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Fractal Realism: The Folding Together of Literature, Technical Media, and Cognition in the Twentieth Century

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Fractal Realism

The Folding Together of

Literature, Technical Media, and Cognition in

the Twentieth Century

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in English

by

James John Pulizzi

2012

ABSTRACT OF THE DISSERTATION

Fractal Realism

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The Folding Together of

Literature, Technical Media, and Cognition in

the Twentieth Century

by

James John Pulizzi

Doctor of Philosophy in English Literature

University of California, Los Angeles 2012

Professor N. Katherine Hayles (co-chair)

Professor Kenneth Reinhard (co-chair)

Media theorists as far back as Marshall McLuhan and as recent as Friedrich Kittler and Jonathan Crary have asserted that since the photograph's and gramophone's invention in the nineteenth century, technical apparatuses have increasingly come to extend and simulate the humans senses. My dissertation argues that the convergence of these technical media with automated technical apparatuses begins a recursive cycle. The technical apparatus encodes itself through various technical media, and as a result, produces new technical media. This cycle

of encoding and re-encoding is cognitive, and constitutes what I call a nonhuman cognitive system. I trace this evolution of this nonhuman cognition from early cybernetic devices like Vannevar Bush's Differential Analyzer to the contemporary digital computer.

This evolution of technical bodies is still closely intertwined with human ones, because the technical media enabling the nonhuman cognition's evolution also encode images, sounds, and narratives for human cognitions. The so-called realism that technical media enable (i.e., a greater degree of verisimilitude to what humans actually see, hear, feel, etc.) is actually what I call fractal realism. It is fractal because humans and nonhumans use different cognitive schemes for mediating or encoding their reality, and so fracture their world as both cognitions work on it. It is fractal as well, because the nonhuman cognitions rely on statistical measures rather than narrative chains of cause-and-effect to order their encodings, just as fractal sets are defined by their statistical self-similarity. Under fractal realism, mediation is not a means of conveying information between parties but rather the conversion of one medium into the pattern of another medium. I argue that we understand mediation as, what Gilbert Simondon calls, a transductive process.

Given the tight link of cognition and mediation, I parallel the account of the nonhuman cognition's evolution with an examination of how its statistical mode infiltrates and affects media as humans understand them. We can then see fractal realism as a new genre that cuts across realism and postmodernist literature and cinema. Some of the works considered include Joseph McElroy's *Plus* (1977), Thomas Pynchon's *Gravity's Rainbow* (1973), Michelangelo Antonioni's *Blow-Up*

(1966), and Mark Z. Danielewski's *House of Leaves* (2000).

The dissertation of James John Pulizzi is approved.

Rita Raley

Mark Seltzer

Kenneth Reinhard, Committee Co-Chair

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University of California, Los Angeles

2012

Contents

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"Narrating Consciousness," 22nd Annual Meeting of the Society for Literature, Science and the Arts, "Reiteration," Charlotte, North Carolina, November 13–16, 2008.

Chapter 1

Introduction

> [A] new consciousness is coming into being. To express and transmit itself, it has developed codes that are not alphanumeric and has recognized the gesture of writing as an absurd act and something from which to be free.
>
> Flusser, *Does Writing Have a Future?* 95

Software engineers start their education by learning to make the computer print the exclamation "Hello World!" to the terminal (usually a screen). This greeting, however, is an empty phrase, because as Flusser notices in the above quotation, the nonhuman cognition that produces the letters operates via codes that are not alphanumeric, that do not belong to the spoken language humans have transformed into written marks, or ciphers. This nonhuman cognition's defining characteristic is then how it enciphers and encodes other materials—a process that implies, as we will see, a specific circuit of bodies and technologies

(or technological bodies, if we prefer to continue thinking of bodies as only biological). The enciphering and encoding circuit specific to human cognition has been (at least for several thousand years) the transformation of speech into marks on a surface, which requires a system of techniques and bodies that we group under the general heading *writing*.

Writing techniques as humans know and use them supposedly transform spoken language into patterns on a medium, which for the phonetic alphabet in Europe would be letters on a flat surface (either stone or processed plant matter). The word *writing* like its Greek counterpart *γράφω* originally meant to scratch, incise, and figuratively to draw or paint.[1] The cavities on the inscriptional surface are true ciphers—i.e., empty marks—that inform and make a pattern on the surface, or rather, that transform materials into media.[2] Creating this pattern means collecting empty marks (words) and ordering them according to some rules (syntax or code) that readers learn to recognize and writers learn to incise. Writing and reading, therefore, encipher and encode spoken language. This process, however, moves language from the brain, mouth, and sound circuit to the brain, hand, pen, and surface one. Once that transfer is complete, we must use our eyes to hear the written words—if only LSD and other hallucinogenic drug users realized their first synesthetic experiences had happened in elementary school.

In converting speech into letters and confusing seeing and hearing, we effec-

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[1] *Graphien* referred to painting and to writing, since they were effectively the same thing—the placing of marks on a surface. One who painted scenes from nature or stories was called *ζώγραφος*, or a life (*ζωή*) painter. Here, however, the life is gone, replaced by an empty mark.

[2] The Latin *ciphra* was a translation of the Arabic term and symbol for zero, which was itself taken from the Sanskrit *śūnya,* or empty.

tively turn language back upon itself—a recursive moment—because writing treats speech not as sound but as a material to be reworked into written words. In yet other words, writing treats speech as a material that it will separate into patterns (language and words) and noise (the air's continuous vibrations). Writing makes language into a medium much in the same way spoken language turned sound into a medium. The new pattern in the new medium takes on a life of its own, as evidenced by the new techniques written language must develop to complete its divorce from speech: paragraphs, commas, periods, and other punctuation. Eventually we learn to read silently and not even pretend that the written and printed text was ever meant for humans to read aloud. We could even argue, as some media theorists do, that phonetic writing engenders an entirely new way of thinking.[3]

Perhaps it does, but more important is the sense in which the written marks are empty, because it is thanks to this vacuity that ciphers and codes must always travel through a circuit of bodies and techniques to generate and to fill themselves, or make themselves meaningful. Always needing to be in action makes these recursive enciphering and encoding processes noisy (entropic) generators of progressively more complex systems, rather than closed, decaying systems. Human cognitive activity for the last few thousand years has announced itself precisely through such recursive cycles of enciphering and encoding of increasing complexity, from the Chauvet Cave paintings, to the Greek's phonetic alphabet, and most recently to the computer's stream of 1's and 0's. The constant activity needed to arrange the ciphers, to fill them with meaning, means it becomes possi-

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[3]The two earliest examples of such work are Havelock, *Preface to Plato*; and Ong, *Orality and Literacy*.

ble to talk about the encoded ciphers as distinct from their media, as though they were a signal that transmitted itself through different bodies and technologies, such as hands, pens, ink, and paper. We think of *language* as a signal whenever we fail to qualify the noun with *spoken, written, printed,* etc.

Thanks to this signal transmission, cognition appears distributed, as many have argued, over a wide range of bodies and technologies.[4] Some, like Kittler, think the enciphering and encoding process that defines this cognition only temporarily coincided with human bodies and has now moved to the automated technical apparatus, particularly the digital computer.[5] Others, like Katherine Hayles, emphasize the co-evolutionary or mutual determination of human body and encoding system. Fortunately both sides rely on recursive enciphering and encoding processes. A two-dimensional drawing transforms three-dimensional objects into marks on a surface, so that we may organize or understand their spatial relations, and a one-dimensional line of text further transforms those two-dimensional images into textual ciphers we arrange narratively, as a catalogue, or an archive. The recursion of images into themselves creates a new pattern or code that is not visual but that can organize visual images as well as new, so-called abstract concepts. Either Hayles' and Kittler's position makes sense, because these recursions distribute cognition through a complex feedback circuit of bodies and technologies. Indeed, such distributed or extended cognition merely continues André

[4]Haraway, *Simians, Cyborgs, and Women*, Hutchins, *Cognition in the Wild* and Clark, *Natural-Born Cyborgs* are two early theories of distributed cognition as it relates to cybernetics.

[5]Kittler, of course, does not call the encoding process cognition, because it smacks too much of humanism.

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Leroi-Gourhan's paleoanthropological research of the 1960s that strongly argued technological development propelled human evolution as much as human bodies did. Humans exteriorized the capacities of their brains and bodies into the technical milieu, and these new technical objects influenced human physiological evolution.

The new cognition to which Flusser refers in the opening quotation arrives as humans automate the technical extensions through which these signals flow. The more automated the technology becomes, the more it becomes an apparatus with a body of its own, which, by design, relies less and less on human bodies. This automating process has been happening since at least the nineteenth century. The photographic camera partially automated the capture of visual images, and the gramophone automated the capture and storage of sound. At the end of the nineteenth and beginning of the twentieth centuries the motion picture camera would continue that work by automating the moving image's capture. Film would eventually be able to record sound as well.[6] Humans still interpreted and acted upon these automatically enciphered and encoded images and sounds, but the analog and digital computers would begin automating even that process. These increasingly automated, recursive loops put more distance between the human body and the codes that arrange its world. It is in this gradually widening gap that we find the nonhuman cognitive system, of which the computer is the most advanced example. We now live in a world in which the touch of a few buttons instructs an unmanned drone on the other side of the globe to launch missiles at

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[6] Kittler, *Discourse Networks 1800/1900*.

enemy combatants.

The automated technical apparatus, or computer, operates through an enciphering system that only it can act upon. Consider the "Hello World!" example in which the human software engineer instructs the automated apparatus to print those letters to the screen—initially a CRT and now to an LCD. The programmer may accomplish this magical feat by one of the methods listed in Appendix A on page 190. First is the plain text, the human readable and comprehensible string "Hello World!" Next is an example coded in Python—a high-level program language whose syntax closely resembles English. Below that, however, we find C++ and its more recent variant Java that while somewhat comprehensible clearly require one first be initiated into programming, or rather instructed in the ways the computer encodes and processes inputs and outputs. Those languages express this processing in terms of functions—more recent computer languages prefer objects—that execute commands on and return results for the data (called *arguments*) passed to them. C++ is a mid-level programming language because it makes some concession to human language, but also does not conceal as much of the computer's processing methods as Python. The computer exposes itself even more in assembly language and hexadecimal codes. Few programmers know how, much less have the ability, to compose such programs, because those encodings are closer to the computer's language—its austere syntax of ciphers and codes—that its human engineers designed to reflect the technical apparatus's structure and operation, rather than their own.

We should remember Hayles' flickering signifier, for active, algorithmic pro-

cesses underlie the black shapes we recognize as words.[7] The letters we see glowing on the screen are actually enumerated codes (either ASCII or Unicode) that point to glyphs (upper or lowercase letters and other symbols) or to invisible (to us) control sequences. Some of these control sequences have familiar sounding names like carriage return, which ASCII defines as CR, ^M, or the octet sequence 0x0D. This so-called character instructs the software to start a new line, which the digits before binary digits would have accomplished by pressing the typewriter's return key. In one sense, the binary code is the direct descendent of the enciphering and encoding system that first used the hand and pen to make marks on the page, and then the fingers to actuate the typewriter's keys and type bars. In another, the octet sequence that represents carriage return signals a new encoding regime that can do so much more than the typewriter's inflexible metal skeleton. These ciphers and codes can act upon and reconfigure themselves so quickly that they can emulate most other enciphering and encoding systems. Indeed, the central processing unit (CPU) is built on the principle that data and command—cipher and encoding—easily fold into one another. The CPU does not draw, read, or write except to the extent it moves instructions from one memory register or stack in the processor to another. Nearly all CPUs fetch, decode, execute, and writeback instructions to and from memory. At the level of assembly language and especially machine code, a human user cannot easily distinguish between data and instructions—at least not as easily as the CPU. Indeed, once the program executes, it will load those codes into active memory and begin rewriting itself depending

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[7] Hayles, *How We Became Posthuman*, 25–49.

on which functions are called, which data requested, and what decisions it and the human user make. The program treats itself simultaneously as a medium for transmitting information (data) and as the technical apparatus (commands) for processing that pattern.

Of course, minuscule ciphers in the shapes of 1's and 0's are not coursing through the computer's circuits. A jagged waveform of electrons (and now photons) determines whether the transistor registers a 1 or a 0, and then whether the circuit opens or closes. Combinations of such open or closed transistors determine how data moves between memory addresses and therefore what operation the CPU performs. The computer relies upon but cannot be reduced to the stream of billions of electrons flowing through its circuits, because future computers may indeed use photons instead. The material chosen certainly affects the design[8] but the signal—the sequence of 1's and 0's—remains. The computing apparatus relies not on the specific material but on the pattern that material can mediate, which in this case is the wave, the aggregate behavior, of billions of particles. A moth trapped in one of the Harvard Mark II's vacuum tube relays was the first official "bug" to impede the delicate, successive informing from particle to instruction to screen image. Grace Hooper logged the error in 1947.[9] Bugs are possible because the program, the signal that distinguishes the nonhuman cognition from a simple record of data, exists as the recursion of technical medium (e.g., the electrical) and technical apparatus (e.g., the transistor and microproces-

[8]A transistor using electrical current will obviously be made of conductive metals and nonconductive insulators. Whereas as an optical transistor would use lenses and mirrors.

[9]The National Museum of American History has the log on display—object ID: 1994.0191.01.

sor) into one another. Only this active feedback can create the signal. Each loop opens the possibility for something unexpected to intervene—a mechanical, electrical, or encoding glitch that interrupts the signal, throws the parts out of synch, and reveals the technical apparatus for what it is—a conglomeration of carefully interlinking systems that translate one medium into another.

The recursion of these exteriorized technologies into themselves allows insignificant matter to become significant symbol and is therefore essential to any exploration of how nonhuman technical apparatuses may themselves be signifying or cognitive machines. Finding the convergence of mediation and cognition in a recursive signal requires a new account of mediation that neither assumes that two parities exchange meaningful messages (e.g., Michel Serres), nor that technical processes transmit empty packets of information (e.g, Kittler). Gilbert Simondon's concept of *transduction* provides just such a theory of mediation. A transductive theory of mediation shows how mediations fold into one another as a way of building more complex systems. Nonhuman cognitive systems are circuits that feed flows of matter and energy back into themselves to generate representations on which the circuit can perform further transformations and mediations. In this way, representations actually perform work in the nonhuman system, but humans only understand them as abstractions, as something separate from the system that created it. In Chapter 2, we will explore Simondon's concept and see it operating in an early cybernetic automaton—Vannevar Bush's Differential Analyzer (DA).

1.1   Narrating and Mediating the Nonhuman Cognition

This new transductive circuit presents us embodied humans—whose cognition is currently so tied to writing and narrative—with the problem of mediating this new nonhuman transductive circuit. How does one represent with writing, particularly the print novel that is supposed to be the paradigm of modern life, the nonhuman cognition's system of ciphers and codes? Chapter 3 will explore that question by showing that languages and bodies are so thoroughly tied together that the shift from human to nonhuman embodiment necessarily alters language and even the very narrative structure humans give to their experiences and thoughts with language. Though nonhuman cognition is a continuation of human cognition's technical evolution, it lacks a human body and therefore establishes a very different signal or transductive loop through which to encipher and encode its world. Joseph McElroy's novel *Plus* (1977) enacts this process by attempting to narrate the experience of a human brain that has been implanted into an orbiting satellite. I would not advocate a return to a Kantian divide between perception and the thing-in-itself, but simply note that nonhuman cognition belongs to a different transductive circuit and would therefore mediate the same events and knowledge differently.

Flusser recognized in the 1980s that some alternative cognitive system was replacing such narrative language, which he called *writing*. The transition should hardly surprise us given the close proximity that media theorists have always posited between thinking and the media that express it. Eric Havelock and Mar-

shall McLuhan propose that the transition from oral to written language destroyed the aural, cyclical world of myth and introduced the visual, linear one of history and logic.[10] Kittler extends their insights into the transformation of human cognition that occurs with the introduction of technical media such as the gramophone, typewriter, and digital computer. The fact that stories persist through the technological shifts from spoken word, written text, printed books, and then modern lithographic and computer printing techniques suggests that whatever narrative is, it is always co-evolving with the human brains that rely upon it to structure experiences and the technical media available to store and recreate it. I will argue in Chapter 4 that there is indeed a transductive loop between human bodies and technologies that generates narratives and the story worlds in which they unfold. It is this recursive loop of bodies and technical media that defines one mode of cognition. Whether by necessity of biological evolution or historical contingency, cognition in the narrative mode has come to define thinking and self in humans—we cannot have an identity until we have a history that connects us to other individuals.[11] The disjunction between the V–2 rocket's encoding regime and the paranoid plots the characters weave around their apparently chaotic world in Thomas Pynchon's *Gravity's Rainbow* (1972) will suggest how the difference be-

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[10] See Havelock's discussion of Plato's hostility to mimesis and its relation to the transition from an oral to written and visual record; Havelock, *Preface to Plato*, 36–60, 197–214. McLuhan generalizes this trend in his discussion of acoustic and visual spaces; McLuhan, *Laws of Media*, 13–66.

[11] Developmental psychologists such as Jerome Bruner and Katherine Nelson propose that language acquisition and the ability to narrate stories is an essential step in the developing child's sense of self, and capacity to empathize with others. See Bruner, *Acts of Meaning*; and Nelson, *Young Minds in Social Worlds*.

tween human and nonhuman cognitive modes is undermining print narrative's ability to convincingly model our world.

We will find that challenge to the narrative mode comes from the technical apparatuses and media emerging in the later nineteenth and early twentieth centuries. These technical media enable new recursive loops between bodies and technologies and thereby better simulate human cognition while simultaneously altering the way people think and perceive.[12] The more effective at simulating narratives the technical media become, however, the more distant the encoded narrative grows from human bodies—it must transduce itself through far more systems in a photographic camera, for instance, than in a painting. One needs the camera apparatus to create the image. With the motion picture, one needs the technical apparatus not only to capture but to project the images and sounds. Human senses cannot perceive and record their perceptions in realtime, so one needs an automated mechanism, a technical apparatus, that operates much faster than the senses, and moreover, independently of them. The necessity for automation and self-regulation meant that these technical media were simply a subset of the cybernetic automata that engineers were developing at the turn of the twentieth century to solve complex mathematical problems, such as calculating a projectile's trajectory quickly and accurately on the battlefield, or designing a rocket, the V–2, that could travel faster than the speed of sound. As we will see in Chapter 5, the growing complexity of these technical media come from a continued recursion of the media into themselves that progressively encodes and re-encodes the

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[12]Crary, *Suspensions of Perception* makes the case that perceptual technologies defined a specific cognitive mode in the nineteenth century.

information until the distinction between that which acts and that which is represented is no longer up to the human but wholly reliant on how the technical apparatus interprets or processes itself. Nonhuman cognitive systems, then, emerge gradually as information transduces itself across the various technical media and apparatuses that have been evolving over the twentieth century. Michelangelo Antonioni's *Blow-Up* (1969) and Mark Z. Danielewski's *House of Leaves* (2000) will be the technical media under consideration.

It is a mode of cognition that is neither the human narrative mode, nor the logical, procedural one of early AI. It replaces the cause-and-effect chains that characterize narrative cognition and its extension in the closure and certainties of logical mathematics with statistical descriptions of events and particles that exist on a scale human cognition cannot comprehend. The narrative time that we embodied humans occupy does not easily comprehend this statistical and random world whose order is not necessarily linear, spatial, or narrative. We can no longer speak of reality, of historical realism, psychological realism, or some other method of creating a correspondence between human bodies and the world. We have only a statistical realm best described as *fractal realist.* It is realist in the sense that it describes ways of mediating the external world, but fractal because human and nonhuman cognitions mediate reality differently and therefore fracture it. Like mathematical fractal sets, these mediations operate recursively as they simultaneously organize and disrupt human representations of the world.

Consider the austere beauty of fractal objects such as the Mandelbrot set that visually presents the infinite complexities of simple iterative, complex-valued function; the Lorenz attractor, which uses a multidimensional space to reveal

a pattern that appears chaotic when viewed as a linear sequence; or the Lotka-Volterra equations of predator and prey relationships. These nonlinear, dynamical systems are no more identical with the images we commonly call fractals, than narrative is with the individual words printed in a novel. The fractal is rather a set whose order lies not in a logical progression of sequences, or in visual representations, but in the statistical self-similarity of any part to the whole. Moreover, images or maps of these systems are only available thanks to the vast improvements in digital computers during the 1960s and 1970s. Edward Lorenz discovered his eponymous strange attractor when using MIT's new mainframe computer to model the differential equations describing atmospheric flow.[13] Benoît Mandelbrot eventually coined the term fractal to describe properties of the strange patterns he discovered while analyzing noise in electrical signals or circuits,[14] and used IBM's computers to generate the first images of the Mandelbrot set.

Fractal realism appears in literary narratives as the disintegration of form, content, and subjectivity, and in cybernetics and media theory as the ambiguous relation (whether cooperative or competitive) between humans and intelligent machines. The proposal here is that two trends are not coincidental but mutually reinforcing. The collision of human and nonhuman cognitions defines a new genre that cuts across novels, films, and theoretical writing. Fractal realism complicates the history that literary critics usually trace from nineteenth century realism through naturalism and modernism (with postmodernism as an extension of

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[13] James Gleick gives a dramatized, narrative account of Lorenz's discovery in *Chaos*. See Lorenz, "Deterministic Nonperiodic Flow" for the mathematical details.

