Mechanisms

New Media and the Forensic Imagination

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Introduction: "Awareness of the Mechanism"

> What we are trying to freeze is actually the present, which offers a highly distorted, fragmentary version of the past.
> —ALEXANDER STILLE, *THE FUTURE OF THE PAST*, QUOTING AN EGYPTOLOGIST ON THE PRESERVATION OF THE GREAT SPHINX OF GIZA

Begin with a mechanism, just the kind you would expect: gears and comb-teeth wheels. The Recodable Locking Device is a mechanical construct for securing access to computer systems, developed at Sandia National Laboratories and described in a press release as the world's "smallest combination lock."[1] An instance of a broad category of technologies known as microelectromechanical systems, or MEMS, it consists of six interlocking code wheels, each about 300 microns in diameter. (By contrast, the diameter of a human hair is 100 microns.) Conceived as an alternative to software firewalls, which are inevitably vulnerable to software-based attacks, the Recodable Locking Device is an actual physical assemblage, ready to be embedded on a microchip where it can interact with computational functions. There are one million potential combinations, and should the wrong one be entered, the code wheels instantly lock and must be manually reset. According to the Sandia press release the Department of Defense regards it as "the first real technical advancement in information security that they've seen in a long time."

1. See http://www.sandia.gov/media/hacker.htm.

While MEMS devices operate on the micron scale, there is an even lower plane of technological development. MEMS are very small, but they are still indisputably objects in the world, accessible (with the aid of appropriate instrumentation) to the human senses. Their materiality is self-evident. But the physical sciences now have a way of naming the precise point at which the normal, observable behavior of matter ceases to be predictable and dependable, at least according to traditional models: science, in other words, can articulate the exact threshold between the material and the immaterial. That threshold is the nanoscale, where molecular structures are measured and manipulated at the atomic level, in billionths of a meter. The nanoscale is the place where the basic atomic properties of things break down—their "conductivity, hardness, or melting point" all become fluid and malleable, subject to renegotiation by "wave particle duality and quantum effects."[2] "A nanoscale wire or circuit," explain Mark and Daniel Ratner, "does not necessarily obey Ohm's law, the venerable equation that is the foundation of modern electronics." The reason is that Ohm's law, which "relates current, voltage, and resistance," depends on the mathematical assumption that a wire is something like a river, with electrons flowing in a broad stream; if the wire is only one atom in width, the electrons must negotiate it in strict linear sequence, and Ohm's law no longer applies.[3]

The nanoscale is now the venue for exotic writing techniques fusing inscription and fabrication. Here is one of those new textual scenes, far removed from the poet's hollow reed and rural pen but staining waters clear:[4]

> Dip-pen lithography achieves its ultraprecision by placing tips coated with the material to be deposited—the pen's ink—within a few nanometers of a surface; a small water droplet condenses from the air and acts as a transport channel for the ink, allowing it to diffuse down to the surface.[5]

Mechanisms is not a book about MEMS or nanotechnology, but by beginning there we can think about inscription and fabrication—and the way a techno-

2. Mark Ratner and Daniel Ratner, *Nanotechnology: A Gentle Introduction to the Next Big Idea* (Upper Saddle River, NJ: Prentice Hall, 2003), 7.

3. Ratner and Ratner, *Nanotechnology*, 7.

4. See William Blake's "Introduction" to *Songs of Innocence* (1789), lines 16–18.

5. Coire Lok, "Nano Writing," *Technology Review* (April 2004): 77.

logical processes such as dip-pen lithography dissolve the distinction between them—as situated on a three-dimensional coordinate axis of visibility, legibility, and instrumentation. Electronic textuality is similarly locatable, even though we are not accustomed to thinking of it in physical terms. Bits can be measured in microns when recorded on a magnetic hard disk. They can be visualized with technologies such as magnetic force microscopy (MFM), which is a variation on the scanning tunneling microscope (STM). When a CD-ROM is burned, a laser superheats a layer of dye to create pits and lands, tiny depressions on the grooved surface of the platter. The length of these depressions is measured in microns, their width and depth in nanometers. (The precise specifications, along with all other physical aspects of the disk and the recording process, are spelled out in a proprietary publication known as the *Red Book*, first printed in 1980 and licensed by Philips and Sony.) That CD-ROM drives are laser *optical* devices that *read* and *write* their data by interpreting patterns of reflected light offers an instance of a certain configuration of instrumentation rendering the physical phenomena of pits and lands both visible and legible (though not to human eyes), thereby restoring this post-alphabetic writing practice to recognizable registers of inscription.

In an essay on digital preservation, Kenneth Thibodeau, Director of Electronic Records Programs at the National Archives and Records Administration, offers a tripartite model for defining digital objects: first, as *physical* objects (''signs inscribed on a medium''—for example, the flux reversals recorded on magnetic tape); second, as *logical* objects (data as it is recognized and interpreted by particular processes and applications software; for example, the binary composition of a Word .DOC file); and third, as *conceptual* objects (''the object we deal with in the real world,'' such as a digital photograph as it appears prima facie on the screen).[6] By digital object Thibodeau means any ''information object'' (his term) whose ontology necessitates all three of these parent classes—physical, logical, and conceptual. The most powerful aspect of this model lies in its potential for interaction among the different classes or levels, which are capable of accounting for many of the unique complexities of new media artifacts. What appears to be a homogeneous digital object

6. Kenneth Thibodeau, ''Overview of Technological Approaches to Digital Preservation and Challenges in the Coming Years,'' *The State of Digital Preservation: An International Perspective*, Council on Library and Information Resources, pub107 (2002), http://www.clir.org/pubs/reports/pub107/thibodeau.html. Subsequent quotations are also from this essay.

at the conceptual level (a database is Thibodeau's example) may in fact be a compound object at its logical and even physical levels, with elements of the database drawn from different file systems distributed across multiple servers or source media. "[I]n order to preserve a digital object," he writes, "we must be able to identify and retrieve all its digital components." The eminently practical concerns of specialists like Thibodeau have given rise to some of our best accounts of the ontology of digital phenomena and their relationship to more familiar forms of representation.

