CSET CENTER *for* SECURITY *and* EMERGING TECHNOLOGY

China's Access to Foreign AI Technology

AN ASSESSMENT

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SEPTEMBER 2019

CENTER *for* SECURITY *and* EMERGING TECHNOLOGY

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ACKNOWLEDGEMENTS

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Cover illustration: "Technology transfer" in Chinese.

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Executive Summary

China's technology transfer programs are broad, deeply rooted, and calculated to support the country's development of artificial intelligence. These practices have been in use for decades and provide China early insight and access to foreign technical innovations.

While cyber theft and industrial espionage may or may not be employed, we judge that the main practices enabling AI-related transfers are not illegal. This inspires optimism on one level, but many—possibly most—of these transfers are unmonitored and unknown outside China.

China's reputation as a copycat is overstated and the formulation itself is simplistic. China is building indigenous S&T capacity and can innovate on its own terms, while taking account of global trends to move to new stages of novel development.

Just as important, creativity is multi-faceted and implemented by different cultures in different ways. The belief that liberal democracies, and the United States especially, are endowed with a creative advantage is not well supported by evidence.

We have low confidence that any combination of persuasion or disincentives will cause China to abandon its idiosyncratic transfer practices. Its current reliance on external models to supplement indigenous research is effective, and the alternative (liberalization) is too risky for China.

China's legal and extralegal technology transfers are likely to continue. The U.S. government should invest in ways to manage the situation that are consistent with our values and legitimate security concerns.

We propose five policy options to calibrate the problem and address a few of the United States' own liabilities that magnify the problem's effects. They are:

- Expand U.S. government (USG) data collection and analysis;
- Define general standards for evaluating transfers;
- Educate the world on U.S. concerns and expectations;
- Promote immigration of AI skilled persons;
- Expand America's S&T base.

1 Introduction

This paper is a survey of China's technology transfer practices and the adaptation of these practices to artificial intelligence (AI) research and products.

Based on Chinese sources and guided by our understanding of U.S. government concerns, the study begins by identifying China's "normal" foreign technology acquisition methods, such as overseas research and development (R&D), company buyouts, joint Sino-U.S. research, and its less typical methods.[1] These methods include talent recruitment programs, "dual base" labs, and mobilization of diaspora populations—in all, a dozen distinct access strategies that define the system's special characteristics.

After identifying the transfer vectors, the paper shows how they are used by China to facilitate the diffusion of AI knowledge and commercialization of related intellectual products. Examples given are representative; there is no attempt to be exhaustive, although we point to areas where additional research might be useful.

Along the way, we clarify some misconceptions about these practices and their implications, namely, the belief that espionage is the main component of Chinese technology transfer; the notion that China's so-called "copycat culture" consigns the country to technological inferiority; and the myth that China's innovation system lacks the capacity for significant advances.

A final section suggests policy remedies, including data collection to support decision making; standards for evaluating transactions; conducting outreach to alert transfer participants to USG expectations; facilitating long-term residency for AI skilled immigrants; and growing America's S&T base.

Our thanks to Tim Heath (RAND), James Mulvenon (SOSI), Anna Puglisi (DNI), and Chenny Zhang (DOD), who read the draft and offered helpful suggestions; to Zachary Arnold, Remco Zwetsloot, and Roxanne Heston at CSET for substantive contributions; and to Jason Matheny, Andrew Imbrie, and Lynne Weil at CSET for editing and critical support.

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2 Chinese Foreign Technology Transfer: Myth and Reality

CHINA'S TECH TRANSFER INFRASTRUCTURE

Shortly after founding the People's Republic in 1949, China began a multifaceted program to access foreign technologies on a scale that would allow China to "leap past" (超越) basic R&D and join the ranks of advanced nations. That program continues to this day.

Students are sent abroad, foreign experts are invited in, technology outreach offices function within ministries and their affiliated NGOs,[2] and a world-class scientific literature monitoring system works around the clock. S&T "cooperation societies" (合作协会) worldwide convey "talent" and ideas to China, while state incentive programs finance long- and short-term visits by specialists to impart specific knowledge. Professionally staffed "innovation service centers" (创业服务中心) and "technology transfer centers" (技术转移中心) commercialize the technology brought to China "by various means" (以多种方式).

Rounding out the program are legal venues, practices, and access points, including direct technology purchases, hi-tech Sino-foreign cooperative ventures, and targeted acquisitions of foreign companies; and the illicit technical acquisition and human theft of intellectual property (IP) that occupies much of the public discourse on Chinese technology transfer. While one can debate the importance of different aspects of the program, the overall construct has been described in U.S. government documents[3] and commissioned reports,[4] scholarly works,[5] and by Chinese themselves working inside the system.[6] The existence of the program and scale on which it operates is incontestable.

It is also evident, from these earlier surveys and the present one, that most of the features comprising the program are—in terms of vectors

alone—*not necessarily illegal*,[7] which renders the question of policy response all the more difficult. A related challenge for policymakers stems from a misunderstanding of what this program implies about China's ability to compete. While some see "borrowing" as an admission of inferiority, and believe that the United States' ability to innovate offsets the advantages China gains from licit and illicit access, China's composite innovation system—a hybrid approach to technological development based on foreign models and homegrown initiatives—is competitive, highly effective, and needs to be taken seriously.

Below is an outline of its major venues and practices as directed toward the United States.[8] These transfer vectors are categories, each with several, to several thousand, examples.

"Extralegal" indicates that the types of transfer these organizations sponsor typically are not subject to outside scrutiny, hence the legality of the transactions is unknowable. Examples of document acquisition facilities are the Institute of Scientific and Technical Information of China (中国科学技术信息研究所) and its military analog, the China Defense Science and Technology Information Center (中国国

Legal transfers[9]

China-based U.S. subsidiaries
Competitions (companies, universities)
Conferences and colloquia
Direct technology purchases
Enrollments at U.S. universities
Investments / acquisition of companies
Joint Sino-U.S. research agreements
Loopholes in trade agreements
Patent mining and exploitation
PRC-backed venture capital funds
Startup accelerators and incubators
State-backed investments in U.S. research
Tech exchanges, trade-for-tech agreements
U.S.-based labs, representative offices

Illegal transfers

Breach of contract
Computer network exploitation
Copyright infringement
Insider operations
Reverse engineering
Traditional espionage
Willful patent infringement
Violation of non-disclosure agreements

Extralegal transfers (organizations)

Document acquisition facilities
Front organizations for PRC offices
Overseas scholar returnee facilities
PRC ministry offices (national, local)
Recruiting and brokerage websites
Sino-U.S. professional associations
Technology transfer centers
Technology transfer forums
Transfer incentive programs
U.S.-based facilitation companies
U.S.-based student/alumni associations
University-linked "innovation" parks

防科技信息中心). The China Association for International Exchange of Personnel is an NGO that fronts for the State Council's State Administration of Foreign Expert Affairs. The two organizations share offices and personnel.[10] Returnee parks, "pioneering" parks, tech transfer centers and technology "incubators"—large physical complexes that collectively number in the several hundred—share the common mission of commercializing foreign technology; their distinctions, an artifact of sponsorship, are evaporating.