[14] Mandelbrot, *Objets fractals*; and Mandelbrot, *The Fractal Geometry of Nature*.

the latter) in the twentieth century. Realism sought to present the external world as it truly was, purged of Romantic literature's fantasy adventures. Naturalism amended that movement by substituting evolutionary forces for historical ones, so that the narrator became a detached, quasi-scientific observer. Modernism reincorporated that detached observer into the observed system, so that the narrative became as much about the internal as the external world. Modernist literature and art explored the interiority of their subjects by inscribing them in the media forms (print narrative, canvas, verse forms, etc.) and technologies (telegraph, telephone, etc.) that constitute and populate modernist narratives. Postmodernism (in some interpretations) then became the realization that this recursion of form and content foreclosed the possibility of a unified subject or grand narrative. Under fractal realism, these trends in literary history implicate themselves in the evolution of technical media and apparatuses.

Chapter 2

Nonhuman Signals: The Evolution of Cybernetic Technical Apparatuses

> [We] deal with automata effectively coupled to the external world, not merely by their energy flow, their metabolism, but also by a flow of impressions, of incoming messages, and of the actions of outgoing messages.
>
> Wiener, *Cybernetics*, 42

Cyberneticists from the early and mid-twentieth century oversaw the birth of the first automata capable of observing and acting on reality. Unlike automata past, navigation systems, weapons targeting systems, missile guidance controls, cryptographic devices, and eventually computers encoded reality, operated on those codes (i.e., re-encoded them), modified their internal states according to those re-encodings, and then transmitted those codes back into the external world

faster than any human could. They were so essential to World War II, because they could better encode and decode the signals flowing across the battlefields than soldiers or general who still thought their enemy was the human in an Axis uniform, rather than the fast-as-light radio signal carrying enigma code across the globe. A large part of the war took place in a reality constructed by and for these intelligent machines, these automated technical apparatuses. Nevertheless Norbert Wiener still preferred to think of them as having "sense organs" and a "nervous system."[1] But comparing vacuum tube and driveshaft assemblages to biological tissue misses the main point—the breath, or soul (*spiritus*), humans use to exchange words has been re-encoded as an electromagnetic signal. Perhaps James Whale implicitly understood this point when he had Colin Clive as Henry Frankenstein intone "It's alive!" once his lab's electron tubes animated the corpse.

The ghost in the machine is now the signal of encoded ciphers[2] that flows through the technical apparatus, whether those encodings or mediations take the form of complexly interconnected, rotating shafts and gears, or electrical pulses traveling through metal wires. Critical military technologies often hybridize these media technologies—for example, early fire control systems included mechanical integrating devices to calculate trajectories but they connected the various com-

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[1] Wiener, *Cybernetics*, 43.

[2] I use *cipher* in the sense of the empty symbol that stands in the place of something, and *code* in the sense of the system of laws or rules that dictate how the ciphers combine. Cipher as hidden or obscured text was a later addition to its original meaning, zero. Hence contemporary encryption schemes always refer back to the process of using an emptiness to hold and hide something meaningful. The interpreter simply needs the code to tell him or her where to look.

ponents of the system (from speed measurement equipment to gun rotation) via a configurable telephone switchboard.[3] This ability to route cipher codes through an electro-mechanical network shifted the focus from the medium's material substrate (e.g. electrons or metal gears) to codes that structure the media making up the automata's feedback circuits. Technologies capable of encrypting or encoding reality were nothing new, as astrolabes, slide rules, telescopes, photographs, and cinema preceded these cybernetic automata, but the recursive loop of encodings that helped automate the technology was unique.

This recursive or feedback loop that turns mediations into codes is the basis of Niklas Luhmann's claim that the mass media not only reflect but determine social systems, which he calls the media doubling of reality; Friedrich Kittler's assertion that these technologies, these media feedback systems determine human thought and action; and N. Katherine Hayles' insistence on the feedback loops that bind together nonhuman automata, human cognition, and embodiment. Remedios Varo's painting *Bordando el Manto Terrestre* (1961) presents a more artistic and less theoretical statement of reality as recursive loop. Women captive in a windowless tower embroider a mantle that spills from slats and becomes the landscape of the external world—it is both a cloak and the geological mantle.[4] The painting cuts a hole in the windowless tower to give the viewer access to what occurs inside, access to the process of producing the representations that produce the world

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[3]In this context integration refers to the mathematical function, which is the inverse of differentiation. It is a key concept in mathematical calculus and has many applications, including solving systems of differential equations such as the motion of a projectile.

[4]*Manto* in Spanish, like *mantle* in English, refers to a cloak as well as to the viscous, rocky mantle that extends from the crust's bottom to the outer core's top.

and the painting. Oedipa Maas looks upon the same painting in Pynchon, *Lot 49* to see in it yet another representation of her life as the great (and potentially oppressive) feedback loop of mediation and reality.

These recursive circuits of mediation give twentieth century automated technical apparatuses and their descendants a degree of cognition, so I call them nonhuman cognitive systems. Technical media—i.e., media technology that automatically converts sound, light, and other materials into a signal—are an important part of these nonhuman cognitive systems. I say these loops are cognitive because they convert materials into representations and back, not because they may emulate the human brain.[5] My focus is then not strictly on human representations of these automata but on representations inside them, on the machines as mediating and encoding engines: "Granted, historians of technology have examined public representations like world's fairs, literature, advertisements, and films, but rarely have they opened the proverbial black box of machinery to study the representations inside. By contrast, here I examine *representation in machines* as much as *representations of machines*."[6]

The only overlap between human and nonhuman cognition relevant here is recursivity. Neuroscientists and cognitive scientists have established that human cognition operates via recursive loops. Humberto Maturana and Francisco Varela

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[5]Wiener, Gregory Bateson, Franciso Varela, and Humberto Maturana do concentrate on the structural similarities of cybernetic circuits and animal nervous systems. Pickering, *The Cybernetic Brain* gives a fascinating account of the connections between cybernetics, neuroscience, and philosophy of mind.

[6]Mindell, *Between Human and Machine*, 16, original emphasis.

advance that thesis in *Autopoiesis and Cognition*, and Gerald Edelman similarly proposes that the various neural networks in the brain function via re-entry, or by feeding back upon themselves.[7] In the cognitive sciences, Douglas Hofstadter places strange loops (his word for recursion and self-reflexivity) at the center of human consciousness.[8] Cognition adheres to no single material substrate (neurotransmitters) or enclosed system (a human body), but is rather the signal that results from the recursive translation (which I will later replace with transduction) of one medium into another and the recognition, of course, that the translation creates a new pattern, a new code. Human cognition relies so much upon technical media as well that it must touch the nonhuman, but that does not mean the two are equivalent. Only neuroscientists can definitely tell us how the human brain functions.

Given their differences, putting the human into contact with the nonhuman requires some translation (what I will call a transduction) from one recursive loop (the nonhuman cognition) to another (the human cognition). Folding one recursive loop into another, however, multiplies the complexities to such a degree that it will be difficult to tell the two apart. The confusion works to our advantage, because the complex media recursions that constitute nonhuman cognitive systems

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[7]Re-entry is a well-established component of Edelman's more speculative hypothesis that brain's plasticity results from the Darwinian competition among numerous neural networks. He elaborates this possibility in two series of works, one for technical and another for lay audiences. The former are *Neural Darwinism* (1987), *Topobiology* (1988), and *The Remembered Present* (1990); the latter are *Bright Air, Brilliant Fire* (1992), *A Universe of Consciousness* (2001, with Giulio Tononi), *Wider than the Sky* (2004), and *Second Nature: Brain Science and Human Knowledge* (2007).

[8]See Hofstadter, *GEB*; Hofstadter, *Strange Loop*.

fashions a site where human and nonhuman touch one another. We see hints of this union in the way novels and films present human cognition, such as the human and artificial intelligences of Richard Power's novel *Galatea 2.2* (1995), or HAL's omnipresent lens and gaze in Stanley Kubrick's film *2001: A Space Odyssey* (1968). As evidence of the complexity entailed by folding these recursive loops together, we need only think of how these media presentations of human cognition feed back into that cognition. Photographic and movie cameras, wired and wireless telephones, electrical cabling, radios, and, of course, the computer have altered humanity's relationship to itself and its environment fundamentally. Here we find, again, Hayles's work on posthumanity, and Jonathan Crary's history of how visual and auditory technologies at the turn of the twentieth technologies altered human attention spans, and consequently, our sense of self and identity.[9]

We should not allow this contact to lull us into thinking this printing about nonhuman cognition is simply an affectation, a new way of talking about human cognition's distributed character. That nonhumans may gain cognition through technical media shifts cognition away from bodies per se and to the signals recursive encoding systems establish within and amongst themselves. We humans with our specific bodies and technologies exhibit one—highly complex and evolved—form of cognition, but ours are not the only bodies and technologies available. Can we imagine, for example, what would count as a pattern, a code for a nonhuman system that lacks a human body? Probably not, since we cannot even register the wash of electrons that a digital photosensor, for instance, detects and eventually

[9]Crary, *Suspensions of Perception*.

translates back into photons. Many theories or accounts of extended (human) cognition treat technical media solely as encoders and transmitters of human perceptions. Edwin Hutchins traces human cognition's distribution through a complex network of technical apparatuses and media aboard a nearly obsolete navy vessel, the USS Palau. The humans and the machines onboard exchange sets of representations (i.e., models) of their environment in order to plot and correct the ship's course. Andy Clark and Rodney Brooks advance well beyond the 1940s-era technology abroad the USS Palau to consider devices that emulate human behavior (e.g., automated factories) and extend human cognition and perception (e.g., cellular telephones, the computer, video conferencing avatars, etc.), but they still see these devices as satellites of human cognition.

This tendency should not surprise us, given how much such theories of extended cognition rely on a much older theory of human and technical co-evolution that dates back to André Leroi-Gourhan's paleoanthropological research of the 1960s. He demonstrated that human phylogenetic evolution differed from that of other animals because it unfolded through a feedback loop of human and technology. Humans exteriorized the capacities of their brains and bodies into the technical milieu, and these new technical objects would then influence human physiological evolution—a process that we will explore in the next chapter.[10] The focus in such accounts is therefore on the material and phenomenological connections of technical apparatuses to human bodies. Those arguing for distributed cognition must confront a problem that Leroi-Gourhan could mostly avoid—a bi-

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[10]The most relevant work available in English is *Gesture and Speech*.

ological one. While he was discussing human phylogenetic evolution, theorists of extended mind can only concentrate on the short timescale that tools and technologies have been available to humans. Technical apparatuses and media of the sort under discussion here are of even more recent vintage. Human bodies cannot evolve fast enough to incorporate these tools into themselves. New technologies can only alter the body (and brain) after birth during its ontogenetic development, as learning to read words and the Internet does.[11] The body's sluggish evolution compared with technical apparatuses means we must choose to either see it as the center—the stable point—around and through which these technologies evolve and derive their cognition, or to see the technical realm beginning to form a cognitive capacity that is increasingly distinct from the human's.

Lewis Mumford's and Martin Heidegger's fear that abstraction would overwhelm humans as the twentieth pushed forward was then the reactionary recognition that automated technical apparatuses would force us to rethink our place in the cognitive world. Mumford was right (except for forgetting about women) when he wrote (before having it printed, of course): "Men became powerful to the extent that they neglected the real world of wheat and wool, food and clothes and centered their attention on the purely quantitative representation of it in tokens and symbols."[12] Heidegger's "en-framing [Ge-stell]" bemoans the same abstraction, or the conversion of the world into manipulable, quantifiable material.[13]

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[11] Hayles, "Hyper and Deep Attention: A Generational Divide in Cognitive Modes" gives a good summary of this trend.

[12] Mumford, *Technics and Civilization*, 25.

[13] See "The Question Concerning Technology" and "The Age of the World Picture" reprinted in Heidegger, *Basic Writings*

These signals are not abstract to the nonhuman cognitive systems that generate and use them. Nonhuman cognitive systems are circuits that feed flows of matter and energy back into themselves to generate codes on which the circuit can perform further transformations and mediations. In this way, so-called abstract, immaterial codes actually perform work in the nonhuman system, but humans only understand them as abstractions, as something separate from the system that created it.

Stephen Mallarmé's quip that the « Le monde est fait pour aboutir à un beau livre » was indeed quite prescient, except that nonhuman as well as human cognitions would print strands of encoded ciphers instead of write pages of words. Revisiting the cybernetic automata of the early and mid-twentieth century will show us the moment these technical apparatuses and media began producing and working on their own encodings; the moment, that is, when they produced a signal distinct from the one human cognitions use. Just how these nonhuman cognitions can emerge from recursive media loops requires a clear explanation of how symbols, signs, or codes in one medium translate themselves through other media and systems. Given the wide variety of media technologies under consideration—from cybernetic automata to literary works—I begin my argument by clarifying how media mediate. Gilbert Simondon's theory of transduction gives an account of how media transmit information/structure from one to another and in so doing shows how they may feed back into themselves to increase their complexity. In fractal realism, transduction augments mediation.

2.1   WORLD AS SIGNAL

Tracking and predicting aircraft flight paths, regulating electrical flow through a network, or even the amount of fuel flowing into an engine required the controllers (whether human or mechanical) to anticipate future states of a constantly changing system. Leibniz and Newton developed calculus in the eighteenth century to calculate changing rates, whether water flowing through a river, the revolutions of celestial bodies, or the flight of a cannon ball (and later a missile). Slide rules, trigonometric tables, and other technologies quickly appeared to simplify the calculus (integration and differentiation) needed to determine these rates of change. By the nineteenth and early twentieth centuries, new technologies and the complex scenarios they helped engender (like navy vessels moving under steam power), however, made it impossible for humans (even with the aid of early computers) to compute rates of change before the system being calculated changed states. For example, a naval vessel could change course before a gunner had time to calculate ordnance trajectories. The situation became even more complicated if one tried to account for wind velocity, the motion of the targeting vessel, and other variables. The linear problems (i.e., involving one dependent variable) of the previous generation gave way to nonlinear ones (i.e., involving multiple dependent variables) in engineering and physics.[14]

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[14]Vannevar Bush makes just such an observation: "Electrical engineering, for example, having dealt with substantially linear networks throughout the greater part of its history, is now rapidly introducing into these networks elements the non-linearity of which is their salient feature, and is baffled by the mathematics thus presented and requiring solution. Mathematical physicists are continually being hampered by the complexity rather than the profundity of the equations

Scientists and engineers tried to solve this problem by automating integration and differentiation with mechanical devices that could compute at speeds far exceeding a human's manual operations.[15] Such mechanical integrators were simple analog computers, because they solved integrals by using the mechanism's physical movements to represent the function's rates of change. William Thomson (Lord Kelvin) outlined such an analog computer in a series of 1876 articles; he represented the integral mechanically as the rotations and lateral movement of a wheel and disc. Held with its axis perpendicular to that of the disc, the wheel would slide across the rotating disc's surface at a rate that corresponded to the rate of change one wanted to calculate.[16] The variable's rate of change and the wheel's movement were analogous.

A human had to set the machine up and record the results, so Thomson's integrator could only integrate one function (i.e., one dependent variable) before halting. Many of the most interesting (and useful) problems, however, involved systems of several dependent variables and therefore a system of differential equations. To solve such systems would require chaining together several

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they employ; and here also even a numerical solution or two would often be a relief" Bush, "The Differential Analyzer: A New Machine for Solving Differential Equations," 448.

[15] Integration and differential are inverse functions, meaning that integration reverses differentiation and vice versa. Therefore a machine that could integrate could also (with some modification either to the mechanism or the inputs) differentiate.

[16] Thomson detailed his plans in two papers Thomson, "Mechanical Integration of the Linear Differential Equations of the Second Order with Variable Coefficients"; and Thomson, "Mechanical Integration of the General Linear Differential Equation of Any Order with Variable Coefficients."

integrators so that one could feed its output into another's input. Feeding the results of one calculation into the same device to drive further calculations is crucial to the mechanism's motions becoming representations for the device and not just for the human. In other words, we need such a feedback loop for the device to become its own observer. Without the ability to automatically feed the output into a new input, the machine would simply cease after it reached the result, which means the parts would stop moving. The ability to use its output to perform work beyond the single calculation would be the first step in treating the work as a signal carrying information that could structure or set up another round of calculations.

The wheel and disc integrator, however, could not generate sufficient power to carry the mechanical energy representing one integral's solution over to the wheel and disc that would calculate the next integral. Vannevar Bush designed the Differential Analyzer (DA), which became available in 1931, to overcome this problem.[17] The DA from 1931 consisted of parallel rotating shafts that connected

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[17]The benefit of starting with this analog computer, rather than with the digital ones that arrive a decade later, is the clear correspondence between the world being represented and the automaton's electro-mechanical functions. Indeed, even after multi-purpose, programmable digital computers superseded the DA, Warren Weaver and others thought the Analyzer should remain as a teaching aid: "[It] seems rather a pity not to have around such a place as MIT a really impressive Analogue computer; for there is vividness and directness of meaning of the electrical and mechanical processes involved [...]. A Digital Electronic computer is bound to be a somewhat abstract affair, in which the actual computational processes are fairly deeply submerged." Quoted in Owens, "Vannevar Bush and the Differential Analyzer," 66. We could, of course, use voltage meters or technical media like the oscilloscope to observe the electrical current in electronic, digital

input tables, the integrating units (which were essentially Thomson integrators), and output tables for recording the results.[18] The input tables held graphs of the functions and constants to be integrated, and the output tables traced the curve of the integrated function. The DA linked the various integrating units by overcoming the friction that hobbled the Thomson-style integrators. Harold Hazen (a member of Bush's research team) realized that the torque amplifier Henry W. Nieman invented in 1925 could produce the necessary amplification if it was used to connect the shafts between machines. By amplifying the mechanical energy in the rotating shaft, the torque amplifier allowed the the output of one integrator to become the input of another integrator. Bush describes this process as back-coupling in 1931 but switches to the then new term "feed-back" in his 1945 paper.[19]

The subtly of Bush's innovation belies the profound change it introduced into automata like his DA and its later digital forms. Amplifying the machine's energy to drive other components of the automaton meant that the mechanical movements were less important than what they represented. The mechanism "abstracted the numerical data away from the machine itself. No longer were the

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computer's wires, but its speed (electrons can accelerate close to the speed of light) and complexity of its interconnections make it difficult to understand how the calculation unfolds.

[18] Bush, "The Differential Analyzer: A New Machine for Solving Differential Equations" provides details of the machine's layout.

[19] See Bush, "The Differential Analyzer: A New Machine for Solving Differential Equations," 450; and Bush and Caldwell, "A New Type of Differential Analyzer," 265. Mindell explains the delay in adopting the term feedback, which was mostly used in telephone and electrical engineering. See Mindell, *Between Human and Machine*, Chapter 5.

numbers tied to the shaft positions; rather they could be renewed, or amplified, with each successive stage."[20] Now the next integrating mechanism, not the human operator, recognized the shaft's rotation as part of the equation's solution. Amplification of energy was the first step in creating a signal that conveyed information rather than just force or matter.[21]

Far from diluting or concealing the signal, the various translations of energy between the DA's components made the signal possible because each translation needed to amplify it. The more material and energetic forms the signal could assume while still being a signal, the more the scientists and engineers designing and using the automata considered it something abstract—like software running on hardware. The benefits of a so-called abstract signal became even more apparent as engineers hybridized mechanical with electrical technology and analog with digital algorithms.[22] The DA's 1945 incarnation (called the Rockefeller Differential Analyzer), for example, would hybridize digital and analog computing schema by numerically encoding the input on punched tapes and by replacing the rotating shafts with electrical connections.[23] Telephone switching technology

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[20]Mindell, *Between Human and Machine*, 156.

[21]The important distinction here is not between analog and digital (i.e., numerical) computation, because "even numerical had internal dynamics that could imitate feedback loops (another transduction of the loop)" (Mindell, *Between Human and Machine*, 295).

[22]A digital computer does not necessarily refer to an electronic machine, but only to one that encodes its computation as numerical data.

[23]See ibid., 170: "In 1935 Bush initiated a project to automate these rearrangements, making the machine a production line for calculation. Instead of rotating shafts to interconnect the calculating units, this new machine would transmit its data electrically. A central switchboard interconnected all the units, which could then be rearranged simply by resetting the switches by remote

was the basis for this new wiring system: "The interconnections required in this system consist of two shielded wires (and a ground connection); these are readily handled by automatic telephone switching equipment."[24] Even in the 1931 paper, Bush recognized the similarities between the DA's configurable circuits and electrical switchboards, remarking that the machine's schematics had the air of electrical circuit diagrams.[25]

The object of study therefore drifted further away from the physical materials and toward the signal itself. Dealing with these signals drove engineers and scientists to devise the theory of control systems that Norbert Wiener would later call cybernetics, after the Greek word for governor or steersman.[26] Cybernetics needed to control or regulate the signal's flow, because feeding back amplified output into the system could lead to violent oscillations, or a runaway, positive feedback cycle. The torque amplifier, for example, produced so much gain when amplifying one integrator's output for another integrator's input that a slight misalignment (perhaps due to the analyzer's vibrations) could feed an integrator its own output.[27] The result was the mechanical equivalent of holding a microphone

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control."

[24] Bush and Caldwell, "A New Type of Differential Analyzer," 285.

[25] See Bush, "The Differential Analyzer: A New Machine for Solving Differential Equations," 459: "The scheme of connecting the machine for a specific problem which has been illustrated is quite general; more so in fact than might at first appear. It has certain features in common with the 'plugging' of a desired circuit on a switchboard, and the resulting diagrams have something of an electrical atmosphere about them. Evidently the complexity of the equations which can be handled is limited only by the number of units available."