My reading of the critical literature on new media suggests that the field has focused primarily on the third of Thibodeau's three levels, the conceptual —that is, the phenomenological manifestation of the application or digital event on the screen—and only somewhat more recently, in the wake of mature formalist studies like Espen Aarseth's *Cybertext* and Lev Manovich's *Language of New Media* (both very different in their own right), on the interaction between the logical and conceptual layers.[7] However much of my attention (especially in the first half of the book) will fall on storage, a category routinely elided in the critical discussion, presumably because the uses to which electronic data is put are seen as wholly independent of any particular mode of physical record.

Storage: the word itself is dull and flat sounding, like footfalls on linoleum. It has a vague industrial aura—tape farms under the fluorescents, not the flash memory sticks that are the skate keys of the Wi-Fi street. Yet storage has never been more important than it is now in shaping the everyday experience of computing, interactivity, and new media. Even a passing glance at technologies like iPod or TiVo, both based on magnetic hard drives, should bring this point home. Like the vertical filing cabinets of a previous era, contemporary information storage devices have distinct affordances that contribute to their implementation and reception.[8] Computers themselves were initially engines of prediction and prognostication (where will an aircraft be in the

7. Lev Manovich, *The Language of New Media* (Cambridge: MIT Press, 2001) and Espen J. Aarseth, *Cybertext: Perspectives on Ergodic Literature* (Baltimore: Johns Hopkins University Press, 1997).

8. The vertical file cabinet, which stored papers without folding them, was first devised by Edwin G. Seibels in 1898, working in his father's insurance office in Columbia, South Carolina. Paper records were previously stored folded, in floor-to-ceiling arrays of pigeonholes. Vertical filing transformed standard business practices of the day.

sky such that a shell can be fired to intercept it), not recollection and storage; they only became so with the advent of the so-called von Neumann model and the somewhat later addition of random access disk memory, which enabled reliable real-time, nonsequential access to large reserves of information.[9] Storage is also a kind of imaginary, a focalized expression of the collecting impulse underpinning everything from the Web's myriad niche cultures (fan sites housing exhaustive MP3 archives of a band's live shows) to the global garage sale of eBay, which Steve Johnson has aptly referred to as an "infinite" storage system.[10] Crucially, storage today is both an accessory, something you hold in your hand or slip into your pocket (your iPod or memory stick), but is also increasingly disembodied and dematerialized as we approach terabtyte-scale disks where users are no longer constrained in their information retention by the capacity of their hard drives. Storage technologies will be a major element of this book because I believe we need to recapture their role in the cultural history of computing.[11]

Storage, along with transmission and computation (or processing), is also a primal media category for German theorist Friedrich Kittler. Yet Kittler's interest in storage is ultimately subsumed by his own idiosyncratic cosmologies and chronologies, in which storage, particularly of audio and visual "data streams," is part of a specifically modern zeitgeist (gramophone and film) that found martial expression in the trenches of World War I (which stored men in armed combat) before wireless transmission broke through the lines with the radio-equipped tanks of the German blitzkrieg two decades later (only to be defeated in turn, rock/paper/scissors-like, by computation, which broke the

9. Friedrich Kittler makes this same point about computation and prediction in *Gramophone, Film, Typewriter*, trans. Geoffrey Winthrop-Young and Michael Wutz (Stanford: Stanford University Press, 1999). See especially pages 253–263.

10. Steve Johnson, *Everything is Bad is Good For You* (New York: Riverhead Books, 2005), 196.

11. The extent to which storage, specifically the hard drive, can participate in a new media imaginary is suggested by the following passage from Hari Kunzru's recent novel *Transmission* (New York: Dutton, 2004): "Behind the walls of his secret garden, which existed not so much apart from as *between* the legitimate areas of the college network, his various experiments were still running their course, stealing spare processor cycles from idle machines, storing themselves in tiny splinters on dozens of hard disks. Together these fragments formed an interstitial world, a discreet virtuality that would efficiently mask its existence from the students and teachers doing their online business around about it" (27; emphasis in original).

German radio codes, thereby paving the way for the Cold War).[12] In ways that are not unlike those of Nicholas Negroponte or even Bill Gates, Kittler offers up a narrative of media convergence in which the original storage monopoly of alphabetic writing is now reinscribed as the universal ones and zeros of digital computation. This is a narrative that I find deeply unsatisfying, and indeed, much of this book is given over to the project of discovering the heterogeneity of digital data and its embodied inscriptions.[13] Despite having memorably claimed that there is no software, Kittler's attention nowadays has turned to chips and circuits, not to the contemporary storage devices that are the true heirs to his trinity of gramophone, film, and typewriter. The hard drive, whose visual resemblance to a turntable is not entirely incidental, therefore figures in this book as a way to read a contemporary storage device back into discourse network 2000.[14]

12. See specifically Kittler's "Media Wars" in his collection of essays *Literature, Media, Information Systems* (G+B Arts, 1997), but also of course the two main works available in English, *Discourse Networks 1800/1900*, trans. Michael Metteer (Stanford: Stanford University Press, 1990) and *Gramophone, Film, Typewriter*. The introduction to *Gramophone, Film, Typewriter* (also offered with a different translation in *Literature, Media, Information Systems*) is perhaps the most compact and best-known summation of Kittler's positions.

13. "Optical fiber networks" are the words which Kittler pronounces to open *Gramophone, Film, Typewriter*, and he proceeds to then articulate the narrative of digital media convergence. The most bracing counterpoint to this narrative that I know is Neal Stephenson's "Mother Earth, Motherboard," an epic travelogue of "hacker tourism" (his phrase) published in *Wired* magazine which consumes the bulk of the December 1996 issue. A kind of prelude to his subsequent novel *Cryptonomicon*, Stephenson travels from England to the Asian Pacific rim as he follows the laying of a deep-sea fiber optic cable, the Fiber-optic Link Around the Globe (FLAG). His account of the politics of the cable laying industry and the minute particulars of the cable itself is all that is needed to remind one of the nonvirtual realities surging through Kittler's bundled phraseology.