Extralegal conduits supporting technology transfer also include the Sino-American professional associations—ethnic guilds focused on a technical discipline or geographic area—with (claimed) memberships that can exceed 10,000. There are two dozen major groups in the United States and another two dozen worldwide. The Chinese language versions of their websites usually include some expression of fealty to the ancestral country (祖国) and pledges to support its development. These groups derive legitimacy from association with the local People's Republic of China consulates, which in turn broker investment and joint research opportunities.

China's "talent" (人才) recruitment programs spot U.S.-based scientists and engineers with skills needed for technical projects. These programs offer incentives for support that range from a year or more onsite to participation in a "two-bases" (两个基地) schema whereby a candidate remains abroad and sends information to China. The "Thousand Talents Plan" (千人计划) is the commonly cited example, but there are hundreds of such programs.

It remains an open question how exactly these venues are mobilized and to what extent transfer initiatives are coordinated across the different access points. Orders to focus on a class of technologies can be traced—historically and today—from their first appearance as State Council directives, through implementation policies by relevant ministries, "talent" calls broadcast by outreach offices, the appearance

Extralegal transfers (personnel)

- Professional facilitators
  - administrators of returnee parks and tech transfer centers
  - diplomats at embassies and consulates (S&T consuls)
  - employees of NGOs that front for declared transfer facilities
  - managers of 'talent' recruitment and other incentive programs
- Scientists, overseas scholars and entrepreneurs
  - attendees at overseas exchange forums
  - awardees of sponsored transfer incentive programs
  - members of overseas Chinese professional associations
  - organized alumni of Chinese technical universities
  - PRC post-docs at USG research facilities
- S&T intelligence workers (科技情报工作人员)
  - talent spotters attached to factories and labs
  - members of S&T 'business intelligence' groups
  - staffers of China's open source S&T collection network

of international conferences on the theme, and as agenda items in the posted minutes of foreign-based advocacy groups and diaspora guilds—all of which typically cite the original directive. Tailored collection of technology for state-favored projects, however, is not normally traceable in open sources to an originating office.

Although aspects of the network are highly systematized (patent and standards exploitation, civilian and military open source procurement, "talent" spotting and recruitment), much of it is disorganized and duplicative. Parts were designed, but mostly it is a product of ad hoc initiatives. Periodically a ministry or consortium of ministries will launch a new incentive program on top of an existing one, tighten qualifications on imported talent, or consolidate redundant venues (e.g., innovation service centers and returnee parks). But its main elements were in place by 2006-7.[11]

The system's growth can also be measured in terms of the type of technology it targeted. Early transfers were of specific components used for weapons and products. This practice evolved over time to encompass technologies needed to manufacture the components, and finally to the basic science from which innovations emerge. Given the abstract nature of AI algorithms, China's ability to tap

new developments in this field at early stages is critical to its success. As we shall see, China has successfully mobilized those parts of its transfer apparatus to meet this challenge.

At its root, we view Chinese technology transfer less as the output of a system and more as the product of a particular mindset. We have seen many articles in theoretical journals and China's own popular press on the need to "absorb" the world's intellectual products. While we also see injunctions against intellectual property rights (IPR) violations, the use and abuse of external models is not stigmatized in China to the same degree as in the United States. It is probably fair to say there are fewer cultural and institutional obstacles to prevent it.[12]

Whatever the motivation for this behavior, it is clear that China—more than other countries[13]—devotes extraordinary efforts to reduce the risk and cost of innovation by accessing research done elsewhere.

THE SHIBBOLETH OF "CREATIVE ADVANTAGE"

Does technology transfer support China's long-term goals? Or are there hidden costs to a "copycat" model? China clearly perceives benefit from broad access to foreign technology. The best evidence of this is China's use of these programs to achieve parity across a wide spectrum of disciplines, the proliferation of projects aimed at facilitating access, and its willingness to fund foreign technology acquisition on a scale that at times has rivaled its budget for indigenous R&D.[14] In the long run, however, China's appropriation of foreign creative resources has been assumed—in the United States especially—to be an Achilles heel that guarantees China will always trail liberal democracies in innovation and in the national power that innovation is believed to support.

This assumption—which we question below—has some historical, theoretical, and empirical support.[15] In particular, China traditionally has not shown the same aptitude for "breakthrough" science as nations in the western tradition. While the causes are many,[16] Asian and western scholars agree on the co-existence of unique Chinese and western preferences for scientific development that bias the former against radical innovation.[17] There is also agreement that these preferences stem from cultural traditions that accord different weights to theory and practice.[18]

By this argument, China's penchant for concrete research and distaste for abstraction, nursed over millennia, inhibit China's ability to compete in theory-driven science.[19] Some also point to "copying" as indicative of a creativity deficit.[20] A more nuanced view distinguishes the type of creativity favored in China, where new ideas emerge by restructuring a given context and a second type favored elsewhere, which depends on similarity judgments between a source and target in different domains.[21] Both are models of creativity, although the latter, associated with fundamental breakthroughs, is the acclaimed western stereotype.

Western bias notwithstanding, our view is that this alternate form of creativity in which China clearly excels accounts for most of what happens in science and should be acknowledged alongside the idealized ("breakthrough") form of creativity. We also believe the West's creative advantage is overstated for several reasons:

- China does important work in fields that it cares about and is closing the "innovation gap" across the board;[22]
- Quantity has a quality all its own. The scale of China's S&T investment itself increases the likelihood of successes;
- The country has compensated for its creativity problem by tapping into innovations done elsewhere before others see them as viable;
- The ability to innovate in the abstract may matter less in real world terms than the ability to apply those innovations practically, wherever they are made;
- The Chinese diaspora and internationalization of science have made discussions of what "China" can and cannot do mostly meaningless.

In sum, we believe China's "S&T information/intelligence[23] operations" (科技情报工作) will for practical, cultural, and political reasons continue indefinitely. There is little downside to China's hybrid foreign-domestic innovation system and few gains to offset the risks a liberalized culture, primed to produce the occasional breakthrough, poses to regime stability. Similarly, America's belief in its innate ability to out-innovate China is probably untenable.

