Other nations frequently have a broader view of security than just military concerns, to include economic and environmental aspects. Particularly within Europe, perspectives about military space are both uncertain and rapidly changing. In the multipolar world that emerged after the Cold War, security issues that were originally military driven have become more complicated. As European roles in the world grow, particularly peacekeeping roles outside the continent, the need for space system support in such areas as communications and navigation also grows.

The emerging technology of small, low-cost space systems (micro-satellites) is changing the dynamic. Microsatellites are 100-to 200-kilogram systems that cost approximately $5 million to $20 million to construct. Coupled with low-cost space launch, generally provided as a piggyback payload on a larger booster, the entire mission cost is $10 million to $30 million—an order of magnitude less costly than conventional space missions. Using new off-the-shelf technology, these microsatellites can perform many of the security-related functions that formerly required large, expensive systems. For example, several nations are now producing microsatellites with 1-meter imagery resolution and significant signals intelligence functions. SSTL, a world leader in developing this capability, has led a global revolution in using the new, more affordable technology not only in Europe but also around the world. While microsatellites probably will not totally supplant large space systems, they can certainly perform many functions currently done by such large systems and could work in concert with them to provide extended capabilities—particularly in the context of shared international constellations such as the Disaster Monitoring Constellation.

The trend toward smaller, more affordable space capabilities has enabled European nations and others to produce significant security capabilities within individual nations' space budgets. Examples of this approach are embodied in the German Synthetic Aperture Radar (SAR)– Lupe imaging satellite system and others now under development.[7] The proliferation of this new national capability offers a new set of opportunities for use of space systems in security modes.

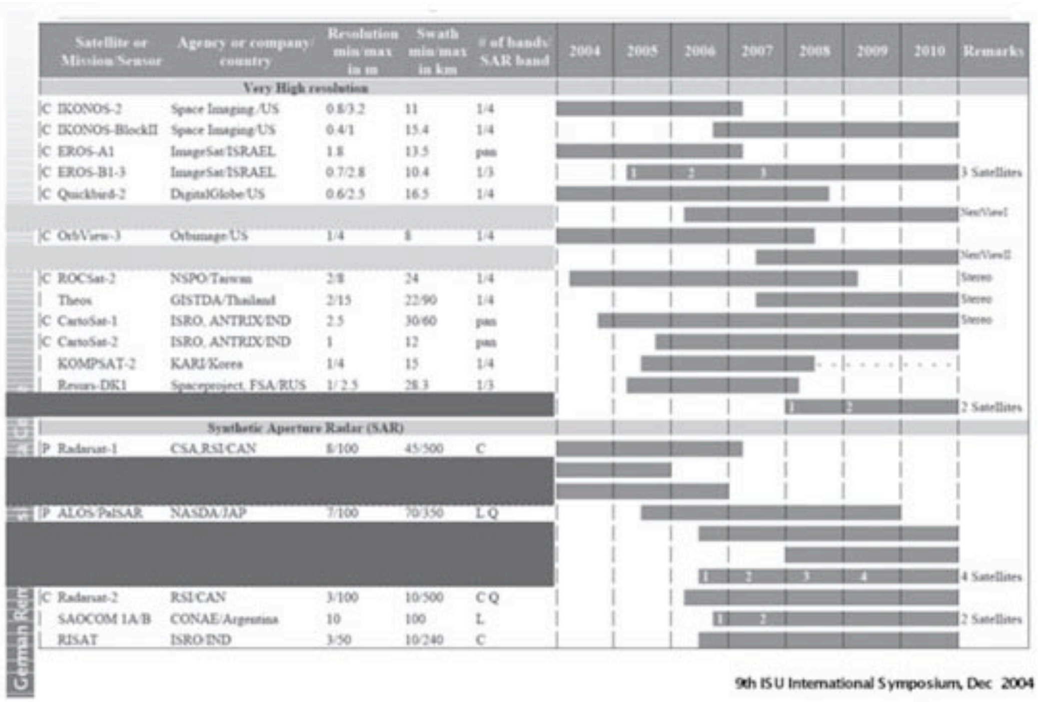
The U.S. challenge in space is more than a strictly military one. The use of smaller, lower cost systems for a series of dual-use purposes is the real challenge. Meeting it will require a change in both the mindset of our security professionals as well as in technological direction—toward small, affordable dual-use systems with direct applicability to economic and environmental security as well as collective security.

Nowhere is the trend toward small, internationally available capabilities more noticeable than in high resolution imaging and synthetic aperture radar systems. Most new efforts (see figure 30–1) are non-U.S. and/or wholly commercial endeavors. The U.S. national security community clearly no longer has a monopoly or even a lead role in this important area.