14. Open the sealed case of a modern hard drive and even an untrained observer will note the resemblance to a small turntable, complete with platter(s) and spindle arm. This visual coincidence harbors deeper correlates. Like the phonograph, magnetic recording was originally intended to preserve sound, specifically speech. Moreover, magnetic recording emerged at almost precisely the same historical moment as Edison's phonograph: the American inventor Oberlin Smith articulated the essential principles in 1878 (a year after the phonograph debuted), and in fact corresponded briefly with Edison; Smith, however, never actually built a recording device. That was left to the Danish researcher Valdemar Poulson, who in 1898 captured the first

While *Mechanisms* aspires to speak directly to contemporary conditions of electronic textuality and the digital literary, its primary case studies are drawn from earlier decades of computing. They range from *Mystery House*, a piece of interactive fiction for the Apple II first released in 1980, to Michael Joyce's *Afternoon: A Story*—the first edition of which appeared for the Macintosh in 1987—to Gibson's "Agrippa," which was first uploaded to the Internet near the end of 1992. While the Internet itself was a real and relevant technology throughout this period, the network had not yet achieved its popular apotheosis, and the World Wide Web was still in its infancy at the time "Agrippa" was released (the first version of the graphical NCSA Mosaic browser was announced in early 1993). Equally important in terms of networked culture were bulletin board systems (BBS) and the colorful if insular scenes they spawned—an elite user would range freely back and forth across the thin membranes between the public Internet (including the nascent Web, as well as Gopher, USENET, and Bitnet), and the deeper pockets of networked connectivity that were the bulletin boards. Certain particulars of this network landscape will figure in my discussions of *Mystery House* and "Agrippa."

The eighties were also the first full decade of home computing. The personal computer was both anthropomorphized and gendered as *Time Magazine*'s

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magnetic recording on a length of steel wire. Poulson immediately set about developing a machine he called the telephonograph, which would allow people record and store a telephone conversation—in effect an answering machine. The telephonograph was never a commercial success (Poulsen's successor, the American Telephonograph company, tried to compete with Edison's phonograph for the market in dictation machines), but the basic principles of magnetic recording had been established. The next major advances came in the 1930s when several German firms, including BASF, introduced magnetic coated tape (first paper and then plastic) as well as a dependable recording apparatus (and made additional advances, including High Bias recording). The magnetophone, as magnetic tape machines were then called, was to prove an important tool for the emerging Nazi regime as well as the wartime German military. After the war the technology quickly migrated to the rest of Europe and the United States. With magnetic audio recording thus commercially launched, it was not surprising that the nascent computer industry began exploring magnetic recording solutions for its increasingly storage-dependant products. For more on the early history of magnetic recording, see Eric D. Daniel, C. Denis Mee, and Mark H. Clark, *Magnetic Recording: The First One Hundred Years* (New York: IEEE Press, 1999), particularly chapters 2–5.

"Man of the Year" in 1982. Disney's *Tron* was likewise released in 1982, literalizing the fantasies of the adolescents who thronged suddenly ubiquitous arcades during what is widely acknowledged as the "golden era" of video games (though by mid-decade the industry had crashed).[15] MTV went on air in August, 1981 with a straight-to-the-point shot of McLuhanesque pop, The Buggles' "Video Killed the Radio Star." Within the first few years of the decade VHS had won out over Betamax. Gibson's *Neuromancer* (written within sight of the glow of the coin-op arcades) was published in 1984, the same year the Apple Macintosh debuted (along with its famous Superbowl commercial with overtly Orwellian imagery created by Ridley Scott, himself not long removed from the set of *Blade Runner*, again 1982). At the other end of our time frame, *Wired* magazine, with a print aesthetic self-consciously designed to look like information, began publishing in 1993, the same year as the public release of Mosaic, the first graphical browser for the World Wide Web. There are several sound reasons to foreground this era in *Mechanisms*, roughly from 1980–1992. First, even the modest temporal distance serves to defamiliarize certain key cultural aspects of computing; for example, storage technologies and disk handling practices differ markedly from what is the norm today, as we will see. In 1981, the Apple II DOS Manual began by telling its readers that it would teach them "how to use the disk," an injunction that surely seems strange in the wake of two decades of ubiquitous and largely invisible hard drive storage. Second, the smaller storage sizes of physical media make some of the close readings and forensic explorations in the book practical. The *Mystery House* disk, which we will examine closely in chapter 3, is a mere 140 kilobytes. It contains 35 tracks and 560 sectors. It is therefore possible to study it in its entirety, as a complete artifact. A modern hard drive, by contrast, holds tens of thousands of tracks and sectors. While the techniques I will discuss are equally applicable in theory, the smaller file systems on 1980s-era storage media allow us to exhaust the physical spaces of the media and bring them into focus. It would be a mistake, however, to think size doesn't matter; we will also consider the ways in which user habits and activities change as storage media grow more capacious. The simple practice of creating subdirectories, for example, is relatively rare with file systems stored on floppies but commonplace, indeed essential, with hard drives. Finally, this work is

15. See Van Burnham, *Supercade: A Visual History of the Video Game Age, 1971–1984* (Cambridge: MIT Press, 2001).

intended (in part) to serve as a kind of primer on the preservation and recovery of digital literary history. Therefore I look backward to electronic objects whose distance from us is measurable not only in years, but also by palpable shifts in hardware, software, data standards, file formats, and other manifestations of materiality.