3 China's Access to Foreign AI Technology

How many of these transfer strategies does China use to access sources of AI technology? A survey of recent online postings indicates that most of the access points and support vectors described in Section 2 of this report. are in play for AI.[24] That is, the same venues China has used over past decades to acquire foreign technology in general are used by China today to supplement indigenous AI research and product development. They are:

Chinese academic institutions	Official PRC policy support
Chinese AI companies	Online and physical exchange forums
Chinese research and investment abroad	Overseas study and research
Co-authorship of academic articles	Sino-foreign AI conferences
Foreign research and investment in China	Sino-foreign cooperation associations
Government outreach facilities	Talent recruitment programs
Government-sponsored labs	Technology transfer centers
Innovation and returnee parks	Think tanks and professional groups

We expand on these venues in the remainder of this section.

OFFICIAL POLICY SUPPORT

The importance of foreign technology in China's AI enterprise is stated unequivocally in a foundational document released by the State Council on 8 July 2017 titled "The New Generation AI Development Plan.[25] Under "Key Tasks" (Section 4, "Accelerate the cultivation and gathering of high-end AI talent"), the plan emphasizes "speeding up the introduction of top AI talent and younger AI talent worldwide" to form China's "high

ground" (高地) of AI experts. It goes on to recommend several actions to facilitate access to this high ground:

- cooperation and interaction with major AI institutes worldwide;
- use of "special channels and policies" to recruit top AI persons;
- the "flexible introduction"[26] of AI talent via projects and consultation; and
- coordinating with China's foreign talent programs ("Thousand Talents").

Under "Resource allocation" (Section 3, "Coordinate international and domestic innovation resources"), the plan reads in part:

> "Support cooperation between domestic AI enterprises and international AI leading universities, research institutes and teams. Encourage China's AI companies to go global (走出去). Facilitate overseas mergers and acquisitions, equity investments, venture capital investments and the establishment of overseas R&D centers. Encourage foreign AI companies and scientific research institutes to set up R&D centers in China."

The plan also urges support for "industry associations, alliances, and service organizations to build a worldwide service platform" (服务平台) for China's AI companies.

This State Council plan was followed by a Ministry of Industry and Information Technology (MIIT) action plan[27] for "full use of bilateral and multilateral international cooperation mechanisms" and "attracting high level AI talent and innovative entrepreneurial talent by various means (以多种方式)."[28] MIIT's plan cites an earlier guide for use of the Thousand Talents and Ten Thousand Talents plans among the resources available for China's AI development."[29]

Another example of documented support for access to foreign AI resources is the Education Ministry's "AI Innovation Action Plan for Institutes of Higher Education" issued 3 April 2018.[30] Its "Key Tasks" are largely foreign-oriented. They include:

> "Increase international academic exchanges and cooperation. Support the establishment of 111 Plan 'foreign intellect bases'[31] and joint laboratories for international cooperation in the field of AI; cultivate international science programs and major scientific projects; accelerate the introduction of internationally renowned scholars to join in establishing scientific disciplines and scientific research; organize high-level interna-

> tional academic AI conferences; promote Chinese scholars for important posts in relevant international academic organizations," etc.

These state pronouncements—in substance and style—mimic the core documents prescribing the mechanisms China uses to transfer technology in general.[32]

OUTREACH ORGANIZATIONS

China's foreign technology outreach organizations appear to be following a similar path. Key functions of the Ministry of Science and Technology (MOST) are to attract foreign scientists to China, contact foreign experts, and conduct training and study abroad. Its sponsorship of AI projects was detailed in a "New Generation AI Development Planning" kick-off meeting held in November 2018 to "strengthen international cooperation;"[33] in a workshop convened in February 2019 by its New Generation AI Development Planning and Promotion Office, seeking "international exchanges in AI;"[34] and in its 2018 and 2019 key projects for "strategic international S&T innovation cooperation," which included AI and robotics.[35] An AI focus is also apparent in each of the ministry's five subordinate offices charged with foreign outreach operations.[36]

Other outreach groups have similar roles. The Chinese Academy of Sciences' Bureau of International Cooperation (国际合作局) ran a six-week project to integrate Hong Kong college students into China's AI ecosphere.[37] The China Association for Science and Technology (中国科学技术协会, CAST), with chapters abroad including a CAST-USA, in January 2018 convened an "International Cooperation Forum on Intelligent Technology" where PRC officials pitched "international exchange and cooperation on multiple levels" to an audience that included American officials.[38] China's State Administration of Foreign Experts Affairs (国家外国专家局, SAFEA) conducts its own recruiting and functions as the sanctioning body for the nationwide outreach network. In May 2018, it co-hosted with the American Society of Mechanical Engineers a "Forum on New Generation AI and Advanced Manufacturing."[39]

The China International Talent Exchange Association—an NGO under SAFEA's "guidance"—had scouts at Japan's "2nd AI Expo" in April 2018. The organization, until recently the "China Association for the International Exchange of Personnel," has chapters in 45 China locations and 10 offices abroad. Its website lists some 6,570 instances of foreign intellectual transfers (引智成果),[40] including "R&D on a new generation of human-computer interaction technology based on AI" originally from Iowa State University,[41] a wearable device for real-time health monitoring based on an AI deep learning algorithm from Australian National University,[42] and an AI-based camera researched at the University of Alabama, marketed by a Wuhan and Silicon Valley-based company.[43]

"TALENT" RECRUITMENT PROGRAMS

An additional source of talent (人才) for China's S&T development are the foreign incentive programs run by state, provincial, and municipal offices, the best known being the "Thousand Talents Plan." This is a short name for the "Recruitment Program of Global Experts" (海外高层次人才引进计划) founded in 2008 as an arm of the Central Talent Work Coordination Group,[44] itself governed by a consortium of 20 ministry-level organizations. Other popular programs are the Ministry of Education's Spring Light Plan (春晖计划), the Changjiang Scholars Award Program (长江学者奖励计划), and the progenitor of the series: the Chinese Academy of Science's "100 Plan" founded in 1994 with 1,569 participants to date.[45]

Thousand Talents had previously posted online[46] lists of selectees, including those in its youth category, but recently discontinued the practice. A keyword search on the program's name and AI disciplines, however, yields multiple hits, which we capped at 100 examples. Within this sample, program selectees were overwhelmingly from the United States, typically university professors—in some cases departmental chairs—with specialties in deep learning, intelligent robotics, blockchain or applied aspects of AI. Some selectees from U.S. institutions have standing dual appointments at Chinese academic or research facilities. Others boast resumes with a history of support from both the U.S. and Chinese governments, including the U.S. Department of Defense. Searches run on Changjiang Scholars elicited similar results.