U.S.Failures

The U.S. security community's recent track record compares unfavorably to the impressive work being done internationally. The American focus on large, complicated systems may have been well founded in the Cold War, but in light of the rest of the world's success in smaller, more affordable space systems, the wisdom of maintaining this direction is dubious. More to the point, the United States is increasingly unable to even field these large systems.

Figure 30–1. Timetable: High Resolution and Synthetic Aperture Radar Satellites



Source: Chart extracted from "High Resolution Earth Observation Imaging Satellites in the Next Decade: European Perspectives" by G. Schreier, Head of Business Development, DLR German Remote Sensing Data Centre, Germany, presented at the 2004 ISU Symposium, "Civil, Commercial, and Security Space: What Will Drive the Next Decade?" November 30–December 3, 2004, Strasbourg, France.

In the 1970s, the U.S. Air Force launched the world's first comprehensive missile warning program, the Defense Support Program. These satellites carry infrared sensors that see the heat of a missile launch. In the 1980s, the United States began developing a follow-on system, now named the Space-based Infra-red System (SBIRS), which was intended to replace the Defense Support Program missile warning satellites with more capable and sensitive sensors. It was also intended to support comprehensive missile defenses. The first SBIRS satellites were to be launched in the early 1990s. Today, after at least a $20 billion expenditure, we are years away from a working system.[8] Moreover, SBIRS is no longer capable of supporting comprehensive missile defenses, and the system is by no means the exception. Other major programs, such as next-generation weather satellites (the National Polar-orbiting Operational Environmental Satellite System [NPOESS]), are seriously behind schedule and considerably overrun.[9]

Congress is increasingly critical of the U.S. national security community and has insisted that it pay more attention to small, low-cost "responsive" space systems. The responsive feature is the ability to respond to crises inside an adversary's act-react cycle as well as being a more effective response to direct military threats. The ability to quickly replace a lost space capability might prove a much better deterrent to foreign space military challenges than various forms of active space control, particularly when most potential adversaries have little reliance on space capabilities themselves.

Congress has now mandated an Operationally Responsive Space program. Its rationale is impeccable. Consider the statement by Terry Everett (R–AL), chairman of the House Strategic Forces Subcommittee:

We must also embrace innovative ways to advance our strategic enterprise. One innovative approach to getting key space capabilities into the hands of our military forces is Operationally Responsive Space (O-R-S). O-R-S is an effort to develop smaller, less expensive satellites that can launch on short notice to meet the immediate needs of the warfighter.

In this year's [2006] defense bill, Congress created a joint O-R-S program office, bringing together: Science and technology; Acquisition; Operations; and Warfighter support. With this effort, I see a stronger national security space portfolio where O-R-S systems complement large traditional space programs.

For this Office to be successful it must retain a strong joint core, bringing together leaders and participants from across the Services, Agencies, research labs, and industry. It must also create an environment that expects and rewards innovation.

I said earlier that the strain of rising costs and affordability will continue to put pressure on our space and defense programs. At the same time, technologies are evolving at much higher rates than our current ten-plus year acquisition timelines. Therefore, I see two key thrusts to O-R-S: First, it is a means to get simple, low cost solutions rapidly on-orbit to meet the dynamic needs of our combatant commanders; Secondly, it provides more frequent opportunities to prove-out innovative concepts and technologies at a lower cost, while strengthening our industrial base and technical workforce. I've said low-cost twice. I can't emphasize this enough; we must control the costs of our space programs.[10]

The national security space community's internal problems stem largely from a variety of "red herring" excuses for the community's shortcomings. As detailed in a paper by Randall Correll and this author, many excuses have been given, from masking symptoms for causes such as citing immature technologies and lack of good requirements definition, claiming insufficient system engineering expertise, poor cost analysis, shifting incumbent contractors, and others. The paper places the blames squarely on poor, often technically unqualified, leadership.[11]

Our bad national security space posture stems from two major difficulties. First, we have not developed a coherent strategy, and second, we have developed neither a cadre of qualified experts to lead it nor the necessary space capabilities to support it. What follows is a prescription for remedying this, starting with a coherent strategy.[12]

Coherent Security Space Strategy

Progress in information technologies has completely reshaped the way humans communicate. The globalization of the economy and culture and the growing importance of worldwide information (such as the Internet) and human (such as al Qaeda) networks have changed relationships between not only people but also states from an exclusive to an inclusive paradigm. In this new era, it is often in the interest of all parties to cooperate with rather than oppose each other. This does not imply that competition has disappeared, but it has changed in nature, being more strongly related to confidence-building and "win-win" strategies.

This new paradigm fits well with space capabilities that are inherently global in nature. Investments are often too costly for a single nation to make. The new developments in space capabilities may enable new security regimes. These possibilities generally come under the heading of soft power. The new options involve shaping the global environment to maximize collective security. They also entail changes in space policy on the part of various nations. Several approaches are possible in this direction.