That last term, *materiality*, will be a watchword of the book. The questions I pursue here have their roots in a 1995 seminar with Jerome McGann on the subject of textual materiality and electronic editing. In what, I then asked, does the materiality of electronic texts consist? This has since evolved into a well turned question in the critical and theoretical conversation in the field, and a number of scholars have contributed their individual glosses to materiality and its seemingly counterintuitive application to new media.[16]

16. For example, according to N. Katherine Hayles, "The physical attributes constituting any artifact are potentially infinite; in a digital computer, for example, they include the polymers used to fabricate the case, the rare earth elements used to make the phosphors in the CRT screen, the palladium used for the power cord prongs, and so forth. From this infinite array a technotext will select a few to foreground and work into its thematic concerns. Materiality thus emerges from interactions between physical properties and a work's artistic strategies. For this reason, materiality cannot be specified in advance, as if it pre-existed the specificity of the work. An emergent property, materiality depends on how the work mobilizes its resources as a physical artifact as well as the user's interactions with the work and the interpretive strategies she develops—strategies that include physical manipulations as well as conceptual frameworks. In the broadest sense, materiality emerges from the dynamic interplay between the richness of a physically robust world and human intelligence as it crafts this physicality to create meaning." See *Writing Machines* (Cambridge: MIT Press, 2002), 32–33. Here we see Hayles placing her emphasis on what I would call forensic materiality ("the richness of a physically robust world") and its emergent interaction with what variously seems to be the artist's intent, the work's own autonomy, and its reception in a user or reader's cognitive faculties; missing, I would argue, is the computationally specific phenomenon of formal materiality, the simulation or modeling of materiality via programmed software processes.

The most elaborate and theoretically rigorous model of (again, forensic) materiality of which I am aware is Johanna Drucker's, in *The Visible Word: Experimental Typography and Modern Art, 1909–1923* (Chicago: University of Chicago Press, 1994). For Drucker, materiality is composed of "two major intertwined strands: that of a relational, insubstantial, and nontranscendent difference and that of a phenomenological, apprehendable, immanent substance" (43). This model is intended to advance the understanding that materiality inheres in "a process of interpretation rather than a positing of the characteristics of the object" (43). The basic contradictions apparent between Drucker's two "intertwined strands"—contradictions which follow from her

My own use of the term develops gradually (over the first three chapters) into a distinction between what I term forensic materiality and formal materiality. Understood in relation to one another, I believe this pairing allows me to accurately represent what the overall term materiality does and does not mean in an electronic environment. In brief: forensic materiality rests upon the principle of individualization (basic to modern forensic science and criminalistics), the idea that no two things in the physical world are ever exactly alike. If we are able to look closely enough, in conjunction with appropriate instrumentation, we will see that this extends even to the micron-sized residue of digital inscription, where individual bit representations deposit discreet legible trails that can be seen with the aid of a technique known as magnetic force microscopy. Less exotically perhaps, we find forensic materiality revealed in the amazing variety of surfaces, substrates, sealants, and other matériel that have been used over the years as computational storage media, and in the engineering, ergonomic, and labor practices that attend computation—everything from labeling a diskette, which situates electronic textuality amid other technologies and practices of writing (indexing and cataloging, longhand, adhe-

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premeditated commingling of difference and transcendence—are, as she acknowledges, necessary if the model is to adequately answer to the relational and contingent claims upon signification that would be advanced by a poststructuralist critique, together with the sensorium's phenomenological apprehension of substance and appearance as such: "The force of stone, of ink, of papyrus, and of print all function within the signifying activity—not only because of their encoding within a cultural system of values whereby a stone inscription is accorded a higher stature than a typewritten memo, but because these values themselves come into being on account of the physical, material properties of these different media. Durability, scale, reflectiveness, richness and density of saturation and color, tactile and visual pleasure—all of these factor in—not as transcendent and historically independent universals, but as aspects whose historical and cultural specificity cannot be divorced from their substantial properties. No amount of ideological or cultural valuation can transform the propensity of papyrus to deteriorate into gold's capacity to endure. The inherent physical properties of stuff function in the process of signification in intertwined but not determined or subordinate relation to their place within the cultural codes of difference where they also function" (45–46). Materiality, in this model, thus consists in a sustainable dialectic (Drucker's term) between relational and contingent social values as they are expressed through various ideologies and economies of production on the one hand, and experiential, physiological, ultimately *bodily* encounters with incarnate phenomena on the other.

sives, the felt-tip pen), to the contours of the keyboard and mouse that make their bodily marks felt in the ongoing pandemic of repetitive strain and white-collar work injuries, to the growing crisis of e-waste (the unsafe disposal and sweatshop recycling, often at third-world dumping sites, of hazardous but industrially precious components inherent to computing machinery). Not all of these will receive equal emphasis or attention in this book, but all can and should be understood as varieties of the forensic materiality I will extrude from the applied field of computer forensics.

Formal materiality is perhaps the more difficult term, as its self-contradictory appellation might suggest.[17] "Instead of manipulating matter, the computer allows us to manipulate symbols."[18] This point, basic to all aspects of computer science, comes in the opening lines of textbook on virtual reality and interface design. Nicholas Negroponte popularized the same distinction in terms of atoms versus bits. Unlike an atom, which has mass, a bit "has no color, size, or weight, and it can travel at the speed of light. . . . It is a state of being: on or off, true or false, up or down, in or out, black or white. For practical purposes, we consider a bit to be a 1 or a 0".[19] Bits are—in other words—*symbols* to be set and reset, set and reset, on again and off again, over and over again. Whereas forensic materiality rests upon the potential for individualization inherent in matter, a digital environment is an abstract projection supported and sustained by its capacity to propagate the illusion (or call it a working model) of *immaterial* behavior: identification without ambiguity, transmission without loss, repetition without originality.[20] Nonetheless, as we

17. Late in the writing of this book I became aware of Paul de Man's use of the term "formal materialism," notably in *Aesthetic Ideology*, ed. Andrzej Warminski (Twin Cities: University of Minnesota Press, 1996). I do not intend my own use of formal materiality to imply any overlap with the particulars of de Man.

18. Thomas A. Furness III and Woodrow Barfield, eds., *Virtual Environments and Advanced Interface Design Design* (Oxford: Oxford UP, 1995), i.