CONFERENCES AND EXCHANGE FORUMS

Chinese businesspeople, scholars, and government officials attend AI conferences abroad and arrange international gatherings within China to keep track of worldwide AI trends and seek out collaborative opportunities. Some examples from 2019 alone:

- On 23 March, the Chinese AI company Sensetime and Beijing's Zhongguancun Hi-tech Park hosted the "First International Artificial Intelligence Fair" to engage secondary school students worldwide, attended by 41 domestic and foreign groups.[47]
- On 1 April, the WTO, ITU and a consortium of Chinese official and semi-official groups hosted a "2019 Artificial Intelligence for Health Summit" in Shanghai to facilitate exchanges, discussions and joint analysis of present and future trends in AI medicine.[48]
- On 16 May, UNESCO and China's MOE jointly hosted an "International Conference on AI and Education" in Beijing with some 500 participants, including AI industry leaders, academic experts, policymakers and practitioners.[49]

Details on 399 China-sponsored AI conferences from mid-2017 through the end of 2019 are available on a Chinese tech portal.[50] Other online forums run by PRC ministries and foreign-based advocacy groups alert diaspora Chinese[51] to China collaboration and employment opportunities. For example, in April 2019 the Chinese American Professors and Professional Network (美国华裔教授专家网) ran a "talent" solicitation notice for Zhejiang's Pinghu City that included projects in AI and robotics.[52] The Chinese Service Center for Scholarly Exchange (中国留学服务中心) has links to an announcement by the PRC embassy in Bern for the "Second All-Switzerland Chinese Scholars AI Seminar."[53] China Human Resources (中华英才网), a job recruitment website, has a page indexing AI jobs to each of China's major cities.[54] The official China International S&T Cooperation Net (中国国际科技合作网) posts hundreds of collaboration opportunities and solicitations for AI-related technology.[55]

These virtual media are complemented by physical forums designed to put diaspora experts in contact with China S&T companies. The best known is an annual "Guangzhou Convention of Overseas Scholars in S&T" (中国留学人员广州科技交流会), which now runs concurrently with a Convention on Exchange of Overseas Talent (中国海外人才交流大会). AI expertise was sought in each of the 2017, 2018, and 2019 events.[56] Shenzhen's "China Hi-Tech Fair" (中国国际高新技术成果交易会, literally "China international exchange fair for new and high-tech products") devoted kiosks to AI, intelligent manufacturing, intelligent homes, self-driving cars and 5G.[57]

CHINA-BASED FOREIGN R&D

High-tech multinational companies establish R&D centers in China to tap China's indigenous talent pool as a means of adapting their products to Chinese taste and expanding their innovation base. In return, China expects the multinationals to "share" technology—that developed in country and its own core assets—with its host for access to China's market. This trade-for-technology formula[58] ("forced technology transfer") is the subject of intense debate between U.S. and China trade officials, and a solution does not seem imminent.[59]

Meanwhile, we note in this context the presence in China of most major U.S. information technology companies that play leading roles in AI research. In 2018, Amazon announced its AWS Shanghai Artificial Intelligence Research Institute. The lab complements its existing Shanghai-Amazon AWS Joint Innovation Center.[60] Apple plans four R&D centers located in Beijing, Shenzhen, Shanghai, and Suzhou. Google's AI China Center in Beijing has been running since late 2017. IBM is an early entrant; its Beijing and Shanghai facilities are staffed with "scientists working daily to develop core AI capabilities."[61]

Microsoft has operated its Microsoft Research Asia facility in Beijing since 1998. In 2018, the company announced a Shanghai branch and a co-located Microsoft-INESA AI Innovation Center to bring in "world-class AI research capabilities."[62] These foreign-owned or affiliated labs are staffed with top AI figures and integrated into China's state-run ecosystem of "science town" incubators. We know of no metric to gauge the marginal utility of these joint arrangements for the United States and China. Our goal is simply to document these access points to AI research.

TRANSFER CENTERS, INNOVATION HUBS AND OCS PARKS

China's drive for practical use of innovative technologies—wherever they originate—is evidenced on a personal level. Entrepreneurs engage in what Sinovation Ventures CEO Kai-fu Lee calls a "bloody battle" to be first to market.[63] It is also apparent on a national scale in the form of Technology Transfer Centers (技术转移中心, TTC), offices and compounds found in all major Chinese cities run by a coalition of state, academic, and industrial sponsors. Their purpose is to "pave the way for the development and expansion of openly available technology" both foreign and domestic, support the creation of technology centers within companies, and "promote the conversion and transfer of technologies held by higher education."[64]

Consider a few examples of their activities. In July 2017, the Jiangsu Center of International Technology Transfer (江苏省跨国技术转移中心) held an "International Collaboration Innovation and Technology Transfer Forum" attended by academics from Carnegie Mellon, UCLA, and other research universities to discuss transfer opportunities in robotics and AI.[65] In November 2018, the Science Ministry and local government co-hosted a conference at Beijing's China International Technology Transfer Center (中国国际技术转移中心) to "establish communication channels and mechanisms for international technology transfer, and promote transformation of international innovation cooperation results." AI was a featured part of the "road show."[66]

Close cousin to China's TTCs are "innovation service centers" (创业服务中心) and "overseas Chinese scholar pioneering parks" (留学人员创业园), or OCS parks. Distributed throughout China inside high-tech civilian and military industrial complexes (the so-called "science towns" 科学城), these multi-story, acres-wide, subsidized facilities provide safe haven to Chinese start-ups focused on single technologies acquired abroad. The complexes house tenants responding to calls from an affiliated ministry or local authority for particular classes of technologies, publicized on PRC government websites, technology brokerage portals, and through Chinese consular facilities abroad. The calls are highly formulaic, suggesting top-down coordination. Applicants typically must have a master's degree or higher from

abroad and "independent intellectual property rights"[67] to an innovative technology of specified type with strong potential for marketability.

There has been a significant proliferation of such calls. Beginning in 2017, these notices started mentioning "artificial intelligence" among the number of disciplines—10 or fewer—sought for the next cycle (calendar 2018).[68] Notably, a 2018 call listed AI in 8th position; in 2019, AI ranked second after advanced equipment manufacturing.[69] An online search conducted by the authors returned data on AI, machine learning, and intelligent manufacturing start-ups in returnee parks located in Beijing, Changchun, Changsha, Chengdu, Dalian, Fujian, Hangzhou, Hefei, Hohhot, Jiangyin, Jieyang, Kunshan, Nanjing, Ningbo, Shanghai, Shenzhen, Tangshan, Tianjin, Wuhan, Xiamen, Yantai and Zhuhai. Each of these cases involves IPR created abroad or as a result of having done research abroad.