The world has entered an era of *global utilities*: capabilities, generally in the information collection and distribution regimes, that enable the emerging global economy, culture, and society. First among them is the Internet, followed closely by global positioning, navigation, and timing systems such as GPS and the European Galileo. Note that the GPS conceived in the 1980s remains exclusive to the U.S. Government, whereas Galileo is more collaborative, including major players outside of the European Union such as India and China.

Other global utilities include global communications grids and global situation awareness such as imaging. New possibilities in this area include identification and tracking of moving objects such as aircraft. Many of these utilities grew out of military needs, but they have become the glue that holds the global economy and culture together. Almost all global utilities depend in some part on space capabilities. Even the Internet uses space systems for many of its long-range communications connections and precision timing. The breakdown of even one satellite can have devastating consequences to the global economy. In 1998, a failure of a single communications satellite carrying remote pager signals plunged much of North America into an unexpected business "holiday."[13]

The first and possibly most potent element of soft power is inclusion in global utility services. Inclusion of a nation, group of nations, or even private concerns in the development of a global utility such as Galileo is a potent inducement for a desired behavior. Europe's experience with China and its inclusion in Galileo is a positive demonstration of this potential. Once connected by the utility, the parties have a strong mutual interest in protecting and advancing it. This provides a lever to bind and influence diverse interests. Finally, the possibility of being denied access to one or more global utilities in response to aggression by a state can be a compelling dissuasion from embarking on a hostile tack. Without global information support mechanisms, a nation would find its economy swiftly devastated.

A related concept to global utilities is the rising importance of a global information connectivity or infosphere. The rise of a global information marketplace, largely originating in the Internet, is apparent. Although some of the explosive growth of the 1990s has slowed, the Internet is still the fastest growing impetus to global commerce.

Equally important is its role as a marketplace of ideas—a two-edged sword, as the Internet has become a medium through which modern terrorist groups recruit members and plan acts. Yet the global infosphere could also mean the end of narrow, fundamentalist ideologies. Modern terrorists do best recruiting among disillusioned and often isolated young individuals. These same individuals might have been recruited and organized through the Internet, but that same medium can and will also expose them to broader and more inclusive philosophies.

A second element of future soft power is to connect the world into a global infosphere. Again, confidence building is a key driver. Space capabilities are integral to this linkage to build cohesion and shared values as space communications segments are the only way to reach much of the developing world. Indeed, India's interest in space began as a way to link remote regions and foster development and education across the entire society. India's success in forming a coherent and rapidly developing nation out of diverse peoples and traditions can be partly attributed to building this space-based connectivity.[14]

With the emergence of low-cost space capabilities such as those developed by SSTL, numerous nations can now afford space developments. However, one or even a handful of low Earth orbit satellites provides limited capability, whereas constellations of small satellites can provide significant capability. If a group of nations pools their efforts, each one providing a single satellite, all can benefit from a new space capability. The Disaster Monitoring Constellation discussed earlier is a prototype of such a multinational system. This cooperation represents a third approach to soft power—a means whereby smaller nations can pool capabilities to provide significant new space options. In the process of building the capability, the member nations also build technology interdependence and open new economic opportunities in other spheres.

The concept of collective security is a longstanding one. During the Cold War, both competing blocs established collective security arrangements where an attack on one party would be met with a response from all. This was particularly effective for the North Atlantic Treaty Organization (NATO); its collective defense arrangements kept the peace in Europe for almost half a century. Only with the end of the Cold War did conflict again break out on the European continent. Yet even with the disturbances in the former Yugoslavia, NATO's collective response has proven effective. Part of the key to collective security is in the pooling of defense resources, but even more important are the perception aspects of collective security arrangements. A potential aggressor must face the prospect of united defense against him. The psychological and societal impact of standing alone against united opposition is a significant factor in preventing war and aggression. A similar concept is especially applicable to global space security.

Perhaps the most interesting aspect of cooperative international space development is its symbolic value as a pathfinder for other agendas. During the Cold War, space cooperation in the 1975 Apollo-Soyuz test project became a symbolic first in an attempt to lead to broader cooperation in arms control and other security and economic issues. The symbolic role of civil space cooperation truly blossomed in the International Space Station. Despite the political difficulties of building and maintaining such a complex space effort, its symbolic value to both governments and people has carried it through. It has been particularly valuable as a means whereby the United States and Russia have been able to divert technical expertise (particularly within Russia immediately after the end of the Cold War) from missile proliferation endeavors. In a similar vein, a European Community European Space Program is viewed by many as the path to broader European unity. Recently, the United States and India have used civil space cooperation as a step in building closer ties for united action against terrorism. With the major new U.S. push for human exploration of the Moon and Mars, cooperative programs in these areas could similarly prove to be effective vanguards for other agendas.