19. Nicholas Negroponte, *Being Digital*, (New York: Knopf, 1995), 14.

20. This conscious model of immateriality is usefully fleshed out in Lev Manovich's account of the constituent features of new media: its underlying numerical or mathematical ontology, its modularity (the "object-oriented" nature of much new media), automation (the subjection of human agency to various programmed or algorithmic processes), variability (the one-to-many relationship characterized by, say, the application of multiple stylesheets to a single source file), and its transcoding (the ability of a digital object to negotiate multiple layers in a computer's

will see when we look more closely at the operation of hard drives, computers are not flawless. Errors typically occur at the juncture between analog and digital states, such as when a drive's magnetoresistive head assigns binary symbolic value to the voltage differentials it has registered, or when an e-mail message is reconstituted from independent data packets moving across the TCP/IP layer of the Internet, itself dependent on fiber-optic cables and other hardwired technologies. All forms of modern digital technology incorporate hyper-redundant error-checking routines that serve to sustain an illusion of immateriality by detecting error and correcting it, reviving the quality of the signal, like old-fashioned telegraph relays, such that any degradation suffered during a subsequent interval of transmission will not fall beyond whatever tolerances of symbolic integrity exist past which the original value of the signal (or identity of the symbol) cannot be reconstituted. As John von Neumann pointed out in 1948 in his "The General and Logical Theory of Automata," digital computers could produce perfect results, "as long as the operation of each component produced only fluctuations within its pre-assigned tolerance limits" (294).[21] This, coupled with digital data's discrete, finitely differentiated ontology—*digital*, separated like the fingers of the hand—engenders the formal environment for symbol manipulation that is the reservoir for every function of a computer, from the workplace to the hot-wired edge.

Formal materiality thus follows as the name I give to the imposition of multiple relational computational states on a data set or digital object. Phenomenologically, the relationship between these states tends to manifest itself in terms of layers or other relative measures, though in fact each state is arbitrary and self-consistent/self-contained. A simple example is a digital image file. An image file is typically considered to consist of nothing but information about the image itself—the composition of its pixilated bitmap, essentially. However, the image can carry metadata (documentation as to how it was

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internal architecture, as well as what Manovich sees as the interface between computational architecture and its various cultural "layers"). See his *The Language of New Media* (Cambridge: MIT Press, 2001), 27–48.

21. John von Neumann, "General and Logical Theory of Automata," in *Collected Works*, volume 5: *Design of Computers, Theory of Automata and Numerical Analysis*, ed. A. H. Taub (Oxford: Pergamon Press, 1963), 288–328.

created, embedded as plain text in the file's header), as well as more colorful freight, such as a steganographic image or a digital watermark. This content will only become visible when the data object is subjected to the appropriate formal processes, which is to say when the appropriate software environment is invoked—anything from the "Show Header" function of an off-the-shelf image viewer to a 128-bit encryption key. At this point one layer of the digital object is artificially naturalized in its relation to the other, typically the original image which suddenly manifests extra, hidden, or special data. Formal materiality is not an absolute term, but rather one that tries to capture something of the procedural friction or perceived difference—the torque—as a user shifts from one set of software logics to another. It might also help to think of it as a way of articulating a relative or just-in-time dimension of materiality, one where any material particulars are arbitrary and independent of the underlying computational environment and are instead solely the function of the imposition of a specific formal regimen on a given set of data and the resulting contrast to any other available alternative regimens. (Formal materiality is perhaps also the lingering perception of some genuine material residue—however misplaced—which presents, like sensation in a phantom limb, when one cannot quite accept the exclusively formal nature of a digital process; for example, the vague sense of unease that attends me after leaving my desktop music player application on Pause for hours on end, something that would harm a physical tape system because of the tension on the reels.)

While it may seem tempting to associate forensic and formal materiality with hardware and software respectively, those associations should not be granted without question, not least because the lines between hardware and software are themselves increasingly blurred, as is manifest in so-called firmware, or programmable hardware, a contradiction in terms that literalizes the conceit of formal materiality at the very level of the chip.[22] Moreover, the

22. For example MRAM, or magnetic RAM, which is an alternative to, among other technologies, EEPROM, electrically erasable programmable read-only memory. The constituents of the latter name are themselves telling: the search for a stable, but also erasable—a variable but nonvolatile—storage medium has been a constant throughout the history of writing technologies, and we see it here in the parameters of erasable/programmable/read-only. This is the same technology used in so-called flash memory, popularized in the form of the keychain sticks that plug into a standard USB port. MRAM technology, by contrast, involves using thin slices of magnetic material to create the conditions whereby a microprocessor can be reprogrammed in response to electrical stimuli. By manipulating the magnetic polarity of the substrate—in

distinction between hardware and software as we know it today, though seemingly naturalized by the von Neumann model, is also a consequence of the various business practices that helped create and define software—a product without any industrial precedent—notably IBM's momentous unbundling decision of 1970, where the corporate giant, then under threat of antitrust legislation, committed to the manufacture and marketing of software as a commodity separate and distinct from the company's hardware (previously, clients buying a computer would have received programs custom-written for their needs as part of the purchasing agreement, a strategy which helped ensure something close to a monopoly).[23] Software's emergence as an industry commodity must be part of any calculus of its materiality, and this complicates any easy association with exclusively formal processes. Software is the product of white papers, engineering specs, marketing reports, conversations and col-

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essence, each layer is a single "bit"—the behavior of all of the standard kinds of logic gates (AND, OR, NAND, NOR) can be emulated. This is useful because microprocessors are typically optimized for particular functions. The chip in a cell phone is laid out very differently from the chip in a digital camera. Interventions in the logical patterns of the chip at this level mean that the same physical processor can emulate any one of those special functions on demand. In one sense this inverts Turing's logic, since it is software functioning to reprogram hardware, rather than programmed software specifying a formal environment by way of internally consistent hardware components. In other words, an MRAM chip is a site of inscription. It is as if an ordinary erasable lead pencil was now being used to write circuits rather than the indelible ink of VLSI and other photolithographic processes. For a generalist's introduction to magnetologic gates, see Reinhold D. Koch, "Morphware," *Scientific American*, August 2005, 57–63. For the technical paper of record, see William C. Black Jr. and Bodhisattva Das, "Programmable Logic Using Giant-Magnetoresistive and Spin-Dependant Tunneling Devices," *Journal of Applied Physics*, 87 no. 9 (May 2000): 6674–6679.