GOVERNMENT-SPONSORED AI LABS

The Chinese government controls hundreds of "key labs" (重点实验室) centered around specific scientific or engineering disciplines. Sponsorship is at the national, provincial, and municipal levels, the most prestigious being the state-run (国家) units of which there were 253 plus six "national research centers" of equivalent status in 2016.[70] [71] Only one of these top-level labs—Qinghua University's State Key Laboratory of Intelligent Technology and Systems (清华大学智能技术系统国家重点实验) established in 1990—focused wholly on AI, although others did so peripherally.[72] That changed in February 2017, when a National Engineering Laboratory for Deep Learning Technologies and Applications (深度学习技术及应用国家工程实验室) was established under Baidu's lead. Months later, MOST stood up a State Key Laboratory of Cognitive Intelligence (认知智能国家重点实验室) under iFlytek's auspices.

Other second-tier laboratories have been doing AI research for a decade or longer, including labs in Beijing, Chengdu, Shanghai, Shenzhen, Xi'an, and elsewhere. In addition, there are labs affiliated with the Chinese Academy of Sciences, such as the Key Laboratory of Intelligent Information Processing (智能信息处理重点实验室), its Institute of Automation and, within it, a Research Center for Brain-inspired Intelligence (类脑智能研究中心), which has published on neuroinformatics and multi-scale brain simulation.

Typical of the genre is Xidian's MOE Key Laboratory of Intelligent Perception and Image Understanding (智能感知与图像理解教育部重点实验室), co-located with an International Joint Lab for IntelliSense and Computing and an affiliated "International Center." The lab is part of China's "111 Plan" (see above), has been awarded projects under the "863 Program"[73] and has Changjiang Scholar recipients. These labs are visited by foreign scientists, dispatch staff for academic exchanges abroad, and engage in collaborative ventures with overseas colleagues.

The following passage on Sichuan's Key Laboratory of Artificial Intelligence is representative:[74]

> "The laboratory held international academic exchange activities and sent some ten visiting scholars to academic institutions such as the University of California, the University of Auckland, the University of Ottawa, the Hong Kong Polytechnic University, and the University of Singapore, and actively carried out related scientific research. At the same time, professors from relevant research fields in Mexico, France and the United States were invited to the laboratory to lecture to the laboratory's nonlinear research team and graduate students."

Shenzhen's Key Laboratory for Big Data and Artificial Intelligence boasts research staff that include academicians from Canada's Royal Academy of Sciences, the American Academies of Engineering and Science, international IEEE fellows, and 21 returned overseas scholars. Some of its staff have been U.S. Natural Science Foundation grantees and others worked on projects with the U.S. Department of Defense and the National Institutes of Health.[75]

THINK TANKS AND PROFESSIONAL GROUPS

China's earliest AI professional organization, the Chinese Artificial Intelligence Association (中国人工智能协会), was established in 1981 by CAST and the Beijing University of Posts and Telecommunications. For decades it was China's only national level AI group.[76] As of 2017, its ranks included 22 academicians and 53 "leading AI figures."[77] Within the past two years, several new China AI industrial organizations arose, including:

- Shenzhen Artificial Intelligence Industry Association (深圳市人工智能行业协会), stood up at the end of 2016 by a consortium of AI companies, including Baidu, with support (支持) from the municipal government.[78]
- Jiangsu Association of Artificial Intelligence (江苏省人工智能学会), formed in 2017 as a non-profit organization of some 1,500 persons and 200 companies involved in AI-related disciplines.[79]
- Artificial Intelligence Industry Alliance (中国人工智能产业发展联盟), organized in October 2017 under MOST and MIIT auspices. Its International Exchange Work Team "introduces foreign high-quality industry resources," i.e., technology and "talent."[80]
- Beijing Academy of Artificial Intelligence (北京智源人工智能研究院) created in November 2018 by the Beijing city government. Its founding members include Peking and Tsinghua universities, Baidu and ByteDance.[81]

Each of these organizations hosts international conferences, welcomes participation from AI researchers worldwide, and encourages international exchange and cooperation.

CHINESE AI COMPANIES

As of May 2018, there were an estimated 4,040 AI enterprises in China, of which 1,070 of those companies are in Beijing.[82] The largest in terms of AI investment are Baidu (百度), Alibaba (阿里巴巴), and Tencent (腾讯)—the so-called "BAT" trio, roughly equivalent to Google (search), Amazon (shopping), and Facebook (social media), respectively. The three companies together have invested in some 53% of China's top 190 AI companies. A second tier of AI-invested Chinese firms is represented by Huawei (华为), JD Research (京东AI研究院) and iFlytek (科大讯飞), which corner another 10%.[83]

Baidu's AI umbrella group (AIG) employs more than 2,000 scientists and engineers spread over five labs in China and Silicon Valley. Its internationally sourced staff[84] are complemented by a Research Advisory Board of distinguished American scientists.[85] Alibaba Damo Academy's (达摩院) head of machine intelligence holds a CMU doctorate and was on Michigan State's computer science faculty. Most of his research team have U.S. pedigrees, as do the top figures in Damo's other nine labs.[86] Access to world talent is ensured by an Alibaba Innovative Research Program billed as a "bridge" to scholars worldwide, and by fellowships "for research scholars around the world."[87] Tencent AI Lab boasts "more than 70 scientists from world-renowned universities."[88] Its Focused Research Program "aims to identify and support world-class faculties pursuing innovative research" in AI fields.[89] A parallel visiting scholars program seeks faculty from universities or research institutes worldwide "to identify research problems from real industry scenarios."[90]

Tight integration of China's AI companies with international "talent" is evidenced within the second and third tier firms as well. JD AI Research maintains offices in the United States and Europe to attract leading global talent.[91] Its Joint JD-Stanford University AI Laboratory scientists work on knowledge mapping, robotics, and scene recognition.[92] iFlytek has "strategic cooperation agreements" with both Princeton and MIT's Computer Science and AI Laboratory. DeepBlue Technology, a Shanghai-based AI company established by PhD returnees, has linked up with "world-renowned colleagues and universities to explore, cultivate and inspire outstanding AI talents around the world."[93] There can be no question that China's AI companies are plugged into the worldwide pulse of AI development.