[26] For Wiener's explanation of why he chose *cybernetics,* See Wiener, *Cybernetics,* 11.

[27] See Bush, "The Differential Analyzer: A New Machine for Solving Differential Equations," 465:

next to its speaker. Despite the microphone being an electrical rather than me-
chanical device, the analogy between it and the DA is quite apt. Bush even com-
pared the feedback problems in the analyzer to the "singing" or erratic oscillations
in electrical circuits.

Bush solved the first DA's oscillation or singing problem with a vibration damp-
ener.[28] The singing of the Rockefeller DA's electrical interconnections, however,
proved particularly intractable. Harold Hazen's 1934 papers "Theory of Servo-
Mechanisms" and "Design and Test of a High-Performance Servo-Mechanism"
established that for any system with continuously varying inputs and complex
loops between components, the oscillations, singing, or runaway feedback exhib-
ited by the DA and telephone lines was inevitable. Telephone engineers, in fact,
had difficulty making any usable circuit that did not experience some feedback:
"Subtle, uncontrolled feedback would arise through unintentional effects such as
stray capacitance between wires or even between elements within the tube itself
and cause the amplifier to go into parasitic oscillation, or singing."[29] Even sys-
tems without amplifiers, in other words, would eventually experience a sort of
amplification thanks to the feedback loops between their parts. Wiener likened

"Now such a torque amplifier is quite analogous to a two-stage thermionic-tube amplifier, and it
has many of the properties of the latter, including the possibility of self-oscillation. It was soon
found, in fact, that when the amplification of such a low-input unit was raised to around 10,000
it was very prone to go into a condition of violent oscillation ending usually in disaster. This was
presumably caused by a small part of the output being fed back in one way or another into the
input. [...] It was finally solved by the use of a vibration damper [...]."

[28] Bush, "The Differential Analyzer: A New Machine for Solving Differential Equations," 465.

[29] Mindell, *Between Human and Machine*, 119.

the oscillation problem to the various motor diseases that cause tremors in humans.[30]

Hazen and others eventually found that while they could not eliminate oscillation, they could harness it to regulate the automata's circuits. Something like the sort of regulator cyberneticists needed had existed since James Watt's steam engine governor, but electro-mechanical automata required new technology. Cyberneticists needed a means of counteracting positive feedback with negative feedback, so that deviations too far from the baseline could be neutralized. The servo-mechanism used an input, an amplifier, and a motor to correct excessive mechanical movements (a modern cruise control system is technically a servo-mechanism). In 1934, Harold Black would also generalize them to electrical circuits and name them the negative feedback circuit.[31] These new feedback circuits would diminish but not completely eliminate the "parasitic oscillation." The impossibility of a completely clear signal was actually a benefit, because engineers could then harness the feedback to regulate the system's fluctuations over the long-term. This averaging of noise and static over the scope of the system enabled it to continue functioning instead of screeching (perhaps literally) to a halt or freezing in a fixed loop.

The feedback loops that were necessary for the automata to form representations for themselves, then, were not accidental or even a part of the initial de-

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[30] See Wiener, *Cybernetics*, Chapter 7.

[31] Black gives a rather Romantic account of discovering the negative feedback amplifier in Black, "Inventing the Negative Feedback Amplifier." The more sedate, technical account is found in Black, "Stabilized Feed-Back Amplifiers."

sign—they were a consequence of creating a complexly connected system with multiple inputs and outputs. It is misleading to think of these signals or representations as abstract or disembodied: "The message was no longer the medium; now it was a signal that could be understood and manipulated on its own terms, detached from its physical embodiment."[32] That emphasis on disembodiment and abstraction is mainly, as Hayles (1999) shows, a choice that facilitates the human scientists' understanding and manipulation of the signals passing through the cybernetic circuits. For the automaton, the abstract signal would be the translation of energy and matter among its parts, a representation of the work done by other components in the machine, and a regulator of its systems.

The supposed abstraction of the signal and its information is even more irrelevant, if we remember that the entire point of building these cybernetic automata was to automate tasks (like integration) previously performed by humans with the aid of simple tools. The human user or observer (if the two are really distinct) was never meant to receive the signal flowing through the automaton. Instead the automaton's signal loops produce a model of the external world unique to the machine—a model of a world that moves much faster than the human nervous system can react. The human then links to the automata through another translation, through a signal designed especially for humans to understand.

> By 1940 the company [i.e., Sperry Corporation] could write coherently
> about "the inability of the unaided man to operate his weapons": "His
> airplanes have become so big and fly so far that he must have auto-

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[32] Mindell, *Between Human and Machine*, 112.

matic pilots instead of flying by hand. The machine gun turrets must be moved by hydraulic controls. The targets of his antiaircraft guns now move so fast in three dimensions that he can no longer calculate his problems and aim his gun. It must all be done automatically else he would never make a hit."[33]

The Sperry Corporation and Mindell are not just describing in the above quotation the proliferation of media between humans and reality. Whether humans have direct or mediated access to reality has been a concern of epistemology since Enlightenment claims of science offering unmediated access to reality. The claim here is stronger—not only do human cognitions have mediated access to reality, but now their technical apparatuses produce and rely upon technical mediations. The cybernetic automata produces its own model of reality through its feedback loops of media technologies.

The technical media such as the telephone and the Differential Analyzer that humans designed to manipulate their world with ever greater degrees of accuracy and speed now operate on their own mediations. They accomplish this by constantly translating, transmitting, and recycling a signal through the circuit that joins their various components. It is not as though some external agent establishes the signal because it arises thanks to the very process of translation, transmission, and recycling (or feedback) that differentiates the cybernetic machine from previous machines. Sperry Corporation's remarks above are not merely bravado but a candid recognition that the technical milieu, which extends the

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[33]Mindell, *Between Human and Machine*, 69.

human body, has folded upon itself to create a representation or model of real-ity—the signal—that is not itself intelligible to humans. The automata's repre-sentations only become intelligible after undergoing another set of translations that convert them into visual and audible signs, such as bleeps on a radar screen.

To better understand the recursive loops of technical apparatuses and media at work in these cybernetic automata, we need a media theory that explains how a structure or pattern (like the signal) emerges from mediation between differ-ent systems. Given the diverse components involved in the mediations discussed above—such as electrical cables, mechanical drive shafts, rotating drums, servo-mechanisms, negative feedback circuits, and the human—such an account of mediation is even more important. How does the so-called abstract signal man-age to leap from one system to another all the while maintaining its identity as a distinct thing? This requires a theory of mediation that can account for the material specificity of the signal and still treat it as a coherent entity that is not necessarily fragmented among many different systems.

2.2   Transductive Media Theory

Gilbert Simondon's theory of transduction and individuation best explains the complex series of translations and recursive loops that signals undergo in auto-mated technical apparatuses. In so doing, it will provide a general account of how the transitions between media technologies that these loops imply are essential to the production of information and spaces of representation. Twentieth cen-tury media theories have either assumed mediation entails the communication

of meaning between parties, or have denied the semantic dimension in favor of quantitative information and technical processes.[34] A transductive theory of mediation, however, avoids the dichotomy by showing how mediations fold into one another as a way of building more complex systems. To understand how I use transduction, it is best to start with its technical meaning.

A transducer converts one type of energy (e.g., electrical, mechanical, chemical, acoustic, thermal, etc.) into another. According to the OED, the technical word first appears in 1924, during the same era of analog computer and telephone engineering that we visited in the last section.[35] Transducers are essential parts of the telephone system because they convert sound waves (i.e., people's voices) into modulated electrical currents that can then be transmitted across the sprawling telephone network. The transducer converts the kinetic energy of the sound wave (the vibration of the air molecules) into electrical energy. Other examples of transducers include antennae (electromagnetic radiation into electrical current), cathode ray tubes (electrical current into electron beams and then into light), light bulbs (electrical current into heat and then into visible light), and accelerometers (velocity into numbers).

Transducing through a transducer means moving some organized pattern from one system to another, which is to say it is the *work* of moving one medium

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[34]Marshall McLuhan and Michel Serres count among the former; and Claude Shannon and Friedrich Kittler among the latter.

[35]The word literally means to lead (*dūcere*) across (*trans*). The OED cites K.S. Johnson's book *Transmission Circuits for Telephone Communication* as the first usage. There he defines a transducer as "Any device by which variations in one physical quantity (e.g., pressure, brightness) are quantitatively converted into variations in another (e.g., voltage, position)."

into another—hence, the scientific definition that it converts energy.[36] Given this definition alone, transduction would play an important role in cybernetic automata such as the Differential Analyzer, because such systems rely upon the converse of energy between different subsystems—e.g., the DA's rotating shafts and the output graph. The ability to treat this energy exchange as a pattern, as a representational space, however, distinguished these automata from other energetic systems, like melting ice. We should bear in mind that energy is not an object or substance so much as a measurement, so that to say something is energetic means it is active or changing. Transduction, then, necessarily expends energy, but in doing so it translates the organized physical activity of one medium into another. Thanks to entropy (the Second Law of Thermodynamics), that transference is unidirectional (i.e., irreversible without adding more energy to the system) and entails some loss of order. A transductive process differentiates pattern from noise as it translates a pattern from one medium to another—the pattern is the activity that successfully moves between systems; the noise is that which transduction leaves behind or the energy it expends (i.e., entropy) in producing the pattern. Therefore, it is not necessarily a cognitive observer that adjudicates the pattern/noise distinction, but the interaction of properties or structures of the systems undergoing transduction.

Revisiting the telephone example further clarify these points. Sound waves are compressions of air molecules, so to convert that compression into a modulated electrical signal requires that one understand how those molecules interact

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[36]Latin *energīa,* Greek (ἐνεργής) meaning work.

with other materials and media, such as the membrane embedded in the microphone. The microphone must convert the vibrating molecules' kinetic energy into vibrations in the membrane, and then translate those membrane vibrations into electrical energy (i.e., current).[37] In the very process of transmitting the sound wave, the transduction helps to define what a sound wave is. The material of which the membrane in the microphone is made will determine its sensitivity to fluid perturbations (in this case, the sound waves) and therefore select what counts as wave and what doesn't. For instance, the microphone will not detect all frequencies, nor other types of waves like electromagnetic radiation (e.g., radio waves, light, etc.). Transduction does not only convert one system or medium into another but also makes that system accessible to another system. We could also understand this "accessibility" as the separation of pattern from noise that, according to Bernhard Siegert, defines mediation.[38]

One might say that the microphone's transduction only occurs because engineers designed it to work that way, thereby attributing the motivating force back to a higher level cognitive system (e.g., the human). While the microphone may in-

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[37]To say that the microphone must do X or Y is already a loose, but unavoidable, way of speaking. Language offers no option but anthropomorphization, and hence the use of mathematical symbols.

[38]"Every culture begins with the introduction of distinctions: inside/outside, sacred/profane, intelligible speech/barbarian gibberish, signal/noise. The fact that they are able to generate a world is the reason why we experience the culture in which we live as a reality and, more often than not, as the 'natural' order of things. Yet these distinctions are processed by media in the broadest sense of the word" (Siegert, "Cacography or Communication? Cultural Techniques in German Media Studies," 5).

deed work as it does because it was designed to do so, its operations occur without human intervention. The telephone system functions by creating and counteracting gradients, or differentials, within itself. The transduction occurs because of some underlying defect, lack, or uncertainty that appears once the two systems come into contact. The conscious intervention of the engineer is neither needed, nor preferred. This movement through gradients of uncertainty shows transduction's kinship with other media and process philosophies. I will concentrate on two: Michel Serres' parasite; and Bruno Latour's Actor-Network Theory (ANT).

In its directionality and focus on translating patterns, transduction blends elements of Serres' and Latour's systems. Because it is based on entropy, Serres' parasitic mediation entails errors (degradations) and is irreversible (like breaking glass or melting ice) unless another party replies, which would be a new communicative act: "The flow goes one way, never the other. I call this semiconduction, this valve, this single arrow, this relation without a reversal of direction, 'parasitic.' [...] The system constructed here beginning with a production, I temporarily placed in a black box, is parasitic in a cascade. But the cascade orders knowledge itself, of man and of life [...]."[39] While ANT lacks an account of causality, it does understand mediation as the action of moving patterns or representations through networks. Actants are the network's atomic units, but they are not strictly media, matter, or objects but more like nodes of action: "Instead of starting with entities that are already components of the world, science studies focuses on the complex and controversial nature of what it is for an actor to come into existence. The

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[39] Serres, *The Parasite*, 5.

key is to define the actor by what it does—its performances [...]. Since in English 'actor' is often limited to humans, the word 'actant,' borrowed from semiotics, is sometimes used to include nonhumans in the definition."[40]

Both these theories helpfully articulate media as active, energetic systems rather than as a passive spaces through which a pattern passes en route to its destination. As a consequence, they cease treating media as reliable transmitters, because the media are now themselves capable of action as material objects in some environment. Imagine the first time you reached for something at the bottom of a shallow pool—unless you understood the physics of refraction, you might wonder why an object that appears to be at one position looks like it is in another. Until that moment, you might have treated light as an invisible medium, or as what Latour calls an intermediator, that "transports meaning or force without transformation: defining its inputs is enough to define its outputs."[41] But the moment the light passes from one liquid (air) to another (water) and appears to break your arm, it becomes a series of mediators, which "transform, translate, distort, and modify the meaning or the elements they are supposed to carry."[42]

Intermediators are black boxes because their inner functions remain hidden from those observing or using them—they just work. They are therefore also *deterministic* systems, meaning that a given input predictably produces a specific output. Mediators, however, are white boxes because their inner functions are visible (and consequential) to those using them. Hence, mediators are *stochas-*

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[40] Latour, *Pandora's Hope*, 303.

[41] Latour, *Reassembling the Social*, 39.

[42] Ibid.

tic systems, meaning that a given input unpredictably produces any number of outputs. Thanks to the unpredictable output, we become aware of the various subcomponents that constitute the whole. These subcomponents we may in turn think of as intermediators, which may in turn become mediators. Actants, then, contain mediators within mediators like the layers of an onion.

Though the directionality of the parasite and the nesting of intermediators and mediators will prove useful for understanding transduction, neither theory gives an explicit account of how their media systems manage to continue working despite the degenerative effects of entropy. Actants seem able to transmit action without any loss whatsoever, and parasitic media systems constantly bleed energy but somehow do not halt once they reach maximum entropy. Neither one will then explain how a recursive system, or one that feeds its input into its output, could ever function without descending into chaos, without eventually losing all coherence like the screeching microphone held in front of its speaker. Yet, my account of nonhuman cognition requires just such a recursive system—not to mention the fact that most living things are precisely such self-perpetuating, recursive exchangers of energy and information.

Putting energy and information so close together implies a closer proximity than common sense might suggest. What exactly is the information that passes through the triad of sender, parasite, receiver in parasitic media theory? Alternatively, what are the representations passing through Latour's actants? Information and representation seem at once materially fused with whatever system carries them—electrons in a wire, or light in a film—and yet something separate or abstract. Its medium forms it, but it *informs,* as it were, its medium. This sit-

uation recalls Hazen's insight that all circuits (whether mechanical or electrical) experience feedback and oscillation, but it is that very process of feedback and amplification that allows the signal to emerge as something at once within but also separate from the system, as an abstraction that transduces itself between the subcomponents.

Just as the physical components of a thermodynamic system generate entropy as they do work, so then does a signal generate entropy as it transduces itself through a system. The parasite is precisely this informational entropy, because it is represents the static, noise, disorder, and confusion that all communication necessarily entails, just as doing work (using energy) means generating waste and increasing chaos: "Mistakes, wavy lines, confusion, obscurity are part of knowledge; noise is part of communication, part of the house."[43] (Serres, 12).1 Serres implies that communication is always the communication of some message, of content, of meaningful information. Rather than detract from that content, noise is a constitutive part of it. But in order for that communication to have meaning, it needs a sender and receiver to interpret it, so Serres' parasitic media theory already includes in the transmission circuit a hidden feedback loop between the content of the message and the ability of the receiver to understand it. He tacitly acknowledges what Hayles makes explicit in her call for embodied information—all information implies a body through which it moves and through which it is interpreted.[44]

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[43]See Serres, *The Parasite*, 12. Serres plays on the double entendre of *parasite* in French, where it means parasite and static.

[44]Hayles, *How We Became Posthuman*, Chapter 8.

Latour's ANT, however, offers no coherent account of how representations and actants relate to one another. Who decides what a representation is or how to interpret and act on it? The actant itself? Another actant? The problem is clearest in the ease with which intermediators and mediators exchange roles. The intermediator transmits representations without deformation, and yet it quickly, as we saw above, shifts to being a mediator that does modify the representation in unpredictable ways. The actant as mediator is the closest ANT comes to including entropy in its framework, but this entropy seems to require a human observer (not just an observer): "Objects, by the very nature of their connections with humans, quickly shift from being mediators to being intermediaries, counting for one or nothing, no matter how internally complicated they might be."[45] I emphasize the humanness of this observer, because it is not at all clear in ANT how a nonhuman actant can observe anything.

Rather than the signal, the information, or the meaning arising from a recursive feedback loop within the system, Latour's theory requires a human to delegate this cognitive act to the nonhuman actant. The best example Latour gives of this is the speed-bump. If civil engineers wish drivers, especially in parking lots, to reduce their speed, they could either post written signs, assign traffic police, or otherwise convey the command to reduce speed symbolically. The speed-bump, however, delegates that intention from human language or gestures to the mound of concrete poured over the ground, which alters the *"matter of expression,"*[46] For

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[45]Latour, *Reassembling the Social*, 79.

[46]See Latour, *Pandora's Hope*, 186, original emphasis. Latour articulates the concept of delegation and circulating reference in *Pandora's Hope* and and carries the concept forward into his more

that matter to activate the expression, of course, requires a driver to roll over the speed-bump.

Simondon's theory of individuation and transduction partly addresses these concerns by explaining how the concatenation and recursion of mediators (a special mode of transduction) enables systems to organize and perpetuate themselves. He lays out his theory in two major works, *The Individual and Its Physico-Biological Genesis* (1964) and *The Psychic and Collective Individual* (1989).[47] I consider these works to be extensions of one another, since they were originally written as one volume, which was his main doctoral thesis—*L'individuation à la lumière des notions de forme et d'information* (1958). He also explores transduction's more technological applications in his complementary thesis, *On the Mode of Existence of Technical Objects* (1958). In that work, he criticizes Wiener's cybernetics and proposes his own account of technical objects and their evolution.[48]

As noted earlier, it is the ability to translate patterns (via work or energy) across systems that defines transduction. Simondon explains how transduction trans-

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sociologically oriented volume *Reassembling the Social.*

[47]Their titles in French are *L'individu et sa genèse physico-biologique,* and *L'individuation psychique et collective.* Since no English translates exist yet, the translations of the titles are mine. For simplicity, I will refer to *L'individu et sa genèse physico-biologique* as IGPB, and *L'individuation psychique et collective* as IPC. Most of my quotations and reference will come from two recent, but partial, English translations of those works. Simondon, "The Genesis of the Individual" is a translation of the introduction to IGBP. Simondon, "The Position of the Problem of Ontogenesis" is the introduction to IPC.

[48]The French title is *Du mode d'existence des objets techniques,* and like IGPB and IPC, no official English exists, but a 1980 English translation by Ninian Mellamphy is available online.

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mits and creates the pattern through the progressive movement, replication, and evolution of energy across a system. Transduction does not simply occur within but constitutes the very structure of the system over which it propagates itself. In this way, each constituted structure serves as a model and constraint for the transduction's leading edge, so to speak.

> By transduction we mean an operation—physical, biological, mental, social—by which an activity propagates itself from one element to the next, within a given domain, and founds this propagation on a structuration of the domain that is realized from place to place: each area of the constituted structure serves as the principle and the model for the next area, as a primer for its constitution, to the extent that the modification expands progressively at the same time as the structuring operation. [...] The transductive operation is an individuation in progress.[49]

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[49] Simondon, "The Position of the Problem of Ontogenesis," 11. The earlier IGPB gives a similar account but in terms of form and matter, see Simondon, *L'Individu et sa genèse physico-biologique*, 16–18 and Simondon, "The Genesis of the Individual," 312–13. French: « Nous entendons par transduction une opération, physique, biologique, mentale, sociale, par laquelle une activité se propage de proche en proche l'intérieur d'un domaine, en fondant cette propagation sur une structuration du domaine opérée de place en place : chaque région de structure constituée sert à la région suivante de principe et de modèle, d'amorce de constitution, si bien qu'une modification s'étend ainsi progressivement en même temps que cette opération structurante. Un cristal qui, à partir d'un germe très petit, grossit et s'étend selon toutes les directions dans son eau-mère sursaturée fournit l'image la plus simple de l'opération transductive : chaque couche moléculaire déjà constituée sert de base structurante à la couche en train de se former ; le résultat est une

A crystal lattice spreading through a fluid is the simplest example of a transductive process, because the already formed crystal informs the lattice's future growth. The transductive edge between crystal and fluid is also the boundary at which one medium or energy is being converted into another—the fluid's kinetic energy becomes the potential energy stored in the crystal's molecular bonds. The dynamism of transduction and therefore of individuation comes not from a polarity between two extreme terms but from a tension between two (or more) orders, such as that between the highly ordered crystal and the highly disordered fluid.[50]

While the crystal offers no more sophisticated an example than Latour's speedbump, it does illustrate how transduction builds complex systems (e.g., the crystal lattice) from primitive ones (e.g., the disordered fluid), rather than delegating from a higher to lower order. A differential between two or more systems is sufficient to start a transductive process, and therefore to create a new structure from the simpler ones without the intervention of a designer, or a pre-existing template. The pattern or the template emerges during it and fluctuates as the transduction continue, so that emerging system structures itself by using its output (e.g., the leading edge of the crystal) as the input for its next state (e.g., further crystallization).