23. For a thorough discussion of unbundling and its significance, see Martin Campbell-Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge: MIT Press, 2003), 109–118. Kelly's distinction between a software "package" and a software "product" in this context serves to further underscore the mutability of software's status as commodity: whereas a "package" was a free entity provided by the manufacturer, "The term 'product' was consciously adopted by vendors to imply a new kind of software artifact for which the vendor took contractual responsibility for performance and reliability in exchange for license fees paid by users" (118).

laborations, intuitive insights, professionalized expertise, venture capital (in other words, money), late nights (in other words, labor), caffeine, and other artificial stimulants. These are material circumstances that leave material (read: forensic) traces—in corporate archives, on whiteboards and legal pads, in countless iterations of alpha versions and beta versions and patches and upgrades, in focus groups and user communities, in expense accounts, in licensing agreements, in stock options and IPOs, in carpal tunnel braces, in the Bay Area and New Delhi real-estate markets, in PowerPoint vaporware and proofs of concept binaries locked in time-stamped limbo on a server where all the user accounts but root have been disabled and the domain name is eighteen months expired.[24] Forensic and formal materiality are perhaps better brought to rest on the twin textual and technological bases of inscription (storage) and transmission (or multiplication), exactly those bases underpinning my earlier narratives of the survival of the WTC hard drive data on the one hand and the proliferation of Gibson's "Agrippa" across the Internet on the other. Forensic and formal materiality also accord with the fundamental duality of a mechanism as both a product and a process.

As all of the preceding must suggest, this book aspires to a strategic rhetorical intervention in the best tradition of forensic argumentation. The methodology for the book draws heavily from bibliography and textual criticism, which are the scholarly fields dedicated to the study of books as physical objects and the reconstruction and representation of texts from multiple versions and witnesses (sometimes collectively called "textual studies"). Given the origins of these methods in the study of paper and parchment, such an

24. This is evident from David A. Kirsch's heroic ongoing labors preserving the legal records and the marketing and business plans of failed technology startups from the dot-com era: http://www.businessplanarchive.org/. The archive includes the electronic records (e-mail, PowerPoint presentations, word processing documents, and spreadsheets rescued from corporate intranets and network share drives) from some 2000 Silicon Valley technology concerns, all of them now defunct. (Manovich would term this "history of the present.") Meanwhile, *net.ephemera* is a limited edition portfolio of documentation from a digital art exhibition at the Moving Image Gallery in New York City in Spring 2001, compiled by Mark Tribe of rhizome.org: "Net.art is made to be experienced online and is thus difficult to exhibit in physical spaces. *net.ephemera* approaches this problem by focusing on drawings, diagrams, notes, receipts, and other physical artifacts related to the making of net-based work." The portfolio contains photocopies of 25 pieces of printed matter, ranging from sketches and pseudo-code jottings on a legal pad to a USPS receipt ($7.45, paid with a credit card) for mailing items related to the show.

approach may seem odd or obscure. But in fact, textual studies should be recognized as among the most sophisticated branches of media studies we have evolved. As early as 1985, D. F. McKenzie, in his Panizzi lectures, explicitly placed electronic content within the purview of bibliography and textual criticism: "I define 'texts' to include verbal, visual, oral, and numeric data, in the form of maps, prints, and music, of archives of recorded sound, of films, videos, and *any* computer-stored information, everything in fact from epigraphy to the latest forms of discography."[25] But though recent years have seen a tremendous acceleration of interest (and much practical progress) in methods of electronic editing,[26] there has been very little consideration of digital media themselves from the specific vantage points of bibliography and textual criticism.[27] Rather, textual critics have tended to treat the computer mainly as a platform-independent venue for studying the artifacts of *other* media.[28] This is unfortunate, because I believe the contemporary textual studies community has furnished us with some of the best accounts we have of texts and textual phenomena.

Mechanisms is also, however, grounded in contemporary computer science, notably the applied field of computer forensics. With its emphasis on reconstructing and preserving digital evidence, computer forensics is the natural

25. Donald F. McKenzie, *Bibliography and the Sociology of Texts* (London: The British Library, 1986), 5. See also page 31 for another such reference. On pages 42–43 he relates the significance of Great Britain's 1984 Data Protection Act, which erected legal distinctions between digital and paper-based texts.

26. A very brief and selective list of important projects would include *The Electronic Beowulf*, ed. Kevin Kiernan, http://www.uky.edu/~kiernan/eBeowulf/guide.htm; *The Canterbury Tales Project*, ed. Peter Robinson, http://www.cta.dmu.ac.uk/projects/ctp/; *The William Blake Archive*, eds. Morris Eaves, Robert N. Essick, and Joseph Viscomi, http://www.iath.virginia.edu/blake; and *The Rossetti Archive*, ed. Jerome J. McGann, http://www.iath.virginia.edu/rossetti/.

27. One exception is D. C. Greetham's "Is It Morphin Time?" in *Electronic Text: Investigations in Method and Theory*, ed. Katheryn Sutherland (Clarendon Press: Oxford, 1997), 199–226. More recently, Adrian van der Weel has put forward this case in "Bibliography for New Media," *Quærendo* 35/1–2 (2005): 96–108.

28. This is, of course, the underlying argument of what may be the most influential essay ever written on electronic editing, McGann's "Rationale of HyperText" (1994): http://www.iath.virginia.edu/public/jjm2f/rationale.html. It is worth pointing out that as of this writing, all of the projects McGann describes in the hypothetical are now mature digital research enterprises.

counterpart to textual criticism and physical bibliography. Both fields necessarily treat their subject as material phenomena, and together they offer the basis for a theory of electronic textuality that differs markedly from existing approaches to the subject—precisely because textual criticism (which at least one authority, D. C. Greetham, has called "textual forensics"[29]) and computer forensics engage their respective media on their own terms. The book's "forensics" is therefore a theoretically and technically rigorous account of electronic texts as artifacts—mechanisms—subject to material and historical forms of understanding. It seeks to provide a corrective to certain commonplace notions of new media writing—that electronic texts are ephemeral, for example (in fact, data written to magnetic storage media is routinely recovered through multiple generations of overwrites), or that electronic texts are somehow inherently unstable and always open to modification (actually, a data file can be just as easily locked or encrypted, preventing any modification), or that electronic texts are always identical copies of one another (computer privacy advocates exposed that Microsoft's popular Word software embeds a code unique to each individual user's system in every document it produces).[30] By overturning these and other false perceptions, I attempt to move beyond the formalism and poststructuralism that has characterized much of the writing about electronic texts to date.