CHINESE AI RESEARCH AND INVESTMENT ABROAD

China's AI companies maintain overseas labs to gauge local markets and access foreign research "talent." The United States is a favored venue. Baidu runs

an Institute for Deep Learning (2013) and a Silicon Valley Artificial Intelligence Lab (2018) in Sunnyvale CA. Alibaba has outposts in Seattle (Bellevue) and Sunnyvale, where it is advertising AI positions. Tencent Holdings has an AI Lab in Seattle (2017) and is recruiting self-driving car experts in Palo Alto. Sensetime (商汤科技), a Chinese AI company doing computer vision and deep learning, has an AI-based health lab in New Jersey, collaborates with MIT on machine intelligence, and engages in "synchronous development" (同步开拓) between its China and Silicon Valley locations.[94]

Smaller Chinese or China-invested AI companies with a U.S. presence number in the hundreds. For example, Pony AI (小马智行), an autonomous driving vehicle company, is "co-located in the heart of Silicon Valley and China" (Beijing and Guangzhou). Its top staff hail from Baidu, Google, Nvidia, Facebook, and Uber.[95] ByteDance (字节跳动), a Beijing company with expertise in machine learning (ML) and creator of the ubiquitous "Toutiao" (头条) AI-based content platform, has a branch in Los Angeles. Aibee is a Chinese-invested AI firm run by the former head of Baidu Research; the company does work in several AI areas at locations in Beijing and Palo Alto. Roadstar (TOP 无人驾驶公司) is an AI startup founded by robotics and ML veterans from Google, Tesla, Nvidia, Apple, and Baidu; it is Chinese-invested with offices in Shenzhen, Beijing and Silicon Valley.[96]

These U.S.-based labs are the visible face of China's AI technology access strategy. Large investment consortia, so-called "angel fund" investors, play a more critical role by funding Chinese and Chinese-American AI start-ups. Prominent among them are:

- ZhenFund (真格基金): A Beijing-based angel investment fund that sees itself as "a bridge for overseas returnees to pursue entrepreneurship in China." Its portfolio includes some 33 AI companies, many of which are located or have branches in the United States.[97]
- TechCode (太库科技): Headquartered in Beijing with offices worldwide. Its focus is AI, big data, and new materials. By the end of 2018, the company had funded some 1,463 startups, including companies in Boston and Silicon Valley.[98]
- Sinovation Ventures (创新工场): Started in 2009 by Kai-Fu Lee, with offices in Beijing, Shanghai, Shenzhen, Palo Alto and Seattle. Its focal areas are AI, big data, robotics and deep software.

According to CB Insights, a tech market analysis firm, between 2012 and mid-2017 China-based investors accounted for 641 AI tech investments in the United States totaling $19 billion, focusing on AI, robotics, and augmented or virtual reality.[99]

Besides these private ventures, the Chinese government invests directly in U.S.-based AI research and incubation via its Zhongguancun Silicon Valley Innovation Center (中关村硅谷创新中心) in Santa Clara, a Hangzhou Silicon Valley Incubator (杭州硅谷孵化器) in Redwood City, and the Shanghai Zhangjiang Boston Enterprise Park (上海张江波士顿企业园). The presumption is that benefits from these projects accrue in both directions, although we lack metrics for comparison.

SINO-FOREIGN PROFESSIONAL COOPERATION ASSOCIATIONS

Foreign-based professional "cooperation associations" (协会), composed mostly of diaspora Chinese, are viewed by Beijing as an important venue for technology transfer. The organizations and their members are courted by Chinese consulate officers domestically and feted by government organizers of exchange forums during their trips to China. The degree to which these associations identify with China (and China's interests) appears to vary: some are loosely organized guilds, while others—based on their charters and observed behavior—may qualify for registration under the Foreign Agent Registration Act. Depending on the criteria, there are some two-dozen major Sino-U.S. science and engineer associations and an equal number in Europe.[100]

The growth in the importance of AI is paralleled by an increase in the attention given to it by these associations. The North American Chinese Scholars International Exchange Center (北美洲中国学人国际交流中心), headquartered in McLean VA, funneled to Tangshan, a city with which it collaborates, only two AI-related projects in 2010.[101] In 2019, the proposed number was eight.[102] In May 2018, the group was plugging relocation opportunities for those with AI skills in Tianjin. In 2017, 10 members of the Federation of Associations of Chinese Professionals in Southern USA (美南中国专家协会联合会), an Atlanta-based organization, presented 10 AI and robotics projects at a Huishan promotion meeting in Jiangsu.[103] Houston's Chinese Association of Professionals in Science and Technology (中国旅美专家协会) in May 2018 demonstrated AI and ML products at a forum attended by persons from Anhui, with which the group has ties.[104]

The Association of Chinese-American Scientists and Engineers (旅美中国科学家工程师专业人士协会), a Midwest group with 12 chapters whose members at one time included currently serving PRC officials,[105] featured AI at its 26th annual meeting in Chicago on 13 October 2018. Two weeks later a branch of the association was stood up for big data and artificial intelligence with a goal to "promote exchange of cutting-edge S&T and strengthen strategic cooperation between the association, US companies and Chinese enterprises."[106]

Santa Clara's U.S.-China Association of High-level Professionals (美中高层次人才交流协会) regards itself as "a platform for entrepreneurs and an engine for

innovation and entrepreneurship" with a claimed membership of 21,000 and advertised record of supporting 5,000 start-ups. Its annual "AI CONNECT" conference serves as a forum to discuss AI "innovation trends."[107] The Chinese Association for Science and Technology USA (中国留美科技协会), a bespoke affiliate of its semi-official China-based namesake,[108] in September 2018 convened in New York a forum on AI's future;[109] its engineering counterpart, the Chinese Institute of Engineers USA (美洲中国工程师学会), met the same month to discuss AI applications.[110]

Similar organizations grew up around the AI theme in other countries in 2017-18, when Beijing publicized its "New Generation AI Development Plan." Some 400 Chinese students, PhDs, and entrepreneurs in Japan created the China-Japan Association for Artificial Intelligence (中日人工智能协会) to facilitate "exchanges, cooperation and globalization" of AI projects and knowledge between the two countries.[111] A China-Britain Artificial Intelligence Association (中英人工智能协会) "was initiated by a group of Chinese nationals living in London, interested in the development of artificial intelligence by utilising [sic] the resources and innovations being made in both countries."[112] The German-Chinese Association of Artificial Intelligence (德中人工智能协会), a mixed group of expatriate Chinese and "Germans who worked and studied in China," carry on a similar mission of cooperation and exchange.[113]

UNIVERSITIES, STUDENTS AND SCHOLARSHIP

The adaptation of Chinese industry and research to the "AI revolution" (人工智能革命) is paralleled by a structural transformation in China's system of higher education. According to data compiled by CERNET,[114] 43 Chinese universities have dedicated new AI colleges or research institutes, founded almost entirely over the past two years. Here is the chronology:[115]

YEAR	AI INSTITUTES FOUNDED
2015	1
2016	1
2017	8
2018	28
2019	5 (as of April)

Thirty-five universities will receive MOE funds in 2019 to offer AI majors.[116] The ministry is budgeting 50 more university-affiliated institutes and "cross-disciplinary research centers" by 2020.[117] Information on the offerings of 33 of these institutes reads like a detailed ontology of artificial intelligence and related disciplines.[118]

Knowledge diffusion is following its usual course: foreign and expatriate professors lecture in China; honorary degrees are awarded in both directions; overseas AI experts are appointed to university advisory boards; joint seminars are hosted; partnerships with foreign universities are formed; collaborative arrangements are made with U.S. companies, e.g., the Fudan University-Google Technology Innovation Lab;[119] and academic papers are co-authored.