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structure réticulaire amplifiante. L'opération transductive est une individuation en progrès »(Simondon, *L'individuation psychique et collective*, 24–25).

[50]"[Its] dynamism comes from the primitive tension of the system of the heterogeneous being that dephases itself and develops dimensions according to which it structures itself" (Simondon, "The Position of the Problem of Ontogenesis," 11). French: « [Son] dynamisme provient de la primitive tension du système de l'être hétérogène qui se déphase et développe des dimen-sions selon lesquelles il se structure »(Simondon, *L'individuation psychique et collective*, 25).

There's a direct correspondence between this aspect of transduction and the DA's successive feeding of outputs into inputs, but, of course, the cybernetic automata we examined in the last section were indeed designed and built by humans. In that respect, to pit Latour's theory of technical mediation against Simondon's transduction seems unfair. We should however keep in mind that the general principles of transduction and individuation still apply to these automata, as Simondon makes clear in the Existence of Technical Objects. It is worth quoting him at length on the difference between *abstract* and *concrete* machines.

> The concrete technical object is one which is no longer divided against itself, one in which no secondary effect either compromises the functioning of the whole or is omitted from that functioning. In this way and for this reason, in a technical object which has become concrete, a function can be fulfilled by a number of structures that are associated synergetically, whereas in the primitive and abstract technical object each structure is designed to fulfill a specific function and generally a single one. [...] Each structure fulfills a number of functions; but in the abstract technical object each structure fulfills only one essential and positive function that is integrated into the functioning of the whole, whereas in the concrete technical object all functions fulfilled by a particular structure are positive, essential, and integrated into the functioning of the whole. Those marginal consequences of functioning which in the abstract technical object are eliminated or attenuated by correctives, become evolutionary stages or positive aspects of the

concrete object. The functioning scheme incorporates marginal as-
pects, and effects which were of no value or were prejudicial become
links in the chain of functioning.[51]

An abstract machine is like a Fordist assembly line, because the work done at
each stage is independent of its predecessors. One worker (or robot arm) need not
know what happens on another part of the line—indeed it is probably preferable
that he, she, or it not know. Each stage is still essential and integrated into the
functioning of the whole, but it should contribute a single effect that advances the
entire machine's work. Errors, imperfections, inefficient movements, and other
types of noise must be dampened as much as possible.

The concrete machine also comprises many subsystems integrated into a
whole, but unlike the abstract machine, the concrete machine's subsystems are so
well integrated that they cannot be readily distinguished from one another. This
indivisibility is in part due to the absence of destructive noise, errors, imperfec-
tions, etc that would impede an abstract machine's functioning. One cannot iso-
late a concrete machine's malfunction to just one subsystem, because the inputs
and outputs flow together so intricately that it becomes difficult to distinguish
successive stages and directions of movement. Simondon, therefore, thinks that
bio-chemical systems best exemplify concrete machines: "[The concrete techni-
cal object is] a system in which a multitude of forces are exercised and in which
effects are produced that are independent of the design plan. The concrete tech-
nical object is a physicochemical system in which mutual actions take place ac-

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[51] Simondon, *Des objets techniques*, 30–31.

cording to all the laws of science."[52]

If we turn again to Bush's DA and other cybernetic automata, we can see that oscillation would be one "marginal consequence of functioning" to be "attenuated by correctives," like the vibration dampeners. Whereas the concrete cybernetic machine would see that oscillation not as a marginal function, noise, or an error, but as essential to regulating the functioning of the whole. The first (mechanical) DA would then be somewhat closer to an abstract machine, while the (electro-mechanical) Rockefeller DA would be closer to an abstract one. The evolution of the DA then illustrates the transition from abstract to concrete, as the "marginal consequences" like vibration and oscillation bring into greater relief the signal that moderates and unifies the automaton. The machine's components are not separable thanks to the amplification and recursion they perform, since each of the cybernetic machine's pieces is simultaneously carrier and generator of the signal moving through it.

Simondon asserts that these differences make the concrete machines living systems, or at least that the distinction between the technical and living ceases to be relevant: "Whatever difference exists between a technical object and a physico-chemical system studied as an object exists only in the imperfection of science."[53] He extends the concrete machine into physiochemical-biological systems such as the cell, the brain, and eventually psychic systems (otherwise called mind and society). All the latter are self-reflective and self-organizing systems that, as Simondon says, individuate themselves. They make themselves individuals that

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[52] Simondon, *Des objets techniques*, 31.

[53] Ibid.

are distinct from one another and from their environment. Of particular interest here are those individuating systems that harness their transductive activity to perpetuate the individuation indefinitely. The crystal eventually comes to a halt when it has exhausted its available energy, when the transduction has brought the system to maximum entropy. Other systems, however, can fold that individuation and transduction back upon itself to use, in other words, the fluctuating entropy to encourage further transduction. Therefore, Simondon often thinks of individuation as a vital process, going so far as to assert that all living things are "theaters of individuation."[54]

Whether or not such systems are alive is less interesting to me than whether they are cognitive. Simondon's sliding scale between the abstract and concrete machine, between transductions in a crystal and those in cybernetic automata enable us to differentiate degrees of cognitive activity. The more capable a system is of recursively folding its transductions into themselves while still remaining a coherent whole, the more sophisticated its cognitive abilities. Human and nonhuman cognitions would then rely on these recursive transductions, except that the systems undergoing the recursions would be different—media technologies for nonhuman cognitions, and electro-chemical ones for humans (and other vertebrates).

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[54] "[The] living being conserves in itself an activity of permanent individuation. It is not only the result of individuation, like the crystal or the molecule, but is a veritable theater of individuation" (Simondon, "The Genesis of the Individual," 305). The French: « [Le] vivant conserve en lui une activité d'individuation permanente ; il n'est pas seulement résultat d'individuation, comme le cristal ou la molécule, mais théâtre d'individuation. » (Simondon, *L'Individu et sa genèse physico-biologique*, 9))

Finally I want to consider exactly how these recursive transductions perpetuate themselves, which is not an incidental point, given that the feeding back or folding of these transductions is essential to my definition of cognition. Entropy again figures into the answer, because it produces what Simondon calls *metastable* states. For a recursive, individuating system, entropy works to increase the system's disorder, and in so doing provides the raw material for the system to organize as it feeds back upon itself. Rather than use the term entropy, he talks about the preindividual, or that which resists individuation. It resembles Hayles' unmediated flux and Deleuze's the virtual.[55] Without the preindividual, transduction would eventually neutralize any gradients in the system and so arrest activity.2 The recursive individuating system is therefore between order and disorder, between ossification and metamorphosis, which is the definition of metastability.

> I can put forward the hypothesis [...] that the process of individuation
> does not exhaust everything that came before (the preindividual), and
> that a metastable regime is not only maintained by the individual,
> but is actually borne by it, to such an extent that the finally consti-
> tuted individual carries with it a certain inheritance associated with its
> preindividual reality, one animated by all the potentials that character-
> ize it. [...] There is a certain level of potential that remains, meaning
> that further individuations are still possible. The preindividual nature,

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[55]We should note that Deleuze was a serious student of Simondon's work, and many of his concepts derive from his work. See Hayles, "Constrained Constructivism: Locating Scientific Inquiry in the Theater of Represenation" as well as Hayles and Luhmann, "Theory of a Different Order: A Conversation with Katherine Hayles and Niklas Luhmann."

which remains associated with the individual, is a source of future

metastable states from which new individuations could eventuate.[56]

Metastability comes directly from thermodynamic far-from-equilibrium systems, which Ilya Prigogine calls dissipative structures.[57] These systems constantly exchange energy (absorbing and expelling it) with their environment in order to stave off the degenerative effects of entropy, for if the system were to reach maximum entropy, it would contain no more gradients or differentials to propel its processes—it would become static. Simondon refuses to call the preindividual a substance that pre-exists individuation, precisely because it is entropic—it is the consequence of the individuating system's ability to do work. The disorder produced from the system's functioning produces new gradients, thanks to the feedback cycles, which drive further transductions.[58]

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[56] Simondon, "The Genesis of the Individual," 306. French: « On peut faire une hypothèse [...] que l'individuation n'épuise pas toute la réalité préindividuelle, et qu'un régime de métastabilité est non seulement entretenu par l'individu, mais porté par lui, si bien que l'individu constitué transporte avec lui une certaine charge associée de réalité préindividuelle, animée par tous les potentiels qui la caractérisent ; [...] un certain niveau de potentiel demeure, et des individuations sont encore possibles. Cette nature préindividuelle restant associée à l'individu est une source d'états métastabilité futurs d'où pourront sortir des individuations nouvelles » (Simondon, *L'Individu et sa genèse physico-biologique*, 10).

[57] Prigogine and Nicolis, *Self-Organization in Non-Equilibrium Systems*.

[58] Such systems are distinct from Humberto Maturana and Francisco Varela's autopoietic ones. While that theory also proposes self-organizing and self-perpetuating systems of which the eukaryotic cell is the paragon, it also assumes the system is closed, i.e., that it does not produce anything other than itself. Simondon's account, however, allows for perturbations that could disturb the system, sending it in a new direction (such as a virus infecting the cell), and for the cell's

This recursive loop of transductions also gives the metastable system a form or structure that is not delegated from a human user or observer. The signal that cyberneticists saw pulsing through their telephone wires or through the electrical and mechanical components of the Differential Analyzer was not designed in advance but arose from the amplification necessary to join the various subsystems together. The scientists did not impose a form on the cybernetic system, so much as allowed the system to inform the materials and circuits from which it was built. Simondon recognized this point as well and therefore preferred to say that recursive individuating systems are informed rather than formed.

> *The notion of form must be replaced by that of information,* which presupposes the existence of a system in a state of metastable equilibrium that can individuate itself; information, unlike form, is never a unique term, but the signification that springs from a disparation. The ancient notion of form, such as provided by the hylomorphic schema, is too independent of any notion of system and metastability.[59]

participation in a yet more complex system like an organ or a human body. Maturana first published on autopoiesis in 1974, but the book he co-authored with Varela, *Autopoiesis and Cognition* gives a more comprehensive statement.

[59] Simondon, "The Position of the Problem of Ontogenesis," 12, original emphasis. French: « *La notion de forme doit être remplacée par celle d'information,* qui suppose l'existence d'un système en état d'équilibre métastable pouvant s'individuer ; l'information, à la différence de la forme, n'est jamais un terme unique, mais la signification qui surgit d'une disparation. La notion ancienne de forme, telle que la livre le schéma hylémorphique, est trop indépendante de toute notion de système et de métastabilité » (Simondon, *L'individuation psychique et collective*, 28, original emphasis).

Information as the "signification that springs from a disparation" presages Gregory Bateson's 1969 characterization of information as "a difference that makes a difference,"[60] or a recursion of a difference into itself, so that it may seed further differentiation. It does not pre-exist the individuation but emerges from it as the system and its environment distinguish themselves from each other. Information is then that dynamic structure that the system evolves during its transductions, and that feed back into the system to direct future transductions. The generation of information is the first step toward the individuation becoming a complex, recursive system.

Nonhuman cognitive systems do not necessarily rely on humans for their intentional or semantic content (as ANT would require), because their very behavior brings about the complex recursions of media that produce what humans call a signal. The systems do not simply transmit electrons or spin metal shafts, so much as feed energy back through their subcomponents. The very act of doing so means they require energy as input, and therefore mimic the thermodynamic processes that require living things to ingest, transform, and excrete energy. Open exchange and recursion of energy allow these nonhuman systems to form representations of their environment and themselves, because the transductive feedback loops give rise to a signal. It is the addition of that extra loop of media technologies that fractures the stream of representations that humans imagine they organize. The nonhuman cognitive system also received those representations and uses them in ways that do not necessarily serve a human end.

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[60] Bateson, *Steps to an Ecology of Mind*, 199.

In a sense, these nonhuman systems become cognitive, because their recursive loops of media make them their own observers.

How nonhuman and human cognitive systems interact with one another remains an open question. We have shown here that these nonhumans exist, that they are cognitive, and that they constitute themselves from media technologies. We need to consider next the site at which nonhuman and human mediations meet, or transduce from one to the other. Especially given a human body's very different construction and operation compared to a nonhuman's, we must account for how communication between them is possible at all. The signals that pulse through cybernetic circuits and the narratives that mark human language must have some point of contact.

Chapter 3

Bio-Technical Cognition: Brains, Languages, and McElroy's Plus

The nonhuman signal's and human cognition's evolve in parallel, and so brings the nonhuman and human cognitions closer together, while also highlighting the conflicts such proximity will cause. Human language depends on a circuit of bodies and technologies not only for its production but also for its recognition as meaningful language, and we will see the extent to which language as speech, writing, and print has been co-evolving with human bodies for thousands of years. At the same time, the technologies in which language partly exists has been evolving its own body (the technical apparatus) and language (the signal), since the turn of the twentieth century. What happens as human language slips into the technical apparatuses that carry nonhuman cognitive signals? Written language is already at a remove from the human body, but print is even farther, for it must travel through a larger transductive circuit that includes offset litho-

graphic printing presses and, later, digital typesetting systems. In the process, writing as computer ciphers and codes starts talking back to humans—Plato's *Phaedrus* did not imagine that once translated into the technical apparatus, writing could enter into dialogue with people much less itself.[1]

Joseph McElroy's print (presumably via lithographic offset technology)[2] novel *Plus* imagines just what transformations (or transductions) language would undergo as it steps through the looking glass into the nonhuman cognition's invisible world of transmitted signals. Indeed, McElroy's experiences with interplanetary craft and a world populated with increasingly automated technology (including that for typesetting and printing books) made his imagining not as fantastic as his story about a brain transplanted into a satellite.

IMP PLUS TO CAP COM. NERVE FIBERS INCLINED TO ORIENT BY CON-
VERGING ON CENTERS OF GROWTH THAT ARE ACTIVE. VISION HARD-
ENING TOWARD MILKY AND TOWARD BONE, CAP COM, BUT A WHILE

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[1] Plato's dialogue *Phaedrus* (Φαῖδρος), which scholars believe was composed around 370 BCE, is an exchange between Socrates and, of course, Phaedrus on love and ultimately rhetorical presentation of any idea. Socrates warns Phaedrus that writing does not answer back but only repeats itself: "You know, Phaedrus, writing [γραφή], shares a strange feature with painting [ζωγραφίᾳ]. The offsprings of painting stand there as if they are alive, but if anyone asks them anything, they remain most solemnly silent. The same is true of written words [λόγοι]. You'd think [δόξαις] they were speaking as if they had some understanding [φρονοῦντας], but if you question anything that has been said because you want to learn more, it continues to signify just that very thing forever. When it has been written down, every discourse roams about everywhere, [...] and it doesn't know to whom it should speak and to whom it should not" Plato, *Phaedrus*, 80–81, sections 275d–275e.
[2] Kipphan, *Handbook of Print Media*, 52.

AGO GIBBOUS EARTH WAS VISIBLE THROUGH WINDOW BY MEANS OF

SHEAROW MEMBRANE. ALSO SEVERAL ELECTRODES ADRFIT ARE VISIBLE

AS IS BRAIN HOUSING ADRIFT.[3]

These uppercase letters are the way *Plus* prints the radio transmissions between the protagonist (of sorts) Imp Plus and the human scientists at Capsule Command (i.e. Cap Com). Those scientists and engineers find the syntactically grouped words incomprehensible, despite their being recognizably English. How do nerve fibers incline? Can vision harden to "MILKY" and "BONE"? What is a "SHEAROW MEMBRANE"? You won't find it in an anatomy textbook. In order for us to find a modicum of sense in these phrases, we must reconstruct a skeletal history of Imp Plus from clues littered throughout the novel: the brain of a terminally ill male scientist (or engineer) was transplanted into an experimental satellite and launched into terrestrial orbit—a military project overseen by two engineers called the Good Voice and Acrid Voice. The scientist's brain was connected to baths containing photosynthetic cells (perhaps algae) to provide glucose, and pierced with slender silver probes to monitor neural activity and to link it with the onboard electronics called the Concentration Loop (e.g. the computer and communications system).

Most criticism of *Plus* begins with just such an orienting framework, a restatement of the context that frames what passes for a narrative, so that the printed text seems less strange and forbidding to the reader. This history makes the novel seem less alien by domesticating it—quite literally by imagining that the human

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[3]McElroy, *Plus*, 176.

brain went off somewhere else, became something distinctly foreign, and then came back to share its experiences over dinner. The new English that Imp Plus is developing, however, reflects an entirely new embodiment and transductive circuit to which humans do not and cannot belong. We will never completely understand what a "SHEAROW MEMBRANE" is, for we are not brains in satellites. Striving for such understanding is besides the point, because it is not what the words mean that matters, but how Imp Plus treats them as material to be molded into new concepts and sensory experiences. We cannot ignore the strangeness of this act.[4]

We can better understand how language, which seems like such a meaningful and distinctly enciphered code for humans, can become the material for a nonhuman cognition's codes, if we think of language not as an abstraction that exists solely thanks to the human brain but as one part of a larger technical milieu. I will follow André Leroi-Gourhan's division of the world into three domains or milieux to better elaborate this aspect of language. Leroi-Gourhan calls them the interior (*milieu intérieur*); the technical (*milieu technique*); and exterior milieux (*milieu extérieur*).[5] Human phylogenetic evolution precedes as the exteriorization

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[4]The curious reader can find a comprehensive statement about the inferred facts of Imp Plus's human background in Porush, *The Soft Machine*, 172–75; Tabbi, *Postmodern Sublime*, 130; and Brooke-Rose, *A Rhetoric of the Unreal*, 272–73.

[5]In French the word *milieu* means environment, habitat, medium, and middle, though only the last two are English cognates. I will therefore use milieu so that all those meanings can remain. Leroi-Gourhan delineates the milieux in the second volume of his first major work on humans, techniques, and evolution: *Milieu et techniques: Évolution et techniques* (1945). He expands on this system in *Le geste et la parole* (1965) in which he introduces the primary elements of human evo-

of the interior into the technical milieu, which in turn incorporates or modifies elements of the exterior. Human language is one transductive circuit across these milieu.[6] The moment the apparatuses in the technical milieu become automated and begin to work on their own ciphers according to their own codes, they need no longer pass the ciphers through the interior milieu that is the human body. They form their own cognitive center by folding the technical milieu on itself, by recursively processing and acting on the ciphers being generated there. The human brain in *Plus* tries to look into that fold by removing the brain from the human interior milieu and placing it in the nonhuman cognition's nascent interior milieu. As a consequence, the printed language the novel must use to encode what that brain experiences is stuck between human and nonhuman transductive circuits. On the one hand, it belongs to an established human world, and on the other, it must serve as the material from which the emerging nonhuman Imp Plus must build its world.

By remaining a printed page, *Plus* can only go part of the way to imagining the

lution: mobility; liberation; and exteriorization. Much of this work is little known in the Anglo-American academy thanks to the lack of translations—there are no English translations of *Milieu et techniques*, and the two volume *Le geste et la parole* was not translated until 1993 as *Gesture and Speech*.

[6]Phylogeny and ontogeny will be important later. Phylogeny studies how groups are related and diverge over the course of their evolution. Charts that show one species branching off from another (such as those showing how humans and other primates can trace their lineage back to a common ancestor) are phylogenetic trees or networks. Ontogeny studies a single organism from its birth to maturation. Developmental biology, psychology, and neuroscience all make use of ontogenesis.

way this nonhuman cognition thinks. The uppercase letters that appear on Cap Com's screens, for example, first had to be re-encoded as a radio wave's frequency pulses (modulated photons, or electro-magnetic radiation), and who can know how Imp Plus, with no eyes (until perhaps a later moment in the novel) or hands, would understand the letter shapes. Moreover, we can only read them, because they are printed on pages (or leaves) that were artificially woven from the cellulose fibers, which previously bound together a plant's cell walls. That printed page rests firmly on earth, in human hands, and awaiting human eyes to scan it. We cannot help but read the letters as letters, for we have been developing with them for too long to do otherwise.

3.1   Escape Velocity

Plus de-automatizes language, according to Joseph Tabbi's and David Porush's critical interventions on the novel's behalf, though neither one makes the crucial caveat that the novel de-automatizes human language—they simply assume language is always human.[7] Being such an inhospitable vacuum at such an ungraspable distance, space is the most comfortable place for us to place an alien sentience, such as Imp Plus, who speaks a de-automatized language. We need not, however, travel into space to find a nonhuman language and cognition, be-

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[7]See Porush, *The Soft Machine*, chapter 9 and Tabbi, *Postmodern Sublime*, chapter 5. Porush borrows *de-automatization* from the Russian formalist critic Victor Shklovsky's essay "Art as Device" (1917). The word *ostranenie* is usually translated as defamiliarization: "The technique of art is to make objects 'unfamiliar,' to make forms difficult, to increase the difficulty and length of perception" quoted in Porush, *The Soft Machine*, 178.

cause de-automatization and space are just euphemisms for the rupture that the cybernetic automata of the early twentieth century caused in the human body's dominance over language as a transductive circuit of ciphers and codes. Rather than travel to the stars in the unfathomable depths of space, we should turn back in time to human evolutionary origins. We will find that the vaunted cognition and symbolic language that separate us from beasts have relied on the technical milieu that Leroi-Gourhan sees enveloping the human and separating him or her from his or her environment.