This approach is not without its problems. Space technology is inherently dual-use, with advances in space providing new military possibilities. Moreover, space technology is often the impetus of and source for new economic products and markets, particularly in the important aerospace field. These considerations are particularly central to U.S. policy. A nation has the choice of ignoring other nations' space exploration interests, dominating mankind's expansion into the solar system, or cooperatively leading the world into the solar system. The United States has chosen the third option. Working to establish consensus on space exploration among numerous global partners could slow progress. However, an open space exploration architecture such as that advocated by Randall Correll and Nicolas Peter would allow nations to proceed at their own pace without sacrificing future opportunities for collaboration.[15]

Space is an important component of global economic development. Space-reliant global utilities such as global positioning, communications, and situation awareness are critical to modern economic development. Communications connectivity is particularly important to remote regions. With new K_a band connectivity, high-speed Internet is available and affordable worldwide. Direct broadcast radio provided by such commercial concerns can bring education and information to even the most disadvantaged peoples. By offering these critical capabilities worldwide, a nation or group of nations will take a major step in providing the means for rapid economic development as well as building global cohesiveness. No element of soft power is more significant than the information-enabling aspect and its associated free exchange of information and ideas.

Space information connectivity may be the key element in combating terrorism, which thrives in regions with little outside information and few economic opportunities. Global information connectivity is a powerful tool for combating both problems. The country of Jordan is a primary example of the power of a successful information strategy and its effect on terrorist activities. In the mid 1990s, Jordan embarked on an aggressive, private sector–oriented information and Internet connectivity campaign.[16] Although still in progress, this campaign is succeeding in connecting schools, businesses, and publics nationwide. It is significant that terrorist attacks against U.S. targets in Jordan were met with wide public outrage there and strong support for Jordan's Western-oriented government.

The first significant philosophical result of deep-space exploration in the 1960s was the view of the entire Earth as a small, interconnected entity. This global awareness continues today with new technology such as the Internet bringing the global perspective to each individual through such tools as Google Earth.[17] Geospatial data is now accessible not only to top-level decisionmakers but also to media and the general public. Every citizen with Internet capability can now access and assess what is happening locally as well as globally. This global perspective will have a huge impact on governments and their decisionmaking. From it will emerge new influences on national policies: a new form of soft power. The National Aeronautics and Space Administration's collaboration with Google to include the Moon and Mars in the products of Google Earth is an example of how governments can work with private sector entities to further the new global perspective.[18] These efforts should pay off not only in expanding space exploration but also in enhancing U.S. soft power influence.

Over and above space exploration and space science, systems such as the international Disaster Monitoring Constellation and European Global Monitoring for Environment and Security are at the forefront of a different definition of security. The security aspects of collaborative efforts offer new opportunities to build soft power influence. By promoting a new strategy where space and associated global utilities function as the primary elements of our security posture rather than as support to warfighters, we could once again attract the best and brightest to space fields.

Developing Leaders and Supporting Systems

A major problem discussed by Correll and Worden is the lack of competent leadership for our national security space programs.[19] There are a number of interconnected issues. First is the intensive requirements process, which has resulted in a cadre of "space professionals" whose expertise is in procurement rather than technical competence. This in turn has produced an aerospace industry dominated by those versed not in technological prowess but in meeting procurement regulations. Often, these corporate leaders are recently retired military leaders. The solution to this problem is to insist on technological competence as a prerequisite for leadership.

Even a change of leadership toward technical excellence will accomplish little if the mindset of technical leaders is one of maintaining the status quo. In today's dynamic new industries such as information technology and biotechnology, growing attention has been paid to what is called *disruptive technologies*.[20] By paying slavish attention to customers—in the case of the national security space community, warfighters—many technologically oriented industries fail to recognize that a new technology that may not interest current customers could offer a way to develop a new, much larger client base. The new disruptive technologies for security space possibilities are small, responsive, information-oriented space systems. The new customers are practitioners of soft power information operations designed for war prevention and not warfighting. As with industries confronted with disruptive technologies, a separate organization that is chartered specifically to ignore current customers is needed. The space community does not have such an organization but desperately needs a disruptive technology development arm.

A major problem is the aging of the aerospace workforce. With an average employee age of near 50 (as compared to an average age of under 30 during the Apollo era), the U.S. aerospace industry is in crisis. Moreover, there is significant evidence that neither industry nor government is able to replace the retiring infrastructure with comparable talent.[21] This problem stems from a perception that aerospace technologies are yesterday's excitement, with much greater future potential in new areas such as bio- and nanotechnology. Moreover, with security space programs in the doldrums and little chance for advancement based on technical prowess, these programs and associated industries are unlikely to attract the top people. For the general aerospace industry, the new "Vision for Space Exploration," with its goal of settling the solar system, could provide a much-needed and exciting new perspective. A similar impetus would exist for security space endeavors with a new strategic purpose. However, to be convincing and sustainable, this new direction must be accompanied by a revised organizational structure. These three basic recommendations are expanded upon below.