As much or more than specific authors and texts, this is a book that foregrounds specific technologies (the hard drive or magnetic force microscopy [MFM]), specific technological processes (hashing, error correction, and packet switching), software (hex editors, Storyspace, and the Concurrent Versions System), data standards (ASCII, JPEG, and SGML/XML), data structures (DOS's Volume Table of Contents), and approaches to digital preservation (porting and emulation)—in short, what Bruno Latour, himself an inveterate opener of black boxes, has taught us to call actants.[31]

29. See D. C. Greetham, "Textual Forensics," *PMLA* (January 1996): 32–51.

30. Mike Ricciuti, "Microsoft admits privacy problem, plans fix," March 7, 1999, http://news.com.com/2100-1040-222673.html?legacy=cnet.

31. Latour's actor-network theory is first delineated in *Science in Action* (Cambridge: Harvard University Press, 1987). Actor–network theory seems indispensable to developing robust theories of computational processes, where the human agent—the user—is only one participant in a long chain of interdependent interactions. As we will see when we look more closely at DOS, for example, the SAVE command marks the moment at which control over an electronic

I have constructed the book in two overlapping halves, like the figures of a Venn diagram. Chapters 1 and 3 develop my distinction between forensic and formal materiality, with the technology of the hard drive, the book's central example of a storage device, situated in between, in chapter 2. The second half of the book, chapters 3, 4, and 5, all offer close readings of individual electronic textual objects, specifically a bitstream disk image of the interactive fiction game *Mystery House*, the various versions of Michael Joyce's *Afternoon: A Story*, and the text file of William Gibson's "Agrippa," distributed across the Internet in late 1992. Chapters 4 and 5 also take up issues related to the longevity and survivability of digital objects in light of the forensic and formal properties of both physical storage media and networked transmission. (One of the key underlying assumptions in both of these chapters is that the practical concerns of digital preservation can function as vehicle for critical inquiry into the nature of new media and electronic textuality.) The chapters on *Afternoon* and "Agrippa" both also draw on significant new primary source materials, presented here for the first time in a scholarly discussion. *Mechanisms* thus breaks new ground in terms of access to recently available archival resources, themselves self-consciously situated here within the horizon of a particular work's transmission and reception histories. Throughout the book, methods and techniques of both textual studies (such as analytical bibliography or critical editing) and computer forensics (with its emphasis on the residual documentary status of digital inscription) are brought into play as the twin armatures on which the arguments rest.

Beyond the first chapter, which lays the conceptual and theoretical groundwork, the book's organization follows a more or less deliberate progression: from the close scrutiny of a physical storage device that is typically both unseen and little understood (the hard drive) to a digital construct that is actually a formal surrogate for an instance of physical source media (the *Mystery House* disk image) to the archival history of a piece of software and works created with it (Storyspace and *Afternoon*) to the reconstruction of an online

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text passes from an organic author to an actor-network populated by the operating system, the disk drive mechanism, and the floppy disk. Theories of electronic textuality have tended to privilege the user, or the text itself, rather than these and other actor-networks, which are the fruits of "science in action" and "laboratory life."

transmission history (''Agrippa''). The following paragraphs discuss individual chapters ingreater detail.

Chapter 1 delineates the screen essentialism and accompanying medial ideology that the book argues has pervaded much of the critical and theoretical writing about electronic textuality to date, and it attempts to bring storage in the tradition of von Neumann computing (the most significant computational tradition of the twentieth century), where data takes the form of marks and physical inscriptions, to bear as a counterweight. The field of computer forensics is introduced, a field whose method and practice routinely contradict many of our commonplace assumptions about electronic textuality and new media, notably its supposed ephemerality, fungibility, and homogeneity. A forensic perspective furnishes us with two key concepts for an alternative approach to electronic textual studies: trace evidence and individualization. Ultimately electronic data assumes visible and material form through processes of instrumentation that suggest phenomena we call virtual are in fact *physical* phenomena lacking the appropriate mediation to supplement wave-length optics; that is, the naked eye. The forensic materiality of new media is thereby demonstrated by the bits and data tracks visible on MFM renderings.

Chapter 2, ''Extreme Inscription,'' is an in-depth look at the specific writing and storage technology that has been central to computing in the last thirty years: the magnetic hard disk drive, or hard drive. The hard drive serves as the book's central example of what it means to consider storage media as a kind of writing machine. The chapter reviews the history of the hard drive and the significance of random access data storage to new media and the database logic articulated by Lev Manovich. I offer a detailed grammatology of the hard drive based on a technical and theoretical examination of the drive's basic operations—what I call a ''machine reading,'' which takes an instrument or device rather than a text as its locus. Finally, the chapter considers the cultural logic of the hard drive: as storage capacities continue to soar the hard drive itself becomes ever more abstracted and removed from daily awareness, even while digital artists begin to construct a forensic imagination of the device and database projects like MyLifeBits make radical claims about the future storage of individual experience.

In chapter 3, '''An Old House with Many Rooms,'" I use a disk image of the vintage interactive fiction game *Mystery House* to conduct a forensic walkthrough, or multivalent reading, of an electronic object, a bitstream image of

an original instance of 5¼-inch disk storage media. This exercise allows us to explore critical reading strategies that are tightly coupled to technical praxis, here including the use of a hex editor to inspect heterogeneous information once deposited on the original storage media. Doing so brings the distinction between forensic and formal materiality more sharply into focus, using the overtly forensically charged spaces of the original game to peek and poke at the content of the disk image (which includes the remnants of earlier, apparently deleted copies of other Apple II games). Ultimately the chapter attempts to locate what Jerome McGann once called the "factive synechdoches" of bibliographical knowledge within new media, while exposing a new kind of media-specific reading, new tools for critical practice (notably the hex editor), and relevant contexts surrounding personal computing in the 1980s. In the second half of the chapter I develop further examples of formal materiality by way of both image- and text-based data structures. Forensics is ultimately presented as a mode of difference or defamiliarization rather than as an attempt to get closer to the soul of the machine. This is the first of three case studies of electronic objects in the book, and at the book's midway point it completes the articulation of forensic and formal materiality.