Leroi-Gourhan initially defined the interior milieu as the "extremely complex bath of mental traditions" shared and transmitted among generations of *Homo sapiens*. The exterior milieu encompasses the material world, such as trees, soil, oceans, etc. The technical milieu, unlike the others, is not a separate domain but a special subset of the interior that surrounds the latter like a membrane, because the "human group takes in its environment through a screen of objects (tools or instruments)."[8] This tripartite schema is more functional than spatial, because

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[8] See Leroi-Gourhan, *Milieu et techniques*, 333–34. The translations are mine, since no English one has been published. The French: « Par le premier terme [le milieu extérieur], on saisit d'abord tout ce qui matériellement entoure l'homme : milieu géographique, climatique, animal et végétal. Par le second terme [le milieu intérieur], on saisit, non pas ce qui est propre à l'homme nu et naissant, mais à chaque moment du temps, dans un masse humaine circonscrite (le plus souvent incomplètement), ce qui constitue le capital intellectuel de cette masse, c'est-à-dire un bain extrêmement complexe de traditions mentales » (333–34). « Le groupe humain se comporte dans la nature comme un organisme vivant ; de même que l'animal ou la plante, pour qui les produits naturels ne sont pas immédiatement assimilables, mais exigent le jeu d'organes qui en préparent les éléments, le groupe humain assimile son milieu à travers un rideau d'objets (outils

the interior milieu is constantly in flux as it progressively assimilates the exterior through the technical milieu: "We see, in the interior milieu, a gradual seizing of the exterior milieu."[9] That movement accords with the thrust of Leroi-Gourhan's project from *Évolution et techniques* (1943, 1945) through *Le geste et la parole* (1964, 1965) to erase the distinction between culture and nature.[10] Interior and exterior milieux were never meant as synonyms for the latter. Brain develops with tool. That raises a problem his oeuvre never directly confronts: which came first, brain or tool? How does the tool (non-genetic and external to the brain) affect the evolutionary development of the cerebral cortex? Such a link does exist—N. Katherine Hayles and I used it to argue elsewhere that language is intelligible not because it refers to universal givens or social constructions (i.e. to something external to itself) but because it arises from the complex co-evolution of the human brain and its environment.[11]

The technical milieu is the site of the transductions that encode the exterior milieu into codes or patterns that the recursive transductions constituting the interior can use as fuel to perpetuate themselves. For humans, the technical milieu contains the transductive processes that give rise to the signal we call language.

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ou instruments) » (332).

[9] French: « Nous y voyons un mouvement, dans le milieu intérieur, de prise progressive sur le milieu extérieur » (Leroi-Gourhan, *Milieu et techniques*, 337).

[10] Both books were published as two-volume works and constitute the most systematic presentation of his philosophy and paleoanthropological research. *Évolution et techniques* came out as *L'homme et la matière* (1943) and *Milieu et techniques* (1945); *Le geste et la parole* as *Technique et langage* (1964) and *La mémoire et les rythmes* (1965).

[11] Hayles and Pulizzi, "Narrating Consciousness: Language, Media, and Embodiment."

Like those signals that we saw technical apparatuses producing in the previous chapter, language is a code that vibrating molecules (speech), writing implements held in hands, typewriter keys impressing pages, or digital code in a computer can all carry. As is true for any transductive process, the properties and patterns already present in the medium partly determine the signal's form. Language as carried by some media (such as speech) has been evolving with the brain for so long that it appears natural, by which I mean a necessary part of human existence. Yet, the difficulty that children have in learning to write and compose text—years of formal instruction and practice—should remind us that some of those transductive circuits rely on more recent technologies than others.

The naturalness of spoken language on the one hand, and the difficulty of learning written language on the other is but the latest example of the tension that marks all human phylogenetic evolution—namely, the co-evolution of technologies and bodies. The anthropocentric narrative of human phylogenetic evolution supposes that our sophisticated brains compelled us to create languages through which the brain could express itself, and our bodies to stand erect so that the hands could design the tools the brain needed to modify the environment. Leroi-Gourhan reverses this teleology. Once the mouth no longer served as the means of acquiring (and grasping) food—the role it continues to fill in other mammals like dogs—the snout could shrink and the forward parts of the cranium expand forward. That forward part of the skull houses the neocortex, which is the focus of what we humbly call the higher cognitive functions. The neocortex and the now free forelimb entered into a positive feedback cycle. A forelimb that could grasp and manipulate objects rather than provide locomotion needed a brain that could

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recognize those objects, and eventually organize them. A larger brain could put that grasping hand to better use, which would therefore increase the primate's chances of survival. The hand—that primal tool—developed in tandem with the brain.

In *Gesture and Speech*, Leroi-Gourhan argues the transference of functions from the mouth to the hand is just one example of the successive liberation (his word) and exteriorization of functions that define human evolution: "Actions of the teeth shift to the hand, which handles the portable tool; then the tool shifts still further away, and a part of the gesture is transferred from the arm to the hand-operated machine."[12] We should recognize this process as transductive.[13] While the liberation from tooth to hand seems clear enough, it also appears different

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[12] Leroi-Gourhan, *Gesture and Speech*, 245.

[13] This migration of the tool-function from body to body does not resemble Deleuze and Guattari's territorialization and deterritorialization process by accident, for they explicitly rely on Leroi-Gourhan's work to illustrate the instability of formal distinctions, or of "expression" (*l'expression*) and "content" (*contenu*). "What some call the properties of human beings—technology and language, tool and symbol, free hand and supple larynx, 'gesture and speech' [*le geste et la parole*] are in fact properties of this new distribution. It would be difficult to maintain that the emergence of human beings marked the absolute origin of this distribution. Leroi-Gourhan's analyses give us an understanding of how contents came to be linked with the hand-tool couple and expressions with the face-language couple. In this context, the hand must not be thought of simply as an organ but instead as a coding (the digital code), a dynamic structuration, a dynamic formation (the manual form, or manual formal traits). The hand as a general form of content is extended in tools, which are themselves active forms implying substances, or formed matters [*matières formée*]; finally, products are formed matters, or substances, which in turn serve as tools [*servent d'outils*]" (Deleuze and Guattari, *A Thousand Plateaus*, 60–61).

in kind from the liberation that transforms the hand into the handheld tool. He calls the leap from body to artifact an exteriorization, though we may call it by its true name—*abstraction,* the concept so loathed by Mumford and Heidegger. Since bodies need many generations (which translates into centuries or millennia for humans) to change, the exteriorized technical artifact presents an opportunity to easily refine and channel the liberated function. It is much easier to refine and evolve a hammer than a hand. As the functions of the arm and hand are liberated from the body, they are transferred first to hand-held tools (like a hammer) and then to machines. The first externalization leaves the gesture in the arm and hand (a person must lift and wield the hammer), but the next externalization transfers even that gesture to the machine.

> Here again the parallelism between technics [*techniques*] and language is clearly apparent. Tools detach themselves from the human hand, eventually to bring forth the machine: In this latest stage speech and sight are undergoing the same process, thanks to the development of technics. Language, which had separated itself from the human through art and writing, is consummating the final divorce by entrusting the intimate functions of phonation and sight to wax, film, and magnetic tape.[14]

The "latest stage" refers, of course, to the cybernetic apparatuses that Norbert Wiener and others brought to fruition decades before Leroi-Gourhan put those words to paper. Thanks to the new techniques cybernetic sciences made available

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[14] Leroi-Gourhan, *Gesture and Speech*, 216.

to engineers for generating and analyzing signals, sight and speech could finally be externalized and disseminated far afield of the human organs on which they had previously relied. Leroi-Gourhan does not fully appreciate the extent to which the designers of these cybernetic apparatuses believed they were replicating the brain in electronic circuits.[15] Cognition is then dependent on the technical as much as on the biological, the brain and its so-called wetware.

We do not need to take Leroi-Gourhan at his word—contemporary researchers have confirmed and refined his sketch of human technical evolution. The psychologist Patricia Greenfield has established that Broca's area—the part of the brain responsible for fine motor control (i.e. grasping and putting objects together)—is also necessary for the organization of elements of speech.[16] The paleontologist Stanley Ambrose amplifies this point and directly connects it with prehistoric tools: "Habitual tool-making and tool-using activities involving bimanual

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[15]I am eliding a long history of artificial intelligence in this sentence, but other excellent histories and resources exist. See for example Rodney Brooks, *Flesh and Machines;* Daniel Dennett, *Consciousness Explained;* Hubert Dreyfus, *What Computers* Still *Can't Do;* John Searle, *The Rediscovery of Mind;* and Joseph Weizenbaum, *Computer Power and Human Reason.* The initial assumption that the human brain functioned along the same principles of logic as digital circuits has been proven incorrect by contemporary neuroscience and by the continued failure of that early branch of AI, which John Searle dubbed Strong AI. Indeed, Norbert Wiener's conception of the brain as an adaptive, self-correcting system has proven to be more prescient, as contemporary AI has sought to simulate those mechanisms in order to duplicate brain functions like object recognition in digital computers. For more on the connection between cybernetics and the human brain see Andrew Pickering's *The Cybernetic Brain.*

[16]Greenfield, "Language, Tools and Brain: The Ontogeny and Phylogeny of Hierarchically Organized Sequential Behavior."

coordination of stabilizing objects and precision tool use may have led to lateralization of brain functions and set the stage for the evolution of language. [...] Speech and composite tool manufacture involve sequences of nonrepetitive fine motor control and both are controlled by adjacent areas of the inferior left frontal lobe."[17] By lateralization, he means the localization of specific functions in certain hemispheres of the brain, and the predominance of right-handedness in *Homo sapiens,* which other primates do not exhibit. Recent research in neuroscience and linguistics has not overturned any of these findings but only abolished the talk of lobes, or modules, in the brain and replaced localized areas with distributed neuronal networks.[18]

Human biological evolution then moves in parallel with technical evolution—a pairing I suggest we call bio-technical evolution. Language has always been a participant in that evolution. Though Noam Chomsky's generative grammar requires that the mechanism or logic for learning language rest entirely in the brain, or rather that our genes program the brain with all the grammatical and syntactical forms languages may take, the co-evolution of technologies (including spoken language) and brains means that language is at least partially outside the head. Terrence Deacon argues instead that language partially parasitizes the human brain in that it has its own set of procedures and forms that are external to the

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[17] Ambrose, "Paleolithic Technology and Human Evolution," 1750–51.

[18] See Pulvermüller et al., "Functional Links between Motor and Language Systems"; Pulvermüller, "Brain Mechanisms Linking Language and Action," but also a broader discussion of the role of distributed systems of neural networks in Edelman, *Neural Darwinism*. We should also not omit the role that the gene foxp2 has been proven to occupy in language production, especially the fine motor control necessary to articulate sounds.

brain but that nevertheless require the brain to survive, because without brains there would be no one to speak. Like parasites and their hosts, Deacon sees language and the brain adapting each others' structures in order to turn the parasitism into symbiosis. For most of human history, this co-evolution involved only spoken language, but now writing and print are involved. Language still seems immaterial to us, because we cannot so easily shrug off the long evolutionary habit of speaking. Yet, the more technologies it flows through, the more language reveals itself to be a transductive process. Oral communication gives way to the written mark, then to print, and most recently to the computer's digitally encoded ciphers.

Leroi-Gourhan does glimpse the possibility that these technical apparatuses possess a cognition of their own, though he unnecessarily identifies it with life: "A biologist will find it hard to resist comparing the mechanisms of animals whose evolution is already complete with these organisms [i.e. intelligent machines] which, in the last analysis, constitute a parallel living world. [...The] distance between ourselves [...] and the intelligent machines we have created is greater than ever."[19] Life is not the important point here, because the machines cannot procreate themselves without assistance from human beings. The point is rather that technical evolution is accelerating to the point that human phylogenetic evolution moves at a trickle relative to it.

If this "parallel living world" populated by "intelligent machines" is flashing by too fast for our eyes to register—like cinema's celluloid frames—then we need

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[19] Leroi-Gourhan, *Gesture and Speech*, 251–52.

only look back to the break between oral and written language that helped start the acceleration. Building on Eric Havelock's thesis that Plato's philosophy seeks to squash the oral tradition with alphabetic writing, Marshall McLuhan and Walter J. Ong see oral and written, or acoustic and visual, language as two starkly defined cognitive modes. The former is immersive, immediate, and nonlinear; the latter is distant, abstract, and linear. Contemporary neuroscience fortunately curbs their excesses (e.g., McLuhan's specious claim that Asian philosophy and writing is more acoustic than visual) and actually suggests a greater break than either McLuhan or Ong propose. Homo sapiens emerged ~200,000 (perhaps even ~300,000) years ago, language and behavioral modernity did not appear until ~150,000 years later (or 50,000 years ago),[20] the first bow and arrow about 12,000 years ago,[21] and then exponentially decreasing spans of time between other technological innovations up to the digital computer.[22] Writing, for example, is a mere ~8,000 years old,[23] which is not enough time for new brain struc-

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[20] "Behavioral Modernity" includes fine tools, jewelry, figurative art, barter and exchange, game playing, music, and burial. Mellars, "Why Did Modern Human Populations Disperse from Africa ca. 60,000 Years Ago?" See.

[21] Knecht, *Projectile Technology*.

[22] "With the appearance of near-modern brain size, anatomy, and perhaps of grammatical language ~0.3 Ma [million years ago], the pace quickens exponentially, suggesting the latter. *Ex terra ad astra:* A mere 12,000 years separate the first bow and arrow from the International Space Station" (Ambrose, "Paleolithic Technology and Human Evolution," 1752, original emphasis).

[23] The figure is difficult to fix because of the fluid definitions of "true writing" compared to "proto-writing." Writing systems derive in large part from other graphic forms of symbolic representation, so where to draw the line, as it were, between symbolic art or painting and a coherent, phonetic written system is difficult. The oldest discovered evidence of such a system are the Jiahu

tures to have evolved to accommodate it, so this exteriorized technology must actually be rewiring, as it were, our brains during their ontogenetic development to make them suitable vehicles for writing.

Stanislas Dehaene, drawing on work by Mark Changizi, suggests that rather than a new area of the brain devoted exclusively to letter recognition, writing systems parasitize those parts of the visual system that have evolved to recognize objects. He makes this conclusion because a very specific area—he calls it the "letterbox"—of the brain activates when we read, regardless of the language, and that area serves other functions:

> Crucially, the "letterbox" area, which is activated when we read, falls squarely within Brodmann's area 37. *Thus reading is not handled by a new and uniquely human brain area. We recognize the written word using a region that has evolved over time and whose specialty, for the past ten million years or more, has been the visual identification of objects.* The brain's letterbox overlaps nicely with the general site where a lesion induces the "psychic blindness" discovered by Lissauer, Klüver, and Bucy.[24]

The "letterbox" is better known in scientific literature as the visual word form area and anatomically as the left occipito-temporal area[25]—it is the first node in

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symbols found on the a turtle shell near modern-day Henan, China. They date from ~6,000 BC, which would make writing at least ~8,000 years old.

[24] Dehaene, *Reading in the Brain*, 125, emphasis added.

[25] Ibid., 62.

the brain to process letters. Because this region evolved to recognize objects, it is located in the same place for readers and writers of alphabetic, logographic, and syllabic inscription systems. We know this because patients afflicted with Klüver-Bucy syndrome have lesions in this area of the brain, one of whose symptoms is visual agnosia, or the failure to recognize familiar objects and faces. Injuries to that region also cause *aphasia* (failure to articulate speech), *alexia* (failure to read), or *agraphia* (failure to draw letters).

For letters to take advantage of the brain's object recognition system, they must at some basic level be similar to other objects the visual system can isolate. Dehaene, Changizi, and others demonstrate that all alphabets share certain visual characteristics: they have sharply contrasted contours, three strokes per character on average, and recurring primitive shapes, such as T, L, Y, and F junctions, crosses (or X's), and circles. The frequency of these primitives in writing systems corresponds with their frequency in images of various landscapes.[26] They theorize that evolutionary pressure hardwired these primitive shape contours into the brain's visual system, and they therefore served as a template when the selecting which writing systems worked best: "We did not invent most of our letter shapes: they lay dormant in our brains for millions of years, and were merely rediscovered when our species invented writing and the alphabet."[27]

How do these primitive shapes find their way into the brain? Not solely through our genetic code; that is, they are not entirely innate, a priori knowledge. On

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[26] Changizi et al., "The Structures of Letters and Symbols throughout Human History Are Selected to Match Those Found in Objects in Natural Scenes."

[27] Dehaene, *Reading in the Brain*, 139.

the contrary, they are learned as the visual system develops throughout infancy. Mark Changizi has shown that these primitive shapes can be found whenever one projects a three-dimensional world onto a two-dimensional plane. Dehaene, Changizi, and others suggest that the brain selects these shapes over others because they are statistically more prevalent than others.

> Even if we allow for an initial genetic bias, it seems likely that most of the neurons involved in object recognition become selective because of interaction with a structured visual environment. We are constantly bombarded by millions of incoming images that provide primary data for our brain's statistical learning algorithm.[28]

Our brains, then, do not recognize a thing/object or face by comparing the image from the retina against a mental photographic library (one picture for a tea kettle, another for Grandma), but by learning that varying combinations of shapes are statistically correlated with specific things/objects. Hence we do not see a tea kettle, but an accumulation of shapes most likely to be one. The environment in which we mature then informs the shapes and contexts we are most likely to associate with specific things/objects. This explains why we might not only associate specific combinations of the primitive shapes with certain things/objects but also why we are used to certain things/objects in conjunction with each other—everything has a context.

Written language, however, transduces those primitive shapes into a new set of ciphers that in turn belong to an extraordinarily complex system of codes. In

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[28]Dehaene, *Reading in the Brain*, 141.

fact, writing works with the brain to produce a cognitive mode specific to it. Vilém Flusser calls this cognition conceptual or narrative thinking, and it is the linear, progressive, and logical cognition that generates history.[29] We will see in later chapters why Flusser does not think writing has a future. For the time being, it is enough that we realize language and cognition are not only bound up with one another in a co-evolutionary spiral but also with exteriorized, or abstracted, technical artifacts. Indeed, the brain is less written language's master than a set of capacities writing must harness to express itself. The difficulty of mastering it has encouraged us to develop cybernetic automata—e.g., the computer—that are better at generating and processing ciphers and codes than we are.

Hence, the difficulty McElroy realizes he will need to confront if he plans to use language, especially narrative language, to imagine what the world looks like from these techncial apparatuses' prospectives. Reporting on the December 7, 1972 launch of the Apollo 17—the last manned lunar landing and first nighttime lift-off—for the *New York Times,* he concentrates not on the launch's implications for lunar exploration, human civilization, and the Cold War, but on the logic of the engineering before him. The triumphs humans achieve through these technical apparatuses will not reveal what systems of encoding are unfolding inside the machines.

> Whatever else my imagination gropes for, it is neither easily familiar
> with nor easily insulated from structural steel, violent combustions
> and printed-circuit electronics. But in fiction—and I don't mean sci-

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[29] Flusser, *Does Writing Have a Future?*

ence fiction—how does one write about technology and its relation to people? Perhaps not directly at all, but rather in accord with some virtue to be found in technology. [...][What] actually went on inside the computer HAL in the film *2001* attracted me more than some paranoid or Bergsonian comedy one might imagine Stanley Kubrick intended. More important, if NASA's systems seemed to erase or revise the great single and possible Self at the core of our Western tradition, one wouldn't necessarily see those systems through refractions of that Self's rhetoric.[30]

The "virtue" these machines possess is none other than the ability to encode and re-encode media in a way that is alien to human cognition and its technical extensions. He does not revert to the tired images from some science fiction of the automata as a distorted, perverted image of humanity—like the schizophrenic HAL and its genocidal successors in the *Terminator* film franchise. Whatever the mechanical virtue is, it is different from McElroy's, and hence the importance placed on that which mediates his relation to "structural steel, violent combustions and printed-circuit electronics." Unable to decide on a medium, his piece ultimately gives neither a representation of technology, nor the machine's view—the former would humanize the machine too much, and the latter seems impossible. The only option left for McElroy is to let go of the human, or rather the human as Self and Subject that stands apart from technology. Hence the final plea to "some virtue to be found in technology," the passive construction of which

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[30]McElroy, "Holding with Apollo 17," 1.

silently begins the erasure.

Plus continues that project. The brain in *Plus* zooms well beyond the interior and even the exterior milieu—in this case, to planetary orbit. Is the brain in the satellite a tool now, only good for monitoring glucose levels and executing basic flight commands? Or is the tool, the satellite as a whole, now a brain, or rather a cognitive, nonhuman agent? We can only answer that question by trying to map how the aforementioned milieux will reorganize what we know as brain, techniques, and environment in that orbiting satellite. Indeed, the prose of the novel is the first attempt at such a mapping. It is so strange precisely because what the technical milieu (including language) inherits from its previous embodied life must adapt to the new medium, the new embodied experience of the growing Imp Plus.

3.2   Media Matter

By the time the terminally ill scientist's brain leaves his body and settles in the IMP, he learned to speak, read, and write (perhaps even to type), and so the technology of writing had left its indelible mark on his cortex. But without hand to write (much less type) or mouth to speak, language can no longer participate in any of the transductive processes that generate and sustain it. The brain now has a new body, new sensory organs, and an entirely new world to explore, so how will these new transductive regimes change it and the language (written and spoken) on which it had previously relied to organize its world? Or, we could turn the question around and ask how does language's exteriorization into the digital

computer and its liberation from the human body change it? What new world does it connect to? *Plus* delves more into the former (a brain needing a new language) than the latter (language or cognition needing a new body), but both are still present.