Technological Prowess

Our problems begin with the requirements process mentality. The current acquisition approach grew out of Defense Secretary Robert McNamara's Planning, Programming, and Budgeting System of the 1960s. Since then, the defense community has built an enormous construct to develop requirements and budget for achieving them. Every time a new system fiasco occurs, a new review process and bureaucratic overlay are added. One such overlay occurred during the 1990s when the Office of the Joint Chiefs of Staff implemented a whole new process, the Joint Requirements Oversight Council. Carefully considering what a new system is supposed to do and what capabilities it must have, in itself, is advisable. However, the current process does not seem to do that. Most of the people staffing these requirements process offices have little technical, acquisition, or management experience. Few have the breadth of background and perspective to understand what is really needed and how it will be used. But each office can and does have the power to halt the process. Usually, a program is held up until every office is satisfied that its special interest item is included. Few have any idea of the feasibility of adding their demands, let alone the cost of doing so. There is supposed to be a process to accurately assess the cost of the requirements and capabilities, but it is bankrupt. With leadership and workforce so short on technical expertise or engineering experience, the government repeatedly deludes itself into believing that a require-ments-laden system can be built on time and on budget. This tendency to swell the scope and budget of programs is inherent in the military-industrial complex even in the best of circumstances, but experienced and competent management is usually able to deliver in the end.

The response to recent space acquisition problems of the lead Service for space, the U.S. Air Force, has been to emphasize the acquisition process. Primary focus has been on repeated bouts of acquisition reform, back-to-basics campaigns, and other methods. In 2006, this translated to large cuts in technical engineering specialties among Air Force officers with increases in system engineering and acquisition expertise without relevant space technical experience.[22] Nowhere is the problem worse than in the Air Force space programs.

The lack of technological competence in security space leadership is simple to fix. The first step is to demand that all leaders in military and security space programs begin with a certified technical grounding. While the U.S. Air Force and other Services and organizations continuously emphasize developing and certifying a space cadre,[23] the actual educational programs and requirements do not include rigorous engineering and scientific content; rather, they emphasize space doctrine and acquisition skills. This soft skill mix contrasts unfavorably with the rigorous technical requirements for officers either entering or maintaining certification in the U.S. Navy's submarine corps.[24] To remedy these shortcomings, individuals entering space career areas, particularly in military officer or civilian management levels, should be required to have technical degrees. Specific qualification courses and certification should subsequently emphasize technical skills over management-oriented expertise. It is more important that all space professionals be versed in orbital dynamics mathematics than being able to recite the elements of total quality management.

A related problem is that top-quality civilian academic credentials matter. While it is true that people with degrees from a local college sometimes perform as well or better than someone with a degree from a prestigious technical school, this is the exception rather than the rule. Thus, security space organizations should make special efforts to recruit graduates of the highest rated civilian institutions. Moreover, graduate degrees from these institutions should be honored and sought. Finally, courses taught and certified by such institutions are much more likely to be more rigorous than internally organized "Space 101" courses developed and taught by the military Services and commands.

Perhaps most important is for senior civilian leaders and Congress to demand technical backgrounds and extensive space experience for those placed in space command or senior leadership positions. Until recently, most flag-level leaders in Air Force space organizations had little or no actual space background. Often, these leaders were aircraft pilots sent to a space billet for career broadening. Consider that the Air Combat Command has never had nonpilots in its senior positions, while the Air Force Space Command has had few (and at times no) senior leaders with space backgrounds. Congress can ensure this is remedied by insisting that senior officers and other appointed officials are not accepted unless they have demonstrable and extensive space technical credentials and backgrounds.

DisruptiveTechnologyDevelopment

While it is important to have a new strategic construct such as the one outlined in this chapter (namely, that space capabilities are a primary means of preventing wars versus fighting them), such ideas do little good if the hardware and systems do not support this approach. It is unlikely that traditional acquisition organizations, such as the Air Force Space and Missile Center, will pursue systems to support these new missions. The type of capabilities needed for information and global utilities–oriented collaboration probably will not be acquired by an organization attending to requirements levied by a Service fixated on space only as support to warfighters. However, even these existing organizations recognize that current structures focused on acquisition are not well suited to developing new types of capabilities.[25]