Chapter 4, "Save As: Michael Joyce's *Afternoons*," takes as its point of departure the colophon to Michael Joyce's landmark hypertext *Afternoon*, which elucidates the numerous versions and editions of the work. Relying on materials newly deposited at the Harry Ransom Humanities Research Center at the University of Texas at Austin, the chapter offers a detailed version history of *Afternoon* itself in the service of a larger argument about the diachronic dimensions of electronic textuality. With its deliberately plural locution "Afternoons," the chapter attempts to reconcile the document versioning that is a hallmark of electronic culture with both the notion of the "version" in literary editorial theory and the cultivation of postmodern variability and instability in the critical literature about creative hypertext. The chapter suggests a scene of electronic textuality that is a hybrid of printed and electronic components, all of which are relevant to the project of versioning and all of which form their own contours amid the newly institutionalized spaces that are now the repository for Joyce's work as its versions are cataloged and accessioned for posterity. The chapter also offers the first detailed record of the development history of the Storyspace software underlying *Afternoon*, as well as a consideration of digital document practices that exploit the medium's capacity to capture the temporal and diachronic dimensions of writing and revision.

Chapter 5, "Text Messaging," completes the trio of case studies by documenting the publication and transmission history of Gibson's "Agrippa," offering, for the first time, an accurate account of the hack that delivered the poem to the New York City-based bulletin board MindVox, and the text's subsequent proliferation across the network. The point is to address the fundamentally social, rather than the solely technical mechanisms of electronic textual transmission, and the role of social networks and network culture as active agents of preservation. As soon as it was released onto the network, "Agrippa" simultaneously cemented its own prospects for longevity and initiated its ongoing dilation as a textual event, an event which continues to unfold even now with the recent release of a substantial body of archival materials on a scholarly Web site bearing the forensically-inflected title *The Agrippa Files*.[32]

Forensics itself is a Janus-faced word, by definition both the presentation of scientific evidence and the construction of a rhetorical argument. *Mechanisms* embraces both of these aspects. While it does not shy away from technical detail (or theoretical nuance), it is first and foremost intended as a practical intervention in the current discourse about digital textuality. As electronic objects begin to accumulate archival identities (by virtue of the libraries, museums, and other cultural repositories increasingly interested in or charged with collecting them), it will become essential to understand the nature of what is being collected and preserved, and where the most significant challenges of digital preservation finally lie. One underlying theme of this book is that those challenges, while massively technical to be sure, are also ultimately—and profoundly—social. That is, this book aims to show that effective preservation must rest in large measure on the cultivation of new social practices to attend our new media. These practices start with the habits of the individual end user, who can herself take active steps to document and protect their own content.[33] Many are perhaps now discouraged from doing so by the

32. Available at http://agrippa.english.ucsb.edu/, *The Agrippa Files* is the work of Alan Liu and a team of graduate students associated with the University of California at Santa Barbara's *Transcriptions* project. The site was prepared with the cooperation and assistance of *Agrippa's* publisher, Kevin Begos Jr.

33. This is the motivation behind Nick Montfort and Noah Wardrip-Fruin's pamphlet publication *Acid Free Bits: Recommendations for Long-Lasting Electronic Literature* (Los Angeles: Electronic Literature Organization, 2004). Also available online at http://eliterature.org/pad/afb.html.

perceived futility of the effort, one outgrowth of the medial ideology I detail in chapter 1: *None of this stuff is going to last, so why bother?* Feeding the forensic imagination is necessary for encouraging people to take responsibility for the digital objects they will create and encounter. One aching example: in a recent essay lamenting the evaporation of literary heritage into cyberspace as the result of routine correspondence among authors, editors, agents, and publishers now taking the form of evanescent email, the *New York Times Book Review* details the plight of the fiction editor for the *New Yorker*: "'Unfortunately, since I haven't discovered any convenient way to electronically archive e-mail correspondence, I don't usually save it, and it gets erased from our server after a few months . . . if there's a particularly entertaining or illuminating back-and-forth with a writer over the editing process, though, I do sometimes print and file the e-mails. . . . conceivably someone could, in the distant future, dig all of this up.'"[34] We can choose to take from this that e-mail is slippery and volatile stuff indeed, or we can choose to take from it that the systems people should stop automatically erasing the server every few months and that in the meantime more things ought to be printed and filed for posterity.

Likewise, in the realm of archives and curatorial practice, it will be important to insist that digital objects are no more homogeneous or self-identical than other artifacts, and that the relationships between individual digital objects (and versions of those objects) should be preserved along with the actual works themselves. Finally, critics and scholars of new media need to begin exhibiting critical habits that are more sensitive to the mature material conditions of new media. Here work must happen at the most basic level: for example, what does it mean to cite a new media object adequately? How do you distinguish between versions and builds? What do we need to know about the operating system? How much RAM is installed? Does it matter what graphics and sound cards are in the machine? And so on. This kind of information is routinely presented with product reviews on gaming sites or in the trade magazines, but it remains a rarity in our scholarship. If the readers of *Gamasutra* need this information but scholars still do not, we would do well to ask why they need it and we do not, and what critical assumptions we have operating in their place. (Unless otherwise noted, all electronic objects discussed in this book were viewed on a Dell Latitude ×300 Windows XP laptop with a 1.20 GHz processor and 632 MB of RAM, sound turned on.)

34. Rachel Donadio, "Literary Letters Lost and Found in Cyberspace," *New York Times Book Review*, September 4, 2005.

I conclude that new media cannot be studied apart from individual instances of inscription, object, and code as they propagate on, across, and through specific storage devices, operating systems, software environments, and network protocols; yet the forensic imagination of the book's subtitle is also conceived as a deeply humanistic way of knowing, one that assigns value to time, history, and social or material circumstance—even trauma and wear—as part of our thinking about new media. Product and process, artifact and event, forensic and formal, awareness of the mechanism modulates inscription and transmission through the singularity of a digital present.