In either case, the signal we call language comes unmoored from the various media that channel and shape it. That signal seems less and less to convey information for humans and becomes more and more the matter and medium on which the growing nonhuman cognition Imp Plus works. The very first sentence already plants the simple pronoun "He" as the germ from which the new cognition will grow: "He found it all around. It opened and was close. He felt it was himself, but felt it was more."[31] The pronoun without person or substance (nouns, after all, are names and substantives) sits on the verge of growth, of "more"-ness.[32] He refers to nothing, it has no meaning as we understand it, it participates in no transductive circuit of human bodies and technologies. From Imp Plus's prospective, it is a material—which, like all materials, has a structure—waiting to inform and be informed by the processes at work in the satellite. Rather than ciphers that code syntactically aligned phrases and sentences, the words here accumulate like atoms combining into molecules (e.g., salts into crystals) until they form new patterns that define Imp Plus.[33] "He" eventually collides with "ɪᴍᴘ" and "Plus"

[31]McElroy, *Plus*, 3.

[32]Noun derives from the Latin *nōmen,* a name or proper name. Nouns, however, are also called substantives after Latin-based grammar, which, of course, comes from substance, meaning to stand under or support.

[33]Brooke-Rose, *A Rhetoric of the Unreal*, 268–88.

to form the designation I've been using so far: "*Imp* was a word. So was *Plus*. On the Concentration Loop Imp Plus had answered messages from Earth that used the words *Imp Plus*. [...] IMP was Interplanetary Monitoring Platform. The answer came from inside. From Imp Plus. Not from Earth."[34] In naming itself, Imp Plus re-encodes the words so that they signify one thing to the scientists on ground and another to technical and interior milieux forming in the satellite.

We see this remodeling through accumulation most clearly, as it were, with color terms. Just as writing and print depict visual scenes not with actual colors but with carefully encoded splashes of black ink, the brain in the IMP now only has color terms or concepts (i.e., words) but eyes to register the light that will eventually transduce itself into the word *green*.[35]

> Imp Plus inclined to think the green thing ate light. Imp Plus had pre-
> pared to remember that eyes developed from a need for nourishment.
> That was the way, but the word for it did not come."[36]
>
> Imp Plus saw that as with the eyes of the green thing before him so
> with the frequency propagating waves, Imp Plus made acts of obser-

[34]McElroy, *Plus*, 10–11.

[35]To what degree color words correspond with spectral colors depends on the number of color words already in the language. Terms for dark/cool and light/warm colors appear first, followed by red, green or yellow, blue, and brown. Only then do pink, purple, orange, grey, and other complex color terms (e.g. aquamarine) appear. See Berlin and Kay, *Basic Color Terms*. For updates to their work, see Kay and Maffi, "Color Appearance and the Emergence and Evolution of Basic Color Lexicons."

[36]Ibid., 4.

vation.[37]

We embodied readers may infer that the "green thing" is a chloroplast (or chloroplast-containing algae), but that formulation only makes sense thanks to the eye, its extension to the cellular scale through the microscope, and the words that encode the colors and shapes the eyes perceive. For Imp Plus, the brain without a body but still with concepts—the remnants of language—"green" is a not a trait, not even a word but the active material that eats light. The green things act on the waves of matter and energy flowing through them. They transduce energy from one medium to another. Hence, Imp Plus's "acts of observation" are further transductions of those energy flows that feed the pattern into itself until it produces a code, i.e., words, that can order it. "Green" and other color terms are just as much things as the chloroplast or light, and given the very different sensory apparatus available to this brain, these codes organize and structure a new world.

Plus may indeed de-automatize English, but it does so as it makes the language suitable to the slowly coalescing Imp Plus. The novel appears to distort print language as human cognition uses it, because it is recursively working on those linguistic ciphers to help generate new interior, technical, and exterior milieux. What is pattern for us is very noisy for Imp Plus, and so what appears as noise, or nonsense, to us is indeed quite meaningful (or potentially so) for our emerging protagonist. The novel therefore *enacts* some process rather than *represents* it, precisely because of the way it highlights the transductive rather than representational processes at work. We cannot then take for granted what will

[37] McElroy, *Plus*, 7.

count as an object or medium in *Plus,* because the relations of interior to exterior milieu that makes such a distinction meaningful to a human—such as seeing air as a transparent medium rather than as a churning sea of diatomic gases (N_2, O_2) and water vapor—do not necessarily apply to the nonhuman cognition in *Plus.* Hence, the novel's critics speak of it as narrating "what being posthuman might be like."[38] Porush and Tabbi make similar claims in their earlier pieces: "[As] readers we become part of a servo-mechanical loop, part of the machinery itself, and therefore, we imitate Imp Plus's fate: we become part cybernaut";[39] "Growth in *Plus* is more than a metaphor, and technology is more than what the book is 'about': both material processes, the technological and the linguistic, are congruent with what McElroy calls 'the building or rebuilding of the language capability of this being.' [...] As a compositional act *Plus* actually participates in a technological process."[40]

Plus does not assume that anything we take to be a medium would also be one for Imp Plus—for example, Imp Plus's "memories" from its days of human embodiment. The human reader recognizes these moments as a scientist at a beach with a woman and children prior to the surgery, a conversation with a street vendor, and briefings with the IMP project scientists (the Good and Acrid Voices), but Imp Plus no longer relates to them as representations of his time on Earth.

But they weren't shadows, these birds. And not birds either, though

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[38] Proietti, "Joseph McElroy's Cyborg Plus."

[39] Porush, *The Soft Machine*, 181.

[40] Tabbi, *Postmodern Sublime*, 130–31.

apogee and perigee from Ground and in the head were near a bird's
two ratios, wingspread to body, body to wings. Until the wings near
three times the body became again shearwater; and a new transmis-
sion said, CAP COM TO IMP PLUS SAY AGAIN IMP PLUS WATER WHAT
WATER?[41]

Shadows, birds, water, wingspread present themselves, to the reader, as clear
references to the scientist's sun-soaked day at the beach. For Imp Plus, the memo-
ries are not ghostly after-images of something real but quite real (*res*) themselves.
They are things that have no necessary connection to the winged creatures that fly
through the sky and dip into the waves, but instead act on Imp Plus as, for exam-
ple, the changing ratio of his orbit's apogee to perigee; or as a growing awareness
of the water in which the brain floats. Only later can we guess that the shadows
are in fact cast by the limbs (or tendrils) that the brain has grown. The scientists
at Cap Com cannot easily interpret what actions "bird" and "water" perform for
Imp Plus as *shearwater,* because they continue to interpret them as English words,
as still belonging to the human interior and technical milieux. Language in *Plus*
is torn between the interior and exterior milieux of the human world and of Imp
Plus's new environment.

Language seems so familiar since our parents and then teachers drill it (in its
various mediated instantiations) into us from birth, but *Plus* reminds us that lan-
guage, especially of the written or printed variety, belongs to larger systems capa-
ble of encoding, re-encoding, and working on other media. Imagine the first time

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[41]McElroy, *Plus,* 14.

you reached for something at the bottom of a shallow pool—unless you understood the physics of refraction, you might wonder why an object that appears to be at one position is actually in another. Until that moment you might have treated light as an invisible medium, or as what Latour calls an *intermediator,* that "transports meaning or force without transformation: defining its inputs is enough to define its outputs."[42] Language, like all media technologies with which we grow familiar over time, seems to be an intermediator. The moment the system breaks down, the moment, for example, light passes from one liquid (air) to another (water) and appears to break your arm, or the moment surgeons take a brain out its body and put it in a satellite, then the nearly invisible, always reliable intermediator fractures into a series of *mediators,* which "transform, translate, distort, and modify the meaning or the elements they are supposed to carry."[43]

The moment language enters the automated technical apparatus and breaks is the moment it becomes capable of being built into a different structure. Marshall McLuhan noticed this possibility: "Everybody notices how coal and steel and cars affect the arrangements of daily existence. In our time, study has finally turned to the medium of language itself as shaping the arrangements of daily life, so that society begins to look like a linguistic echo."[44] This call does not presage the social construction theories of 1970s social science so much as the recursion of the technical milieu into itself that would produce a society of nonhumans. Language, like steel and coal, once transduced through those nonhuman techni-

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[42] Latour, *Reassembling the Social*, 39.

[43] Ibid.

[44] McLuhan, *Understanding Media*, 59.

cal apparatuses informs and is informed by the nonhuman, as though it were any other material. Language's destiny is not abstract information as Claude Shannon's mathematical theory of information understands it, but something quite concrete for nonhumans. N. Katherine Hayles explores the human dimensions of this embodiment and our task is to look to the nonhuman.[45]

The longer the IMP (including the brain) remains in orbit, well beyond the world in which human bodies evolved to live, the more alien and incomprehensible it becomes to Ground. Imp Plus even begins to sense through a new organ—a membrane extruded from what used to be the visual cortex—but it does not recall willing such an organ into existence: "But rung or not, Imp Plus had had the feel of that shadow across his seeing before: and now knew he had already known that the membranes were what he saw with. Though not eyes."[46] Instead, it is as though these material transformations have functions and execute operations of which the growing nonhuman cognition Imp Plus is only vaguely aware.

3.3   REWIRING THE BRAIN

McElroy's encounter with the Apollo 17 spacecraft and the technical accuracy of his novels demonstrates he was more than familiar with the electrical and mechanical apparatuses whose interior he sought to probe with his prose. *Plus* therefore betrays an awkward reality—the printed words that attempt to convey to the embodied human reader the recursive nonhuman cognitive inside the technology

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[45]Hayles, *How We Became Posthuman*, 4–8.

[46]McElroy, *Plus*, 76.

(i.e., the IMP) rely on technical apparatuses that appear obsolete in comparison to Imp Plus. The novel constantly reminds us that various probes and sensors are monitoring the brain and transmitting that information back to the scientists at Cap Com. When Imp Plus responds in all uppercase letters, it is actually transmitting information in the same way the sensors are. It broadcasts radio waves, modulated pulses of electro-magnetic radiation that likely encode the data as a digital rather than analog stream. That wave is invisible to the humans at Cap Com until receiving antennae detect it and transduce it into an electrical current, which the computers at the facility will transduce further into codes (words and numbers) the human scientists can perceive and understand.

Imp Plus, however, no longer requires those human readable codes, because it is evolving a new encoding all its own. The order that the demands of the print novel and its narrative place on Imp Plus's story similarly begin to fade away, which is the primary reason *Plus* is so difficult to read. The narrative does not advance in a linear sequence, but gives way to gradual coalescences or repetitive cycles of phrases that evolve with the protagonist Imp Plus. Even narrative techniques (such as analepsis and prolepsis) that allow for the discourse to unfold nonlinearly do not adequately capture what is occurring in *Plus,* because the novel—we must use the term loosely—is rewriting the code that otherwise structures plots as a succession of events that influence one another or that are under the control of a guiding force, particularly the author. The cognitive agent that serves as a narrator does not learn its name until the narrative has started and, as we will see, is constantly revising that designation. What then controls the plot? What governs Imp Plus? No single thing does. Like the transductive processes de-

scribed in the first chapter (see 2.2, page 35), the patterns formed as one medium translates itself into another provide the ordering principle. *Plus* depicts a system (a plot) that informs itself.

These differential coding regimes (one for the human and one for Imp Plus) manifest themselves in the encryption that the satellite silently and invisibly performs on each of Imp Plus's transmissions. Afraid that some "alien monitor," as Imp Plus calls it, would commandeer the satellite, the scientists at Cap Com devised some camouflage (or cipher text) for the transmission circuits to use: "Someone was to be persuaded by the camouflage. [...] The someone could be an alien monitor. [...] The alien monitor would be outside."[47] We, the readers, are that alien monitor, and are meant to be persuaded by the English prose that *Plus* is still a novel (albeit an experimental one) under the control of an author and about a brain in a satellite. As we saw, however, those printed words are just another material that Imp Plus's growing cognition will transduce into ciphers that it can fill with new concepts and new codes. The printed words provide the illusion of control and understanding on our part while simultaneously reminding us that Imp Plus is busy at work modifying those concepts in ways quite alien to us and the narratives we usually construct.

The Nazi forces discovered during WWII that automated mechanisms, like the Enigma Machine, could re-encode printed letters into an incomprehensible cipher that no human with pencils and paper could decode. The Allies needed another machine, the aptly named Colossus, to filter the enemy machine's code

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[47]McElroy, *Plus*, 24.

through its circuits. That first electronic, digital computer operated not by try-
ing to understand the encrypted language, or to match it with German and En-
glish, but only by using a CPU to sort digitally encoded bits around its memory
circuits.[48] If it is indeed some virtue inside the machine that McElroy wants to
explore by implanting the brain in the machine, he must accept the fact that the
machine, especially the digital computer, works by encoding codes, by treating
what we consider meaningful articulations as material to be turned upon itself
and squeezed through circuits. Human language and desires do not control the
machine—only probably configured codes do. Hence the confusion of agency as
Imp Plus ponders just what the alien monitor could be.

> But Imp Plus was the IMP PLUS of the transmissions, and dim echo
> inside his head had said the letters TL which Imp Plus knew stood for
> *Travel Light;* and since he had no head, the dim echo with these extra
> words that had made Ground say O.K. could be the alien monitor,
> except the dim echo had felt familiar, and if it was not inside Imp Plus's
> head because Imp Plus himself was not inside his head because he
> did not have a head, the echoing voice was still inside; and was it then
> more familiar to Ground than Imp Plus was?[49]

The possibility that Imp Plus, the signals it transmits to Ground, or its tra-
jectory might be manipulated by an alien would make for an interesting plot, a
difficulty to drive narrative progression, but there is not even an identifiable sub-

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[48] Copeland, "Colossus: Its Origins and Orginators."

[49] McElroy, *Plus*, 25, original emphasis.

ject and object called Imp Plus capable of following such a trajectory. Imp Plus is
constantly changing as it moves and acts in its new world, or rather organizes the
environment into interior, technical, and exterior milieux. The dim echo is just
that, an echo of distant Earth, of the words, ideas, and sensations that connected
the brain with its old milieux. It is the ghost of the embodied consciousness of
the scientist whose brain now floats in the IMP. We cannot explain Imp Plus as
the remnants of a human consciousness fighting for survival in orbit, away from
its body, and subject to interference by secret enemy agents. That consciousness
(that vestige of the old interior milieu), as Imp Plus astutely guesses, is more
familiar to those on Ground than to whatever Imp Plus has become.

The need to liberate itself from outside forces is therefore irrelevant. To think
so would assume the existence of Imp Plus as distinct from some other entities
that think and decide and force their will on it. As we saw in the above quotation, it
barely understands itself as a single entity much less Ground as human scientists
clustered around screens monitoring the IMP's telemetry. Imp Plus must find a
way to recursively encode itself, that is, to devise a code that can organize Imp Plus
as Imp Plus, rather than as a talking brain in a satellite, or as an alien monitor's
puppet. This pattern does not crystalize until much later in the novel, when Imp
Plus encodes and is therefore able to knowingly manipulate its velocity: "But then
Ground asked how had Imp Plus stabilized IMP's attitude. [/] Imp Plus found the
firmness to think as he would."[50] To create that encoding system, it has simply
reprocessed concepts, sensations, and experiences it had as an embodied human.

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[50] McElroy, *Plus*, 174–75.

The Good and Acrid Voices, for example, are as constant a set of companions as the liquid chloroplast bath.

> Yet try as he would, he no more lost Ground than he could unbind the calcium and phosphate salts from the protein fibers they made bone, [...] He had to begin in his own way but knew what would be, and partly because the beginning was not now but long before.[51]

Just as calcium bound with phosphates is by definition bone, so Ground's constant interjections are by definition part of Imp Plus.[52] There is no possibility of escape, because all these myriad components are part of the complex system of transductions that constitute Imp Plus. At this early stage, before it even has an interior milieu, to try to free itself from Ground would be tantamount to bone trying to free itself from the tyranny of calcium apatite. Only once it has coherent interior and exterior milieux can Imp Plus reflect upon itself as a unified entity with a past and a future. At that point it can articulate a narrative of its having evolved from a fusion of the IMP and its human past. Only then can Imp Plus experience a moment of "liberation" that it has been working toward.

Imp Plus is establishing a teleology—all its starts, impulses, and thoughts have been leading to this point. The noisy excess that recursive transductions

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[51]McElroy, *Plus*, 176.

[52]The term "phosphate salt" is somewhat redundant given that phosphate (PO_4) is the salt form of phosphoric acid (H_3PO_4), but McElroy's description of bone is correct. The bone organ comprises marrow, nerves, blood vessels, and osseous tissue among others, but it is to the last that McElroy refers. It is composed of mostly bone mineral, or hydroxylapatite ($Ca_5(PO_4)_3(OH)$), which is another name for calcium apatite.

create is essential to this process, because the excess helps drive a feedback loop between Imp Plus and its thoughts about itself: as Imp Plus gains a more concrete idea of how it thinks and develops, it uses that "output" to explain its past and itself (its "input"). With this new code, Imp Plus can retrospectively explain itself to itself. Tabbi finds the same backward causation (or teleological thinking) at work in the final moments of the novel: "The IMP had burned up in the first friction of the atmosphere: thought wondering what chances [...] the glint of its arrival *must have been* brief for any who saw it [...]: thought wondering, too, if at last the great lattice *had let* this happen or *had been* surprised."[53] The italicized verb tenses confuse cause and effect because the narrative around this descent into the atmosphere is in the present tense—the IMP is supposed to be searing its hull in the mesosphere as we read. But the past tense suggests the IMP has already burned up, which would therefore make Imp Plus (or the great lattice) incapable of imagining (never mind narrating) Cap Com's response to the capsule's disintegration.

This reverse teleology shows that even the print narrative we read is not immune or excluded from the transductive loop Imp Plus is using to generate its new codes. Print narrative is simply one more set of codes to add to the constant looping of Imp Plus's growing consciousness, the impulses it receives from Ground, and from the IMP's components. The narrative process will never be complete, because we human readers lack the context, the system of codes, that Imp Plus is articulating to structure its new world. When we read a character's

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[53]Tabbi, *Postmodern Sublime*, 215.

name in a novel, we can easily imagine it refers to a specific, fictional person with a face, hands, arms, etc. but that is not the case for Imp Plus. True to the word *plus,* Imp Plus is not complete. From as early as page 13, another word has been gradually absorbing the excess that has been accumulating around what we and it provisionally called Imp Plus—the lattice: "Hard, so hard. For what was that old name *Imp Plus* now in the face of the lattice layers?"[54] Lattice is a particularly apt word as it refers to a complex of planks (laths) fastened together, usually with empty spaces between them.

The lattice is not so much the final assemblage of planks as much as their form or arrangement—like the lattice of sodium and chlorine that constitutes salt. This point crucially differentiates the lattice from an essence or substance, because unlike the latter, it constantly changes temporally as well as spatially.

> The lattice was a field of times. He was as much the motion as its place.
>
> For here in this lattice whose three-dimensional field was exactly as regular as Imp Plus now saw [...] that it also lacked boundary—here in this lattice that seemed impure only in the motion visited upon it—the motion was no longer the life of animal or vegetative or some wendo-zoan grip moving: but was instead the lights whose pieces were broken conversely back into streams of flow and bent and conducted into spirals of spirals by this lattice of himself.

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[54]McElroy, *Plus,* 199, original emphasis.

He was now his thought.[55]

The lattice seems to self-generate despite being apparently made of exogenous components (e.g. the lights) that flow into it. Every point seems connected to another, such that Imp Plus/the Lattice cannot see its own edge—like an ant walking on the surface of a sphere. The subject, verb, and objects of the second quotation likewise bleed into one another. Does the Lattice "now see that it also lacked boundary" or does Imp Plus? Perhaps both? The subject of the sentence matters less than the act of perceiving a lack of boundary, because Imp Plus/the Lattice is as much motion as place. The subsequent em-dashes emphasize this dynamism by piling object upon object and act upon act until finally circling (or spiraling) back to Imp Plus/the Lattice itself.

The clearer the new code becomes that Imp Plus/the Lattice uses to understand itself, the less Ground and reader understand what is transpiring in orbit. The new code implies a new transductive circuit in which humans play no part and which is rewiring the erstwhile human brain transplanted into the satellite. The data the satellite transmits and the phrases Imp Plus/the Lattice strings together for its communications with Ground become so opaque that they may as well be the encrypted data we use for secure digital communication.

Ground did not answer his data. Ground must think what it would. About how he lived here, what he did for water and food. Ground could be now as silent as the dissolving dark had been. Ground must think

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[55]McElroy, *Plus*, 181–82.

> what it could about what Sun did to water and to brains. [...] cap com
>
> to imp plus, what is licking? [...] we do not read.
>
> He had told Ground (how long ago) that the flaming gland had dis-
> persed, been licked up and absorbed, and that so had the hypothala-
> mus—what he thought to be that—with its many controls—or were
> they forces—of pain and pleasure.[56]

Imp Plus/the Lattice constantly revises the terms it uses to articulate itself, most notably its very name, so it cannot be relied upon as an authority in any sense. As we see in the above, Ground too is left in confusion when Imp Plus/the Lattice tries to communicate with it. Neither can understand what the other is saying.