The relative impact of these academic activities on one country or the other is hard to measure. As described in Tsinghua (Qinghua) University's "China AI Development Report," China's output of AI-related scientific papers reached first place worldwide in 2006 and has maintained that lead to the present.[120] Based on this metric, it would appear that diffusion accrues to the world's greater benefit, although this conclusion should be tempered by the fact that 53% of these papers were co-authored by international collaborators.[121]

The same lack of data, indeterminacy of models, and conflicting value frameworks stand in the way of assessing the bottom line (long-term) value to the United States of Chinese AI students at US institutes of higher learning.[i] Arguments concerning counter-intelligence risks on the one hand and the clear benefits the United States receives from its ability to attract top talent on the other hand are not easily reduced to data-based analysis. Certainly, the answer is a mixed bag, which would suggest in policy terms a need for flexible measures.

i. CSET analysts have not surfaced a credible number for Chinese nationals doing AI-relevant graduate school or postdoctoral work in the United States. Very rough estimates of 2,600-3,500 will change by an order of magnitude with the emergence of hyphenated disciplines and as the field grows in importance and popularity.

4 Summary and Recommendations

Two principal facts emerge from this survey. First, the Chinese state, organizations within China, and China's diaspora population have responded with agility and in lockstep to the challenge of merging indigenous AI development with worldwide talent and trends. Chinese documents now reference the need to respect IPR—language seldom seen five years ago[122]—but the same venues and unsupervised access points available historically are used by China to transfer AI technology today. The transfers may be further masked by a diminished need for physical access.

Second, China's AI technology acquisition strategies span everything from licit collaboration to unobservable transfers by "talent" recruits and advocacy groups. The intricacy of these venues and access points, and the difficulty of distinguishing between them and China's own legitimate development efforts, complicates policy formation by governments eager to address a perceived loss of industrial competitiveness, or monitor these transfers for the sake of evaluating global threats. Accordingly, we conclude this paper with some recommendations that apply both to AI and the general problem of technology transfer:

1. **Gather information on the transfer issue.** Comprehensive data are needed to inform transfer decisions in a general (policy) sense and in specific cases where the merit of transfers is or should be called into question—data that consider historical behavior, the synchronicity of the transfer system as a whole, and the *likelihood* of transfers occurring based on observed gaps. We recommend establishing an integrated task-force under DNI auspices and rotating operational control to identify, monitor, and evaluate AI

and other technology transactions on a scale much larger than the present CFIUS effort.

- To avoid parochialism and loss of focus and to have sufficient resources to meet this urgent need, the unit should be given access to all-source intelligence and staffed with cleared personnel drawn from the IC, law enforcement, Department of Defense (DOD), State, Commerce, other non-Title 50 USG organizations and contractors with skills in Chinese language, data science, trade, financial analysis, international business practices, and the targeted technical disciplines.

  This approach will appeal simultaneously to three constituencies, whose perspectives differ: (a) it supports rational decisions to reject transactions where and as needed; (b) it highlights opportunities to collaborate where both countries' interests are served; and (c) it generates data needed to monitor and mitigate technological threats.

2. **Develop standards and metrics** to judge what transactions, or classes of transactions, benefit U.S. and global interests. We propose an ad hoc consortium of government, industry, and academic experts be convened to develop normative criteria on three levels: short-term (immediate impact on U.S. economy and security), longer-term (impact on trading partners and international trade practices), and geo-scale (the impact a transaction or failure to collaborate has on global development).

   We do not propose sanctioned technology lists, although standards can be a precursor to lists and, in particular, to calibration of a "watchboard" served by data streams (proposed above) to monitor technology development and exchange. Hard questions of what makes up value and how to measure it will challenge the best minds. But we believe that data-driven criteria, while hard to create, are preferable to the alternative.

3. **Institute a comprehensive outreach program,** coordinated by the DNI's National Counterintelligence and Security Center with active participation from State, Commerce, and FBI, to alert U.S. businesses, universities, and research labs; foreign governments; foreign students entering the United States; and foreign advocacy groups already in the United States to the risks (penalties) of some forms of unsupervised transfers. In particular, we recommend:

   - implementing a media strategy to foster respect for American technology, aimed at building a national consensus on acceptable cooperation between law enforcement and U.S. entities employing or trading with non-U.S. persons in high-tech sectors;

- encouraging U.S. companies to think long-term when faced with foreign competition and to consider the national interest in their international dealings; also needed are measures to lessen corporate sensitivity toward exposure of IPR theft;
- engaging positively with China's official, quasi-official, and private entities on our expectations of IPR protection, on the benefits of genuine collaboration, and on cooperation in technology risk avoidance.

4. **Encourage foreign students and researchers to remain** in the United States, become citizens, and help their new country prosper, especially in areas such as AI, where we face critical shortages. Among steps that can be taken to achieve this are:
    - Provide AI students and scholars a clear path from temporary status to permanent residence and citizenship, potentially through dedicated visa and green card categories for computing talent;
    - Address processing delays affecting AI workers in the employment-based immigration system, including by lifting numerical limits and country-based caps,[123] and by tying new security measures to increased resources for screening;
    - Establish reliable immigration pathways for foreign-born AI entrepreneurs, who currently have no visa categories available to them;
    - Review existing security safeguards related to immigrants and foreign visitors in STEM fields, including the State Department consular interview process and the Mantis interagency screening program, and revise them as needed to ensure focus on the venues, actors and practices of greatest concern.
5. **Increase America's S&T base** to avoid a zero-sum struggle. Mitigation is no substitute for positive efforts to expand America's S&T base. Accordingly, we favor:
    - Primary and secondary school curricula that promote early awareness by U.S. students of AI's importance, prompt appropriate academic decisions, and ensure the students' competitiveness at US universities for seats in AI fields;[124]
    - National incentives, including placement in STEM programs, scholarships, and low-cost loans to encourage American citizens and students from other liberal democracies to take up S&T careers in the United States.