What is needed are development organizations chartered to identify new possibilities and develop these to the point of capability demonstration. The Department of Defense has such an organization: the Defense Advanced Research Projects Agency (DARPA), which has a specific mandate to develop new technological capabilities to meet potential long-range security needs. In 2002, in specific response to the Rumsfeld Commission recommendations, DARPA greatly increased its focus on space capabilities, particularly on fast-paced launch systems in its Falcon program.[26] In a similar vein, the short-lived DOD Office of Force Transformation (OFT) pushed the development of responsive, low-cost satellites—those systems capable of being launched during a crisis, not so much to fight a war as to provide a means of preventing a war. For example, a responsive space surveillance system might be launched by the United States or another nation to guarantee an agreement between two potentially hostile neighbors. Just such a move could have helped defuse the crisis between nuclear-armed India and Pakistan in 2002. Each nation accused the other of preparing for an attack. A space-based means of verifying that no such attack was in the works and launched by a neutral third party could have served much the same way as space systems functioned as national technical means of treaty verification during the Cold War. Such systems allowed agreements to be developed and verified as a way to keep the peace, not fight a war.

Unfortunately, neither DARPA nor OFT had a charter or resources to carry the new capabilities beyond technical proof-of-concept. Converting these potential new capabilities into reality requires a development organization specially chartered for this purpose. In addition to lacking such an organization, DARPA also suffered much criticism for trying to develop new information technologies for conducting the global war on terrorism and has largely stopped pursuing such directions.[27] This lack can only be remedied with a new organization separate from traditional channels particularly chartered and funded to develop war prevention systems.

A New National Security Organization

While some personnel policies and even a new development organization are possible, none of this will be meaningful without a supportive home for such activities. The Rumsfeld Commission recommendations were quickly undone.[28] The commission recommended establishing a single national security space program including intelligence (the National Reconnaissance Office [NRO]) and DOD, mostly Air Force programs. A single leader was appointed to oversee both offices. However, no fundamental changes were made to any roles and missions. Consequently, traditional vested interests, particularly within the Intelligence Community, lobbied successfully to return to having the NRO completely separate from DOD programs. Similarly, within DOD, where the Rumsfeld Commission had advocated moving toward a new "space force," progress has been reversed, with the longstanding U.S. Space Command disestablished and its functions integrated into the U.S. Strategic Command (USSTRATCOM), which was formerly focused solely on nuclear warfighting and strategic deterrence. The U.S. Air

Force, once thought to be on the path toward becoming a "space and air" force, is now firmly in the "air" column. To show how far the ball has been dropped, the Air Force is now seeking to transition many formerly space functions into a new category called "near space," whose primary technology would be balloons and airships.[29]

In order for real progress to be made in either developing true professionals or novel technologies, a completely new organization devoted to a new mission is needed. This organization should have a specific charter to work the use of space, information, and collaborative international efforts as a crisis mitigation, war prevention focus. It is useful to note that USSTRATCOM, which now incorporates most DOD space responsibilities, does include many of the necessary elements, including war prevention deterrence functions, information operations, space activities, command and control, and intelligence, surveillance, and reconnaissance functions. It may be easiest to expand USSTRATCOM's functions to include budget and direct operational control in much the same manner as Special Operations Forces are managed by the U.S. Special Operations Command. In this way, personnel, research, development, and acquisition would be run by leaders with a new focus. If this is done, however, it is essential that senior civilian leadership in DOD also exercise direct oversight.

If this new space and war prevention direction and management approach bears fruit, these moves could expand—unlike the Rumsfeld Commission's approach—to create a new arm of U.S. security assurance including separate budgets, military service, and civilian leadership. But it is essential that basic warfighting responsibilities be removed from the new organization's functions. Otherwise, backsliding into business as usual, as occurred with the good start in 2001 on developing a coherent space approach, will swiftly negate even the best intentions of our leaders.

Conclusion

The United States faces many security challenges. One of the most significant is the growing global use of space capabilities—not just for security but also for a broader range of economic, environmental, and political goals. We are not developing the necessary technological tools— particularly low-cost, smaller, and fast-development-time space systems. We are losing technically competent leadership, resulting in unaffordable systems. And we do not have a compelling rationale for our large space expenditures. These problems can be remedied in two ways.

First, there exists a convincing security case for space systems. Space capabilities form an increasingly vital role as global utilities, which serve as the glue that enables a truly interconnected worldwide economy. By working hard to use new, lower cost space capabilities as a crisis management and war prevention device rather than as an adjunct to warfighting, space systems and the organizations and people who develop and support them can bring a new perspective to the public on space.

Second, armed with a persuasive rationale, we need to focus on a technically competent and intellectually responsive leadership cadre. We need to insist on having our space capabilities in the hands of the best and the brightest people. In addition to getting technically sophisticated staff, we need a DARPA-like development organization to create the affordable space tools to support the new direction. Finally, we need a new strategic organization—possibly growing out of the existing U.S. Strategic Command—to manage all aspects, especially budgeting and technology development. This organization needs to be completely separate from traditional national intelligence and warfighting military functions.