No single authority controls the flow of the narrative—not Imp Plus/the Lattice, not Capsule Command, and not even the syntactical and grammatical requirements of English prose. Instead, a decentralized, self-organizing transductive process drives the generation of new patterns, new codes that in turn structure the nascent nonhuman cognition called Imp Plus/the Lattice. Absent a brain, body, and other technologies that constitute human cognition, *Plus* begins to abandon narrative logic in favor of a new, non-narrative mode unique to its nonhuman cognition. The inspiration for the non-narrative dimension of the novel comes not necessarily from other postmodern fiction, but from McElroy's encounter with post-World War II technologies. During his observation of the Apollo 17 launch, the proceedings come to an unforeseen but temporary halt that with-

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[56] McElroy, *Plus*, 180.

holds the pleasure of the concluding blastoff—the end of the narrative—for reasons unknown to him and the other spectators. The delay in the launch obliterates the narrative quality and drama of the event to reveal something else:

> Out there 3½ miles was the rocket—phallus or gowned bride or Saturn launch vehicle. When the curtain didn't go up, the attenuation and burden of waiting brought into view not some dramatic necessity according to whose time-line one might have counted on being overwhelmed at 9:53 pm, but rather a non-narrative field of collaborative functions much closer to what was really happening.[57]

The "non-narrative field of collaborative functions" is the new transductive encoding and re-encoding described above. What has frustrated the humans' expectation that the rocket would punch through the atmosphere into space? Malfunctioning electronics in the shuttle? A missing washer? A fuel leak? Or some failure of communication between the astronauts and mission control, the astronauts and the shuttle's sensors, or the sensors and the control room? It's impossible for McElroy to know at that moment. There are too many objects mediating between him and the shuttle, the shuttle and the astronauts, and the shuttle and itself to pinpoint a clear chain of cause and effect.

His use of the phrase "non-narrative collaborative functions" signals just how removed the technology on the tarmac feels from the "Self at the core of our Western tradition."[58] The events before him are so inscrutable because they are occur-

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[57]McElroy, "Holding with Apollo 17," 2.

[58]Ibid.

ring simultaneously and because the "virtue" of technology has liberated itself, so to speak, from the interior milieu. While Leroi-Gourhan classified the technical milieu as a subset of the interior one, which mediated between it and the exterior world, McElroy instead sees how the technical milieu can be less a medium than the bleeding of the interior milieu into the exterior and vice versa. What was once matter (or Nature) outside of humanity's collective culture and memory (i.e. symbols) and only accessible through techniques now has a motive and teleology unique to it. It is no longer inert matter waiting for a god or a printing press to breathe life into or inform it.

Because Imp Plus/the Lattice cannot craft a coherent narrative, it cannot treat words as encodings of human reality or concepts. Instead, they are in flux as Imp Plus/the Lattice works on them and they on it in the construction of a new mode of cognition. Indeed, the words themselves are at times treated like the raw material with which Imp Plus/the Lattice builds its sense organs.

> *And light!*—the words met: the two words, but more two pairs—two
>
> lattice shapes layered over the other [...]
>
> —the words layered their light through what he thought.[59]

"And light" may as well be *"et facta est lux"* for the resonance is the same—the words here operate not like human artifacts that represent something else but as agents themselves. The opening "And" emphasizes the process of conjunction and accumulation that has been occurring throughout Plus from the first word "He" to "Interplanetary Monitoring Platform" to "Imp Plus" to "the Lattice" and

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[59] McElroy, *Plus*, 190, original emphasis.

onward. Even the verbs evoke joining or putting together (e.g. "met" and "layered") more than making (as my Biblical allusion suggested). The novel is less mimetic fiction than construction project.

What is it constructing? A new set of constraints and distinctions in which Imp Plus/the Lattice can operate, even if that means the desires, decisions, and thoughts pulsing through the IMP do not correspond with those of the "great single and possible Self." They are not something that can be directly communicated to Ground: "And with such torque in mind, Imp Plus tried to tell the Acrid Voice of the breathing between the helical crimson strands and Sunbraids."[60] The term "Sunbraids" is another of Imp Plus/the Lattice's neologisms—an attempt to fashion with English words a new fact of its being a brain-in-a-satellite, and while the term is at best metaphorical to us, Imp Plus/the Lattice treats it quite literally, as referring to some object.

We need the few and fleeting similarities that remain apprehensible in the work's modified English in order to see the final paragraphs of the novel as Imp Plus/the Lattice's first decision: "The lattice dipped pale and still and contained what it yet might not wholly have: an idea of itself: itself not wholly self-possessed [...]. [...] *No desire to carom into space, no desire for re-entry.*"[61] This moment of self-comprehension remains incomplete, because it gives birth to a desire that does not fit any of the possible scenarios one might imagine for the IMP—shoot off into space, continue orbiting, or re-enter the atmosphere. It heads in a direction that we cannot easily follow, a direction in which cause and effect do not work as

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[60] McElroy, *Plus*, 212.

[61] Ibid., 215, original emphasis.

we expect them to. The confusion of verb tenses in this quotation and the one cited earlier testify to this point. Is it contemplating suicide? An act of liberation? Those possibilities only exist for embodied humans and narrative written in their conceptual languages. Imp Plus/the Lattice has shown itself to not require those narratives or language as they are, but only as the fuel for a new transductive process.

Rather than dwell on the fate of Imp Plus/the Lattice, which we would understand as suicide, we should instead appreciate the novel's other lesson: the co-evolution of humans, language, and techniques must now include nonhuman cognitive systems. *Plus* subtly emphasizes this shift by literally removing the brain from the human body rather than extending it through various prostheses. By so doing, the idea that some things, such as language or perception, are "internal" to the human and only extended into the external world by techniques vanishes. Instead, we witness the possibility of an electro-mechanical device (the IMP) as a cognitive agent with an interior apart from human awareness of that interior. To put it another way, we do not know Imp Plus/the Lattice's fate at the end of *Plus,* because the media and other techniques at our disposal (such as print narrative) do not entirely align with those of Imp Plus/the Lattice.

Chapter 4

Narrative, Technical Apparatuses, and Pynchon's Gravity's Rainbow

> "Do you find it a little schizoid," aloud now to all the Achtfaden fronts
> and backs, "breaking a flight profile up into segments of responsibil-
> ity? It was half bullet, half arrow. It demanded this, we didn't. So. Per-
> haps you used a rifle, a radio, a typewriter. Some typewriters in White-
> hall, in the Pentagon, killed more civilians than our little A4 could have
> ever hoped to.
>
> Pynchon, *Gravity's Rainbow*, 453–54

Experiencing delusions thanks to Herero (calling themselves *Schwarzkom-mando*) administered drugs, Horst Achtfaben, an aerodynamics engineer at the secret Nazi wartime V–2 (A4) research facility Peenemünde,[1] glimpses the frag-

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[1] The V–2 (*Vergeltungswaffe* 2, or Vengeance Weapon 2) succeeded the V–1, or buzz bomb, which

mentation, the schizoid-ness, of his world. His hallucinations analogize the recursive divisions of the V–2 rocket's flight path with the compartmentalization of the German military. The Toilet Ship *Rücksichtslos* (or Reckless) is a division of the *Kriegsmarine* (or navy), which is itself a division of the *Wehrmacht* (the others being the *Heer,* army, and *Luftwaffe,* air force). The narrator will try to explain this mania for compartmentalization with the "strange connection between the German mind and the rapid flashing of successive stills to counterfeit movement"[2] The novel traces this mania as far back as Gottfried von Leibniz's breaking apart of functions into infinitesimally smaller pieces to calculate rates of changes (derivatives) and areas (integrals)—we call this new mathematics calculus.[3]

made a sputtering noise before diving silently to impact. Unlike it's predecessor, the V–2 was the fourth generation in the *Aggregat* rocket project, and hence its other name—the *Aggregat* 4 or A4. It was the first long-range ballistic missile weapon, and the first human artifact to break the sound barrier, during its first successful launch on October 3, 1942 at Peenemünde. By the end of the war, V–2 rockets usually achieved speeds near Mach 4 during descent. See Neufeld, *The Rocket and the Reich*.

[2] Pynchon, *Gravity's Rainbow*, 407. For brevity, I will abbreviate *Gravity's Rainbow* as GR in running text and notes.

[3] These definitions of derivatives and integrals are somewhat loose. A derivative describes the rate at which one quantity changes with respect to another. The most relevant example for us would the rate at which distance (s) changes over time (t). The first derivative of distance as a function of time, or s'(t), would be velocity (v). Since distance is continuously and smoothly changing over time, the derivative can only return a linear approximation of s(t). For real-valued functions of one dependent variable, like s(t), the derivative at a point equals the slope of the tangent line to the graph of the function at that point. For functions of multiple dependent variables (i.e., higher dimensional ones), we must instead think of the derivative as a linear map that connects two vector spaces (i.e., the functions) and that maintains vector addition and scalar multiplication.

This continual process of breaking apart and reintegration suffuses *GR*'s plot—it continually shifts agency between humans and various nonhuman things, such as typewriters and crude oil. We see this dynamic at work in Achtfaben's hallucinations thanks to the ambiguity of the "it." What "it" breaks the rocket's flight into infinitesimal fragments, and ultimately breaks agency into innumerable little pieces, such as the humbly dreadful typewriter that redirects supplies, troops, and forces with the clang of its keys? Is it the V–2? The engineers designing the rocket? The Nazi party leaders? The multinational corporations extracting oil and using it to synthesize plastics and other materials for the war? Or maybe it is the physics of the rocket's flight, such as air resistance or the tensile, compressive, or shear forces exerted on the rocket's materials. All these possibilities would integrate the rocket back into a coherent cause-and-effect narrative.

The constant fragmentation of the novel, however, suggests we need to focus instead on the process of integration and differentiation itself, rather than hunt for ways to fuse the fragments into narratives, even ones as subtle and absurd as killer typewriters. This shift is especially justified given how poorly narrative integration works in Pynchon's novel compared to the differential equations the V–2 rocket integrates to approximate and guide its course from launch in the Netherlands to landfall in London. Achtfaben gestures in this direction when he talks about that trick of calculus that breaks the flight into segments that are "half bullet, half arrow." It is a trick the print narrative never quite manages to achieve. It is

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Integration inverts differentiation, and for a real-valued function of one dependent variable, it can be thought of as the area between the function's graph and the x-axis. Lebesgue integration extends this concept beyond the real line to higher dimensions and complex-valued functions.

a trick that points to a non-narrative cognitive mode that nevertheless uses the elements of narrative (e.g. the digital alphabet printed in a book) as raw material in the construction of a world quite alien to the human reader and those characters we identify as fellow humans. We did not fully explore this possibility in the last chapter, which traced the integration and self-organization of many pieces into a whole and imagined how language would change with the shift from human to nonhuman embodiment, given that language, bodies, and media technologies co-evolved. Of course, *Plus* kept the human brain, so we saw the transition from a somewhat human, as it were, perspective. With that human perspective came the striving for a coherent narrative, one that would allow us to predict Imp Plus/the Lattice's actions, or at least form a consistent, logical—albeit fictional—world.

Rather than vanquishing narrative, however, the tension between narrative and non-narrative cognitive modes allows us to filter narrative through a non-human perspective. Narrative ceases to be a unified thing and becomes instead a transductive loop connecting human bodies and media techniques and technologies.[4] Narrative, from this angle, resembles the signals pulsing through cybernetic automata's transductive loops (See 2.1, page 25). Recall that the signals flowing through cybernetic automata only appeared as such because an observer—whether a human examining the machine's output, another machine receiving the signal as input, or the machine in a recursive loop with itself—interpreted them as such. Narrative is similarly the observation (by self or other) of the transductions be-

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[4]With *techniques* and *technologies,* I am just highlighting the continuum between techniques like spoken language, techniques/technologies like handwriting, and media technologies like printing presses, photographs, and digital computers.

tween bodies and their technical milieu. Because nonhuman cognitive systems lack a human body but share its technical milieu, they would not produce narratives but would rework the raw materials, as it were, of narrative. We see this reworking in Tyrone Slothrop's final conversion into a wave or modulated signal, as nonhuman cognitions infiltrate this narrative transductive loop and thereby disrupt *GR*'s narrative integrity. Since narrative transductions cannot make sense of the nonlinear, nonspatial, statistical or fractal logic of the nonhumans (like the V–2) in the plot, the novel turns to film as an alternative media technology for that loop.

4.1   Narrative as a Transductive Process

Narrative is the pattern that emerges from the energy or information transduction among these different systems and that constitutes what I call cognition in the narrative mode. While human bodies provide most of the energy essential to performing these transductions (people must pick up and read books, for example), the narrative is not contained in any one body or technology, but forms dynamically as the two interact. Jerome Bruner, Katherine Hayles, and many others have written about narrative as a dynamic construction of bodies and various discourses.[5] They usually write in terms of self-organization and emergence, but adding transduction allows us to see how nonhumans access and alter this narrative mode without human intervention or awareness. These alterations will become particularly clear as we see how the growing presence of nonhuman cog-

[5]See Bruner, *Acts of Meaning*; Hayles, *My Mother Was a Computer*; and Hayles, *Writing Machines*.

nitions undermines the preference for cause-and-effect—or at least a framework that explains why one event in one space happens—that typifies most narratives.[6]

To better understand the role nonhuman cognitions will play, it would be beneficial to see how intimately tied narrative is to human bodies and their technological extensions. In exploring why people construct narratives about virtual creatures (i.e., artificial life), Hayles articulates the advantage narrative technologies confer on humans: "[Narrative] has an explanatory force that literally makes the world make sense. It is easy to see why the creation of narratives would confer evolutionary advantages on creatures who construct them. Without the presuppositions embedded in narratives, most of the accomplishments of *Homo sapiens* could not have happened."[7] Jerome Bruner persuasively argues that humans, starting from an early age, rely upon narrative to make sense of their world: "[There] is compelling evidence to indicate that narrative comprehension is among the earliest powers of mind to appear in the young child and among the most widely used forms of organizing human experience."[8]

Bruner draws on Katherine Nelson's studies of language acquisition and childhood development to support narrative's role as a world constructor.[9] She argues

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[6] Much narrative theory concerns itself with stories' causal structures, particularly how readers extract that structure from the narrative. See Edward Said, *Beginnings* (1975) and Frank Kermode, *The Sense of an Ending* (2000).

[7] Hayles, "Simulating Narratives: What Virtual Creatures Can Teach Us," 9.

[8] Bruner, "The Narrative Construction of Reality," 9.

[9] Bruner draws on her early, edited collection *Narratives from the Crib*—in which he published an essay, but I will mostly refer to the more recent Nelson, "Narrative and the Emergence of a Consciousness"; as well as Nelson, *Young Minds in Social Worlds*.

that once a child acquires the ability to narrate his or her experiences, he or she understands himself or herself in time (i.e., in relation to past, present, and future) and as a separate individual with distinct experiences. In Simondon's terms, the child individuates him- or herself through narrative, because the process of constructing stories feeds back into the child's growing conception of self. At the same time children are learning to speak and to narrate events, their bodies are growing and their brains are adapting to the various sensorimotor systems. Children must learn how to focus their eyes on objects while simultaneously learning how to distinguish objects; how to move their limbs; how to walk, how to grasp things with the hand; and the fine motor skills necessary to articulate language, whether as speech or writing. The skills that make up this complex of language learning, narrative, and motor control develop simultaneously, which enforces the conclusions in Hayles and Bruner that these complex of skills are mutually reenforcing.

We must complete the picture, however, by looking at how media technologies other than spoken language enter this model. We need only look, as Hayles and I have argued, to the complex temporalities that often structure and fragment experimental fiction, especially modernist and postmodernist works to see that Nelson's account needs this technological extension to be useful to literary critics.[10] Since she studies children of pre-school age or younger, Nelson emphasizes spoken language, and we might therefore assume that narrative, like spoken language, is an evolutionary adaption, an inherent part of the mind, or the land-

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[10] Hayles and Pulizzi, "Narrating Consciousness: Language, Media, and Embodiment," 140.

scape of consciousness.[11] Separating narrative from its inscriptional or encoding technologies would indeed be a futile task, since the two are so intimately bound together.

> As with all accounts of forms of representation of the world, I shall have a great difficulty in distinguishing what may be called the narrative mode of thought from the forms of narrative discourse. As with all prosthetic devices, each enables and gives form to the other, just as the structure of language and the structure of thought eventually become inextricable.[12]

Bruner is giving voice to the same process that Deacon sees at work in the co-evolution of brains and language technologies, and at the same time implicitly comparing narrative to other "prosthetic devices" through which humans apprehend (and construct) the world around them. This conclusion corresponds with the co-evolution of brains, language, and techniques that we traced in Chapter 2. The inextricability of narrative from its technologies of encoding and the brains that interpret it means that narrative like cognition is distributed. The model, simulation, or representation that one constructs of reality cannot, therefore, ever reside entirely inside the head, even if it is in a narrative mode. In being so distributed, however, narrative and cognition can only arise as the result of some transductive circuit among all these distributed nodes.[13]

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[11]That phrase is Jerome Bruner's. See *Acts of Meaning*, 91.

[12]Bruner, "The Narrative Construction of Reality," 5.

[13]Some theorists do assert this evolutionary theory of narrative in various forms. See Carroll, *Lit-*

If cognition and narrative are distributed between bodies and technologies, then we do not necessarily gain much by seeing them as entirely distinct things. Their conjunction instead means that narrative is a cognitive mode—a self-reflective mode in which humans can think about their cognitive processes and formulate theories about them, such as the concept of distributed cognition.[14] Cognition refers to a circuit that constantly converts or transduces matter into symbol and back, and narrative is one mode by which it does so. Narrative is not a thing one finds in a book, a film, or a graphic novel; it is not laid out linearly and awaiting a passive human brain to receive it piece by piece.[15] On the contrary, it is a dynamically created, emergent phenomenon. Bruner cannot meaningfully distinguish between narrative thinking and narrative discourse precisely because narrative comprehension simultaneously informs and is defined by the way humans in-

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erary Darwinism; and Carroll, *Evolution and Literary Theory*. An animus against post-structuralist theories and perceived relativism motivate them, and so they primarily draw on works by psychologists and anthropologists. Quite tellingly, few natural scientists figure in their work. See Boyd, *On the Origin of Stories*; and Pinker, *The Stuff of Thought*.

[14]Bruner makes this case as well: "Originally introduced by Vygotsky and championed by his widening circle of admirers, the new position is that cultural products, like language and other symbolic systems, mediate thought and place their stamp on our representations of reality. In its latest version, it takes the name, after John Seely Brown and Allan Collins, of 'distributed intelligence.' An individual's working intelligence is never 'solo.' It cannot be understood without taking into account his or her reference books, notes, computer programs and data bases, or most important of all, the network of friends, colleagues, or mentors on whom one leans for help and advice" (Bruner, "The Narrative Construction of Reality," 3).

[15]See as well Ryan, *Narrative Across Media* in which she defines narrative as a cognitive construct that the reader or viewer constructs from cues in the story's medium.

terpret their sensorimotor perceptions and experiences.

The transductions between narrative discourse and these embodied experiences produce what narratologists Catherine Emmott and David Herman call contextual frames and story worlds. Emmott underscores that readers do not sequentially string sentences or other atomistic units together when reading and interpreting a story.[16] Indeed, readers often do not strongly distinguish between what is present in the discourse, and what they have inferred from reflecting on the story.[17] The same inferential or filling in process compromises the validity of eye-witness testimony, much to the consternation of judges and lawyers.[18] This blurring occurs because the reader constructs and navigates a fictional world through various feedback loops between the his or her sensorimotor experience, memory, and mental model of the fictional world.[19] Emmott insists that the interpretation of events in this fictional world (the one the narrative conveys) unfolds using the same contextual frames on which participants in a conversation rely: "Just as speech involves relating utterances to a real-world context, so narrative sentences need to be viewed in relation to mentally represented contexts created from the texts themselves."[20]

Herman extends Emmott's contextual frames into story worlds that hold all the background contexts necessary for the events depicted in the story to tran-

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[16] Emmott, *Narrative Comprehension*, 18.

[17] Beaugrande, *Text, Discourse, and Process*, 168.

[18] See Loftus, "Leading Questions and Eye-Witness Report," and Loftus, *Eyewitness Testimony* for updates to her earlier research.

[19] Hayles and Pulizzi, "Narrating Consciousness: Language, Media, and Embodiment," 140.

[20] Emmott, *Narrative Comprehension*, 58.

spire. This coherent world and its conventions are essential if the story's interpreter is to understand what happened in the past (of the story world), what is happening in the present, and what may occur.[21] The story world emerges dynamically as a feedback loop between interpretative frames and discourse elements: "Discourse models can be defined as emergent, dynamic interpretative frames that interlocutors collaboratively construct in order to make sense of an ongoing stretch of tale."[22] He proposes this model of narrative comprehension as an alternative to the conduit metaphor that imagines the text and other "semiotic formats" as channels that transmit ideas, images, and other concepts—perhaps the conduit metaphor's proponents are not familiar with media theory since at least Marshall McLuhan. Readers often find avant-garde, experimental, or postmodern fiction challenging, because they must extract from the discourse a coherent, causally ordered story.

We could understand (that is, providing a narrative explanation) this predilection for difficult narratives (print and film) in the later twentieth century as a growing skepticism about the techniques humans use to construct and understand their world, which goes a bit beyond a T.S. Eliot-like angst about the relevance of tradition after World War I. The problem is rather epistemological and goes back at least to Kant's separation of human consciousness from things-in-themselves, and Nietzsche's genealogical understanding of truth. Now the doubt spreads to the distinction between textual representations and the contexts that enable us to interpret them.

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[21] Herman, *Story Logic*, 14.