- In global terms, the contributions a strong S&T cadre can make to human progress and security weigh equally with the benefits America's open research environment offers to itself and the world. Both should be cherished and encouraged.

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Endnotes

1. Known in the technical literature as "informal," "extralegal," and more recently "non-traditional collection."

2. "Outreach office" refers to organizations set up within state and local governments or within nominal NGOs to facilitate collaboration with, or access to, foreign-based entities that lead to the transfer of technology. Most of China's ministries have one or more such departments. "Advocacy group" is the term used by analysts for foreign-based organizations whose stated goal is to support China's transfer initiatives.

3. Section 301 *Report into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation*. Office of the United States Trade Representative (27 March 2018).

4. "The IP Commission Report." The Commission on the Theft of American Intellectual Property (May 2013). And Michael Brown and Pavneet Singh, "China's Technology Transfer Strategy" (DIUX, February 2017).

5. Hannas, Mulvenon and Puglisi, *Chinese Industrial Espionage*. (Routledge, 2013) hereafter "CIE."

6. Huo Zhongwen and Wang Zongxia, 国防科技情报源及获取技术 (*Sources and Methods of Obtaining National Defense Science and Technology Information*) (Beijing, 1991). And Miao Qihao, "Technological and Industrial Intelligence in China: Development, Transition and Perspectives" in Prescott and Gibbons, eds., *Global Perspectives on Competitive Intelligence* (Alexandria VA, 1993).

7. They do not violate U.S. legal statutes and laws of other nations subjected to the same aggressive transfer practices.

8. Based on sources in notes 5-8, and primary Chinese sources listed in CIE, pp. 274-276.

9. Transfer venues and practices that do not violate the legal statutes of the country from which technology is sought or obtained.

10. Currently undergoing a name change to "China International Talent Exchange Association" (中国国际人才交流协会). The website still bears the old English name and logo. (www.caiep.net/achieve/index.php)

11. Hannas, Mulvenon, Puglisi. CIE. 2013.

12. "China's startup culture is the yin to Silicon Valley's yang: instead of being mission-driven, Chinese companies are first and foremost *market*-driven... It doesn't matter where an idea came from or who came up with it. All that matters is whether you can execute it to make a financial profit." Kai-fu Lee, AI Superpowers, p. 27.

13. Unclassified annual reports by the National Counterintelligence Executive and its successor, the DNI's National Counterintelligence and Security Center invariably rank China first among "informal" collectors of US proprietary technology. The office at one time considered issuing separate China reports.

14. Ministry of Science and Technology statistics for years 1997 through 2005 cited by Chen Jiugeng, Director of the Institute of Scientific and Technical Information of China ("Actual Strength of S&T Information Service System in China," *China Information Review* no. 10, 2006, pp 17-22).

15. Andrea Gilli and Mauro Gilli. "Why China Has Not Caught Up Yet: Military-Technical Superiority and the Limits of Imitation, Reverse Engineering, and Cyber Espionage." *International Security*, Vol. 43, No. 3 (Winter 2018).

16. See Hannas, *The Writing on the Wall* (2003) for an overview.

17. Baum (1980), Herbig (1995), Logan (1986), Nakamura (1964), Nakayama (1973), Nisbett (2001, 2003), Suttmeir (1986)

18. Joseph Needham's multi-volume record of China's S&T accomplishments is universally cited as a marker of China's scientific skills. But Needham himself (1956, p. 11; 1969, p. 15) was perplexed by "the lack of theoretical

science in China" and distinguished China's practical science from the abstract science that emerged in the West.

19. "China's incapability of developing modern science has been so conspicuous that, even with conscious and official importation, the state of non-development nevertheless dragged on and on." Qian Wenyuan (1985) p. 50.

20. Hannas (2003, 2013)

21. Called "intrarepresentational" creativity or "template matching," and "interrepresentational" or "analogical," respectively. In the former case, a goal-directed search is made of existing mental models that correspond to the surface features of a problem. In the latter case, two abstract patterns from separate domains are combined, often fortuitously, yielding insight into problems that resisted solution in their original form. (Hannas, 2003, p. 116-7). Also see Ingar Brick, "The gist of creativity" p. 8, in Andersson and Sahlin, eds., *The Complexity of Creativity* (2013).

22. E.g., hypersonics, plasma stealth, inertial confinement fusion, genomics, data visualization, and cryptography. See also Robert D. Atkinson and Caleb Foote, "Is China Catching Up to the United States in Innovation?" Information Technology & Innovation Foundation. April 8, 2019.

23. The Chinese term *qingbao* (情报)is a unified concept that covers both "information" and "intelligence."

24. Documented cases of human or technical espionage, if they exist at all, are beyond the scope of this unclassified study.

25. 新一代人工智能发展规划

26. 柔性引进 (flexible introduction) is a term of art encompassing both formal and informal acquisition processes.

27. 促进新一代人工智能产业发展三年行动计划 (Three-Year Action Plan to Promote the Development of New-Generation AI Industry), MIIT, 14 December 2017. Section 4, "Accelerate the cultivation of talent."

28. "By various means" is a canonical expression used in the Chinese technical literature to denote informal access.

29. 制造业人才发展规划指南 ("Manufacturing Talent Development Planning Guide"), Ministry of Education, 14 February 2017.

30. 高等学校人工智能创新行动计划

31. The "111 Plan" is a project begun in 2006 by the MOE and State Administration of Foreign Experts Affairs to recruit some 1,000 top international scientists to serve at 100 centers for "introducing foreign intellect" (引进国外智力) established at Chinese universities.

32. Hannas, Mulvenon and Puglisi, *Chinese Industrial Espionage*, pp. 274-276.

33. http://www.most.gov.cn/kjbgz/201711/t20171120_136303.htm

34. 新一代人工智能发展规划推进办公室. www.most.gov.cn/tpxw/201902/t20190221_145137.htm#

35. www.most.gov.cn 国科发资 (2018) No. 264, 国科发资 (2019) No. 143.

36. MOST's Foreign Talent Research Center (国外人才研究中心), International Cooperation Office (国际合作司), China International S&T Cooperation Program (国家国际技术合作专项), China International Talent Exchange Foundation (中国国际人才交流基金会), and the affiliated China Science and Technology Exchange Center (中国科学技术交流中心).

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39. http://www.safea.gov.cn/content.shtml?id=12750366

40. www.caiep.net/achieve/index.php. 引智 is an abbreviation of 引进国外智力 (baike.baidu.com/item/引智). See footnote 28.

41. http://www.caiep.net/achieve/content.php?id=7016

42. http://www.caiep.net/achieve/content.php?id=7067

43. http://www.caiep.net/achieve/content.php?id=7040

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45. baike.baidu.com/item/百人计划

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