With these political recommendations (which, admittedly, will be difficult to implement), space can realize its full potential as the lynchpin for 21st-century global security.

Notes

1. *Report of the Commission to Assess United States National Security Space Management and Organization*, Pursuant to Public Law 106–65, January 11, 2001, available at <www.defenselink.mil/pubs/ space20010111.html>. This report is often referred to as the *Space Commission Report* or *Rumsfeld Report*.
2. The University of Surrey and its Surrey Space Centre have chartered Surrey Satellite Technology, Ltd. (SSTL). SSTL's products and approach can be reviewed on its Web site at <www.sstl.co.uk/>. The history of small and micro satellites is available through the SSTL Web site at <http://centaur.sstl. co.uk/SSHP/>.
3. The Department of Defense has long had a policy of disproportionately reducing its science and technology military expertise. The 2001 National Academy of Sciences' Review of the U.S. Department of Defense Air, Space, and Supporting Information Systems Science and Technology Program (available at <www.nap.edu/openbook/030907/6080/html/38.html>) raises an alarm about the quality and retention of qualified technical personnel. The Air Force reportedly has recently slashed its science and engineering officer billets as part of its "force shaping" flight plan. Even the Air Force Association warns against cutbacks, stating in its 2007 Statement of Policy (as approved at the AFA National Convention, September 24, 2006) that "the Air Force cannot afford cutbacks here if it hopes to retain air dominance in the future."
4. The Disaster Monitoring Constellation is the creation of SSTL. It is now run by a spin-off consortium, DMC International Imaging, collocated with SSTL. Details of the systems and program are available at <www.dmcii.com/index.html>.
5. President George W. Bush signed a new National Space Policy on August 31, 2006. On October 10, 2006, the White House Office of Science and Technology Policy released an unclassified summary, available at <www.ostp.gov/html/US%20National%20Space%20Policy.pdf>.
6. *Report of the Commission to Assess United States National Security Space Management and Organization* (Washington, DC: Commission to Assess United States National Security Space Management and Organization, January 11, 2001).
7. The manufacturer of SAR Lupe, OHB Systems of Bremen, Germany, has provided considerable information on the system including an extensive brochure, available at <www.ohbsystem.de/ Security/sarlupe.html>.
8. Much of the background on the space-based infra-red system (SBIRS) problems can be found in General Accounting Office (GAO) report GAO–04–48, "Defense Acquisitions: Despite Restructuring, SBIRS High Program Remains at Risk of Cost and Schedule Overruns," released on October 31, 2003. An additional "Nunn-McCurdy Overrun" breach occurred in 2005. The original contract consisted of two high Earth orbit satellite sensors and two to three geosynchronous orbit (GEO) sensors (and satellites) with an option to buy a total of five GEOs. In December 2005, following the third SBIRS Nunn-McCurdy violation, the government decided to compete GEO four and five, with an option to buy GEO three contingent on the performance of

the first two. Additionally, the government started a potential SBIRS High replacement program in late 2006. See <www.spacewar.com/reports/USAF_ Seeks_SBIRS_Alternatives_999.html>.

9. NPOESS is also suffering bad overruns of at least 10 percent. Almost all major security space programs are similar, according to Government Accountability Office (GAO) report GAO–05–891T, "Space Acquisitions: Stronger Development Practices and Investment Planning Needed to Address Continuing Problems," statement of Robert E. Levin, Director, Acquisition and Sourcing Management, before the Strategic Forces Subcommittee of the Committee on Armed Services, U.S. House of Representatives, July 12, 2005, available at <www.gao.gov/htext/d05891t.html>.
10. "Space: The Strategic Enabler," remarks by the Honorable Terry Everett, Chairman, Strategic Forces Subcommittee, at the Strategic Space and Defense Conference, Omaha, Nebraska, October 11, 2006.
11. Randall R. Correll and Simon P. Worden, "The Demise of U.S. Spacepower: Not with a Bang but a Whimper," *Astropolitics* 3, no. 3 (Winter 2005).
12. This discussion is based on an unpublished manuscript, "Soft Power and Space Capabilities" by Simon P. Worden and Major Patrick Chatard-Moulin of the French Air Force prepared in 2005–2006. *Soft power* is defined as power based on intangible or indirect influences such as culture, values, and ideology; see <www.wordspy.com/words/softpower.asp>.
13. The May 1998 failure of the PanAmSat Galaxy 4 satellites stopped over 90 percent of electronic pagers in NorthAmerica fromoperating.SeeBBC News,"SatelliteFailure Silences Beepers,"May 20,1998.
14. The India Space Research Organization has as its primary purpose national and eventual international educational and information connectivity. See, for example, a presentation by P.S. Roy from the UN-affiliated Centre for Space Science and Technology Education in Asia and the Pacific at the 15th UN/International Astronautical Federation Workshop on Space Education and Capacity Building for Sustainable Development, Kitakyushu, Japan, October 14–15, 2005.
15. Randall R. Correll and Nicolas Peter, "Odyssey: Principles for Enduring Space Exploration," *Space Policy* 21, no. 4 (November 2005), 251–258.
16. The nation of Jordan embarked in the late 1990s on an ambitious program to provide the population with good Internet and communications connectivity, particularly in schools. The European firm Alcatel played a key role. See a 2003 press release from that company for details of this success at <www.home.alcatel.com/vpr/archive.nsf/DateKey/09012003uk>.
17. NASA and Google are partnering on a variety of new approaches to bring space data to the general public as well as a variety of new users. See NASA press release 06–371, "NASA and Google to Bring Space Exploration Down to Earth," December 18, 2006, available at <www.nasa.gov/home/ hqnews/2006/dec/HQ_06371_Ames_Google.html>.
18. See <http://earth.google.com>.
19. Randall R. Correll and Simon P. Worden, "Leadership for New U.S. Strategic Directions," *Space Policy* 21, no. 1 (February 2005), 21–27.
20. Disruptive technologies were identified in the late 1990s as a key to long-term industrial success. The seminal work is by Clayton M. Christensen, *The Innovator's Dilemma* (Cambridge: Harvard Business School Press, 1997).
21. Commission on the Future of the U.S. Aerospace Industry, *Final Report of the Commission on the Future of the U.S. Aerospace Industry,* November 18, 2002, 4–4, available at <www.ita.doc.gov/td/ aerospace/aerospacecommission/AeroCommissionFinalReport.pdf>. The commission was established by Congress and the President. It specifically identified that the fact that the average U.S. aerospace worker was over the age of 50 is a threat to national security and that aerospace fields are no longer high in the new generation's career aspirations.
22. A report delivered in 2006 by the director of systems acquisition of the Air Force Space and Missile Systems Center summarized space experience of major space acquisition leaders. The following table is extracted from that report.

Total	**Grade**	**Average acquisition experience (in years)**	**Average space experience (in years)**
155	Captain	3.3	2.8
55	Major	0.5	1

34	Lieutenant colonel	3.3	1.8
22	Colonel	15	7.5

23. The Air Force Space Command frequently identifies its shortcomings in developing space professionals and starts new programs. See, for example, a 2004 initiative on developing a space "cadre." Little technical rigor is apparent in the resulting programs. See <www.af.mil/news/story.asp?storyID=123008740>.
24. The U.S. Navy requires substantial basic undergraduate education in engineering, mathematics, and physics to enter the submarine corps. In addition, the Navy provides graduate-level education before Sailors enter the submarine service; see <www.navy.com/careers/officer/submarine/>. The U.S. Air Force has no such technical requirements for entering the space field. It is hard to imagine how space operations are less "technical" than submarine operations, but the Air Force apparently thinks so.
25. The establishment of a new Space Development and Test Wing by the Air Force Space Command suggests that some within the Air Force recognize the need for a new, different type of organization to develop new space capabilities. See <www.af.mil/news/story.asp?storyID=123024576>.
26. The Defense Advanced Research Projects Agency's Falcon program is discussed at <www.darpa.mil/tto/programs/falcon.htm>: "The Falcon program objectives are to develop and demonstrate hypersonic technologies that will enable prompt global reach missions. This capability is envisioned to entail a reusable Hypersonic Cruise Vehicle (HCV) capable of delivering 12,000 pounds of payload a distance of 9,000 nautical miles from CONUS in less than two hours."
27. According to Wikipedia:
    The Information Awareness Office (IAO) was established by the Defense Advanced Research Projects Agency (DARPA), the research and development agency of the United States Department of Defense, in January 2002 to bring together several DARPA projects focused on applying information technology to counter transnational threats to national security. The IAO mission was to "imagine, develop, apply, integrate, demonstrate and transition information technologies, components and prototype, closed-loop, information systems that will counter asymmetric threats by achieving total information awareness." Following public criticism that the development and deployment of these technologies could potentially lead to a mass surveillance system, the IAO was defunded by Congress in 2003, although several of the projects run under IAO have continued under different funding.
    See <http://en.wikipedia.org/wiki/Information_Awareness_Office>.
28. Simon P. Worden, "High Anxiety," *Bulletin of the Atomic Scientists* 62, no. 2 (March–April 2006), 21–23.
29. Hampton Stevens, "Near Space," *Air Force Magazine* 88, no. 7 (July 2005), available at <www.afa.org/magazine/July2005/0705near.asp>.

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