[22] Ibid., 19.

In the second half of our century, as the apparatus of skepticism comes to be applied not only to doubting the legitimacy of received social realities but also to questioning the very ways in which we come to know or construct reality, the normative program of narrative (both literary and popular) changes with it. "Trouble" becomes epistemic: Julian Barnes writes a stunning narrative on the *episteme* of Flaubert's perspectivalism, *Flaubert's Parrot;* or Italo Calvino produces a novel, *If on a Winter's Night a Traveller,* in which the issue is what is text and what context [...]. It is not simply that "text" becomes dominant but that the world to which it putatively refers is, as it were, the creature of the text.[23]

The problem here is not the same as the classical, Platonic or Cartesian skepticism, which questions whether our knowledge of reality and reality itself coincide. Rather, this skepticism is not about our knowledge of reality, but our knowledge of our knowledge; it is a recursive skepticism that suspects narratives (among other ways of knowing) are not reducible to the way our bodies or technologies know or perceive, so to speak, reality. The skepticism that Bruner sees in narrative is none other than the growing awareness of narrative as a transductive loop that is not reducible to any of the systems it comprises. The bodies, techniques, and technologies that make narrative possible are not like narrative, which is to say, they are multicursal and multi-causal.[24]

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[23]Bruner, "The Narrative Construction of Reality," 16, original emphasis.

[24]The term "multicursal" comes from topology and graph theory in which it refers to a graph (or

Recent studies of the differences between human experiences of visual perception and the functions of the visual system give us a model for how the narrative transductive loop works to integrate many systems into a unified, holistic consciousness that is always in the process of becoming, of negotiating itself with the rest of the sensorimotor system and other media technologies. Philosopher Daniel Dennett and psychologist Marcel Kinsbourne indeed argue that narrative or syntactical concepts are not distinguishable from visual perceptions, and perhaps other sensory modes. The way ours brains and sensorimotor systems fill in perceptual gaps uses a mechanism similar to the one that fills in and combines the missing and disjointed pieces of discourse into a story, as Emmott and Herman noted above.

The orthodox view of visual perception, which is likely the one that causes the classical skeptic some anxiety, holds that our consciousness perceives the world by building a complete, mental model. In this view, we look not at the world but at a picture of it that our sensorimotor system and brain have painted. The classical skeptic doubts the model's accuracy. Dennett and Kinsbourne, however, doubt the very existence of such a finished model or Cartesian Theater where the body's various systems come together in a single, coherent narrative or representation. Dennett helpfully recasts the metaphor in filmic terms—consciousness is not

network) that permits one to traverse many different paths to go from node A to B. A unicursal network allows for only one such path to exist. Espen Aarseth uses these terms in *Cyberntext* to characterize ergodic, hypertext, and digital literature. Most print narratives are unicursal, so that even if complex temporalities structure the discourse, the story ultimately unfolds over one path from beginning to end.

the contemplation of one, long take, but the composition of many micro-takes that the brain is constantly splicing together and editing.[25] The model has both visual and syntactical dimensions as it is an image seen by the eyes, but it is also a sequence of images strung together by a trajectory or sense of movement—a grammar, of sorts, that determines how images fit together.

Their conclusion seems all the more plausible when one considers the physiological research they cite. Humans have poor parafoveal vision—the visual field is less sharp at the periphery than at the center—as the human eye has fewer photoreceptors (rod and cone cells) at the edge of the retina. Yet, we experience a uniformly sharp visual field. The optic disc—the point on the retina where ganglion cell axons exit the eye to form the optic nerve—is a blond spot because it has no photoreceptors, but only elaborate experiments can make us temporarily aware of that gap, or discontinuity, in the visual field.[26] Our perception is also attention-dependent, so that we must actively focus (to varying degrees) on a detail to notice it (especially to perceive if it changes).[27] Human perception is then

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[25]Dennett, "Vision and Mind."

[26]Scientists usually accomplish by asking the subject to stare at a screen that has a yellow (or other large colored dot) and a smaller one at some distance to the dot's right. If the subject closes one eye, focuses on the smaller dot and moves either closer or further from the screen, the larger dot will eventually disappear from his or her peripheral vision.

[27]The so-called invisible gorilla is the most famous example. When asked to pay attention to the ball in a video of people playing basketball, half the subjects missed a man masquerading in a gorilla suite across the background. See Simons and Chabris, "Gorillas in Our Midst." Simons revisited this research in 2010 to see if the subject's familiarity with the original video allowed them to see the gorilla this time. It did to an extent, but they still missed other, new, unexpected events. See Simons, "Monkeying Around with the Gorillas in Our Midst." Simons and Chabris

a complex folding together of sensory perceptions, conceptual knowledge, and conscious attention.

Their "Multiple Drafts" model explains how these micro-takes of reality self-organize into a total, conscious experience. Dennett lambasts the orthodox view for supposing the existence of a Cartesian theater where sensory data, memories, and other mental processes come together in a coherent drama that our consciousness observes. Absurdist theater might be closer to what Dennett and Kinsbourne believe occurs in the brain: "In the model that Kinsbourne and I recommend, the Multiple Drafts Model, this single unified taking is broken up in cerebral space and real time, we suggest that the judgmental tasks are fragmented into many distributed moments of micro-taking."[28] Because of the word draft's textual implication, Dennett replaces it with cut to suggest the brain is like a film editor—the draft metaphor casts the brain as the feverish writer and revisor of a narrative, while the cuts model evokes the splicing and reordering of various, discrete scenes or frames into a continuous, visual narrative.[29]

The Multiple Drafts or Cuts model parallels the contextual frames and story world that Emmott and Herman propose for narrative comprehension. In both cases fragments come together by filtering through and simultaneously defining a frame or world that arranges them into a useful whole. Consider the way Den-

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summarized and popularized their research on attention and perception in *The Invisible Gorilla*.

[28] Dennett, "Vision and Mind," 483.

[29] Dennett is aware that writing and film are metaphors to aid comprehension, but ones with the unfortunate side effect of making it seem that perceptions are disordered visual or raw sensation and that concepts are syntactical (either linguistic or sequences of images).

nett talks about micro-takings influencing one another: "The micro-takings have to interact. A micro-taking, as a sort of judgment or decision, can't just be inscribed in the brain in isolation; it has to have consequences—for guiding action and modulating further micro-judgments made 'in its light.'"[30] The same could be said for a narrative's events—the story must arrange events so that it appears that one influences the other, and therefore explains what came before and what will come after.

The perceptual experience generated by the brains Multiple Drafts or Cuts and the story that emerges from narrative discourse constantly adjust and adapt themselves thanks to their distribution throughout the sensorimotor system and the technologies (like the print book) that partially constitute them. The construction of perception requires the activity of the entire body from the sensory organs, the networks in the brain that receive impulses from those organs, to the memories or concepts that the brain holds of those experiences. Narrative is then the recursive transduction of media techniques and technologies—such as language, print books, and films—that occurs as the human sensorimotor and nervous system observe and convert elements of those media systems into a story world full of information, context, and ultimately meaning. By thinking of narrative as a transductive process, we can then appreciate how it at once seems to float above the systems that compose it and also be embedded in those systems. As we saw in the cybernetic automata of the first chapter, this transductive process necessarily sorts pattern from noise. Narrative is that pattern. We should then expect

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[30] Dennett, "Vision and Mind," 494.

that the nonhuman cognitions we have been exploring will necessarily transduce perceptions and concepts into different signals than those of human bodies.

4.2   The Grand Illusion

> Reading and paranoia coincide with each other.

> Kittler, "Reading Matters," 161.

The network of distributed systems that form narrative may be heavily under the sway of one hundred thousand or more years of human phylogenetic evolution, but nonhuman cognitions do not necessarily inherit that history. Indeed, the media technologies that humans transduce into coherent narratives, which unfold in spatially and temporally consistent possible worlds, can also produce quite different spaces and temporalities when different systems (and bodies) participate in the transductive loop. Not having the same sensorimotor system as a human body, nonhuman cognitive systems would not produce narratives, because the latter, by my definition, require a human body and its associated world. They do, however, utilize some of the same media technologies as the narrative and human transductive loop, so they can intrude upon and disrupt that loop. Hence, my preference for the term *fractal* in fractal realism—nonhuman cognitions fracture and remake the narrative cognitive mode and the realism (i.e., way of making sense of the world) that it supposes. *Gravity's Rainbow* is a site of fractal realism, of the collision of human and nonhuman cognitive and narrative modes.

Set in the years just before and after World War II's end, the novel situates itself in the political, economic, and technical maelstrom that encouraged the development and dissemination of cybernetic technologies. One of the novel's central concerns—as much as we can point to any center—is the emergence of the military-industrial complex and the petrochemical industry that fuels and, perhaps, drives it.[31] As much as Pynchon's novel is about anything, it explores the complicated networks of humans, corporations, and technologies that seem to have colluded in making the American Lieutenant Tyrone Slothrop respond sexually to the V–2 rocket. What mechanism connects the two is never clear, and indeed, the quest to unravel that mystery drives many of comic, absurd, and perverse sub-plots that pit the Elect against the Preterite, or the passed over dregs of society.[32]

Others have interpreted the proliferation of paranoid plots and Slothrop's final conversion into a wave as a sign that new media technologies are fragmenting reality as they expand archival space, or cultural memory.[33] Older media technologies must then attempt to translate or remediate this fragmentation in order to remain relevant. John Johnston proposes that the novel, in particular, must somehow incorporate these new archival media into literary narratives—a process he calls *mediality*. Pynchon's texts, especially *Vineland* for Johnston, exhibit and re-

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[31]The military-industrial-entertainment complex might be a more apt name given how important film and other technologies were to wartime research and development.

[32]Befitting a novel of its proportions, GR is the subject of a many literary critical and media theory articles. For criticism specifically on the grand arcs that run through the novel's plot see Hayles, *The Cosmic Web*, specifically pages 168–97; Tabbi, *Postmodern Sublime*, specifically pages 74–103.

[33]Johnston, "Reading Matters."

flect on this process. Whether the novels succeeds in performing this translation or how it might affect human cognition in the narrative mode are not questions that Johnston answers, because he is primarily concerned with how a discourse network (*Aufschreibesysteme*) modifies and utilizes existing media technologies. Joseph Tabbi partially takes up the consequences of mediality for narrative and human cognition in *Cognitive Fictions*. He argues that human minds recursively map themselves into distributed media networks, and that for the literary work to avoid obsolescence, it must enter a new self-reflective or recursive period in which it recognizes itself as a new model of the mind: "From its position to the side of the dominant media of our time, print narrative might then recognize itself, at the moment when it is forced to consider its technological obsolescence, as a figuration of mind within the new media ecology."[34]

For Tabbi, this trend in contemporary fiction signals a new realism that allows texts to admit their materialism and, ultimately, to put authors and readers into "contact with formal and procedural conditions that are always present, always constraining, supporting, tweaking, and unconsciously controlling the creative process."[35] Authors and readers meet as co-creators of the print work—presumably as writers and interpreters of the narrative. While Tabbi's thesis fits well with what I have argued thus far, it does not sufficiently distinguish nonhuman from human cognitive modes in its entanglement of authors and writers. The situation is more contentious than Tabbi's argument suggests. Cognition in the narrative mode has a complex dependence on human bodies and brains, and to this

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[34]Tabbi, *Cognitive Fictions*, xi.

[35]Ibid., 130.

mesh we must add cognition in the non-narrative mode, which flows as a signal through cybernetic automata. The novel's mediality or its "figuration of mind" as a distributed set of inscriptional procedures is one dimension of the conflicting recursions that human and nonhuman cognitions are performing.

This conflict certainly has implications for how we read, because it brings, as Kittler remarks, reading and paranoia closer together. One's impulse upon reading a discourse is to interpret it as part of some contextual frame or story world that causally orders and therefore explains all the events. Yet, the presence of nonhuman cognitive systems means that the contextual frame, or story world, is also inhabited and modified by a transductive loop that does not necessarily include the human. Events appear increasingly random, absurd, or even surreal, because no single story world seems able to circumscribe them. The more we attempt to draw a simple line connecting events, the more we find ourselves traveling through a labyrinth of possible interpretations and the worlds they entail. Are these paths connected? Is there a way out? A solution? Reading quickly becomes paranoia, or the idea that everything is connected, that some story—if we could only discover it—gives everything meaning. If the stories grow too large or too ridiculous, we could easily conclude that nothing is connected—the opposite of paranoia.[36] *GR*'s various plots attempt to congeal the seemingly disparate political, economic, and technological events into a story—one whose context extends infinitely until everything seems embroiled in a vast conspiracy overseen by a

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[36]This struggle between total connection and disconnection, between integration and disintegration has been remarked in most major criticism on *GR* since its publication. See, for example, Hite, *Ideas of Order in Pynchon*.

shadowy Elect, a nebulous "They." With every additional action and connection that Slothrop or the other characters make, the novel collapses under the weight of too many possible narratives, contextual frames, or story worlds.

The impulse to find that order is so strong and untenable that Enzian, the leader of the Herero who now call themselves the *Schwarzkommando,* will find meaningful patterns even in the noise wrought by the war's destruction. To him even the ruin of the Jamf Ölfabriken Werke AG reveals a design, the intention of some intelligent agent.

> This serpentine slag-heap he is just about to ride into now, this ex-refinery, Jamf Ölfabriken Werke AG, is *not a ruin at all. It is in perfect working order.* Only waiting for the right connections to be set up, to be switched on ... modified, precisely, *deliberately* by bombing that was never hostile, but part of a plan both sides—"*sides?*"—had always agreed on ... yes and now what if we—all right, say we *are* supposed to be the Kabbalists out here, say that's our real Destiny, to be the scholar-magicians of the Zone, with somewhere in it a Text, to be picked to pieces, annotated, explicated, and masturbated till it's all squeezed limp of its last drop ... well we assumed—natürlich!—that this holy Text had to be the Rocket, orururumo orunene the high, rising, dead, the blazing, the great one ("orunene" is already being modified by the Zone-Herero children to "omunene," the eldest brother) ... our Torah.[37]

[37] Pynchon, *Gravity's Rainbow*, 520, original emphasis.

Here the *Schwarzkommandos* in the Zone—the ungoverned turmoil cover-ing continental Europe in the wake of the Nazi defeat and Allied advance—come across a bombed oil refinery only to find not arbitrary destruction wrought by aerial bombs, but new structures carved, as if by a scalpel, out of the old refinery. The naïve observer sees ruin rather than some new order's surgically planned al-terations. Enzian situates these patterns in and extracts them from new mytholo-gies, which borrow from Kabbalist mysticism and the natural sciences. He en-shrines the Rocket at the center of this new order, because he cannot decide if it is the product or the director of the materials, money, and other objects that flow through the Zone. The narrator reveals this ambiguity by replacing the Herero prefix for inanimate objects (*oru-*) with the animate one (*omu-*).[38] The Rocket's holy text is precisely that—a coherent narrative that allows Enzian and the reader to temporarily grasp the possibility of a new structure permeating the Zone's chaos. The order that Enzian finds in, and the life his narrative imbues into, the ruins is too delicate to endure, and we indeed see it constantly breaking apart and reforming throughout the novel as interpretations change, new information arrives, or random events change the story's course.

Some of the characters resist this entropic tendency by trying to mute the nonhuman, by incorporating it back into a cause-and-effect narrative. One par-ticularly memorable instance occurs during an analepsis to Berlin in 1929 or 1930 during which elite Nazis, including Generaldirektor Smaragd of IG Far-ben (Interessen-Gemeinschaft Farbenindustrie AG),[39] and Franz and Leni Pök-

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[38]Weisenburger, *A Gravity's Rainbow Companion*, 228.

[39]This literally means Community of Interest of the Dye Industry. AG stands for *Aktiengesellschaft*

ler gather in psychic Peter Sachsa's home to hold a séance. They plan to summon German Jewish industrialist and statesman Walter Rathenau's spirit. The narrator describes him as a "corporate Bismark" who erected the "cartelized state" that would replace ideological, political, and philosophical struggles (e.g., between Communism and Fascism) with "a rational structure in which business would be the true, the rightful authority" (Pynchon, *Gravity's Rainbow*, 165). These moves are just the first attempts to supplant one totalizing narrative with another. We could follow Kittler and suggest another that strips away even those vestiges of humanity—perhaps the war in GR is not between people or nations or corporations but different technologies.[40]

Denying Kittler's logic is difficult particularly given how mauve dye, according to Rathenau, flows through a mesh of materials, technologies, economics, and politics. Like other artificial dyes, mauve is synthesized from the petrochemicals in crude oil (Pynchon, *Gravity's Rainbow*, 166) after a long chain of chemical transformations. Mauve and other artificial dyes are but one possible product—the more important ones for Gravity's Rainbow and for us are plastics. Like crude oil, coal tar is also the dead sediment of prehistoric creatures, is similarly toxic, and is used as fuel, particularly to feed the fires needed to manufacture steel, which is essential for building cities and war machines: "'Consider coal and

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and designates a joint stock company, which we would render in English as incorporated.

[40]"[The] enterprise of systematic death and the simulation of relations between enemies and friends only serves as a pretext for the competition between various technologies that are themselves based not on adventure and narration but on blueprints, statistics, and intelligence operations" (Kittler, "Reading Matters," 160).

steel. There is a place where they meet. The interface between coal and steel is coal-tar. Imagine coal, down in the earth, dead black, no light, the very substance of death. [...] But to make steel, the coal tars, darker and heavier, must be taken from the original coal"' (Pynchon, *Gravity's Rainbow*, 166). Starting from a dye we arrive at plastics and steel and also at the political imbroglios of occupying foreign lands under which the oil and coal lie, and so Rathenau's all-encompassing pattern expands.[41]

This ever-expanding cascade of transductions, however, encompasses the text itself, which reveals itself to be another integrative narrative, which may split, diverge, and reform as the transduction continues. The chains linking coal-tar and steel, crude oil and plastics are just as contingent and involuted as those linking Rathenau's control over Sachsa's lips, and Rathenau's words to the printed text. Rathenau, the narrator, and the reader are all cognitions in the narrative mode that, like Rathenau's voice flowing from medium (both Sachsa and the printed text), are always under construction, always striving to give shape to something. A something that cannot reside simply in the text, which is just ink infused on the page thanks to a mechanical operation. Ink no doubt derived from petrochemicals and handled by machines driven either by gasoline or by electricity from coal-burning power plants. This séance is a recursive moment in which

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[41]Industrial processes may transform crude oil into several products including asphalt, diesel fuel, gasoline, jet fuel, tar, and petrochemicals. From the latter come artificial fibers and plastics, adhesives, cosmetics, materials to create electronics, flavorings and other food additives, inks and dyes, and paint. Coal tar is a liquid form of coal used as fuel in industrial processes thanks to its flammability.

the novel reflects on itself as a technology that generates a narrative by flowing through other bodies and technologies in a circuit or feedback loop. It attempts to gather up all these nonhuman systems and mute them by ironically giving them a human voice in a terrifying story world of plots, intrigues, and destruction.

It is no longer possible, however, to mute the nonhuman through a cause-and-effect narrative once the nonhuman arrives faster than sound; that is, when the human sensorimotor system and its set of perceptions and concepts no longer apply. I am, of course, referring to the supersonic V–2 rocket: "But a rocket has suddenly struck. A terrific blast quite close beyond the village: the entire fabric of the air, the time, is changed—the casement window blown inward, rebounding with a wood squeak to slam again as all the house still shudders" (Pynchon, *Gravity's Rainbow*, 59). This blast occurs as the statistician Roger Mexico and Jessica Swanlake are, appropriately, having sex. Despite how human the act may be, it merges with the rocket's explosion and roar. The rocket strike indeed changes human time. It ceases to be the steady, mechanical steps that link one moment and event to the next on which the Pavlovian behaviorist Ned Pointsman bases his world: "[Pavlov's] faith ultimately lay in a pure physiological basis for the life of the psyche. No effect without cause, and a clear train of linkages" (ibid., 89). Understanding the rocket's arrival as just another instance of *hysteron proteron*—a rhetorical device that puts effects before causes—obscures how something as apparently fundamental as the march of time changes upon contact with the non-human.

Mexico thinks linear chains of cause-and-effect are now sterile, for they will never explain, as Pointsman hopes, why the map of V–2 rocket strikes exactly

matches Tyrone Slothrop's reported ejaculations. For him, only the mathematical model, the Poisson distribution, that predicts the number of times an event (like the rocket strike) will occur in a given interval or space matters. Even when many of these intervals are strung together in the Poisson process, it is not time's inextricable forward march that is of interest, but the time between events—whether between rockets or raindrops hitting the ground. That time between is statistically independent from the time between the last events and future ones. When viewed sequentially the process appears random and unpredictable. One must instead look at the Poisson process statistically, that is, analyze a large sample of events, to reveal patterns. Hence Mexico's exasperation that Pointsman and Swanlake constantly ask him to predict the precise time and location of the next V–2 strike—it is mathematically impossible to know.

Despite that impossibility, there remains the unsettling coincidence between Slothrop's erection and the V–2's impact, one that even his sex partners cannot help but wonder about: "The floor has twitched like a shaken carpet, and the bed with it. Slothrop's penis has sprung erect, aching. To Darlene, suddenly awake, heart pounding very fast, palms and fingers in fear's pain, this hardon has seemed reasonably part of the white light, the loud blast. By the time the explosion has died to red strong flickering on the shade, she's begun to wonder … about the two together" (Pynchon, *Gravity's Rainbow*, 120). This anomaly that cognition in neither the narrative nor non-narrative modes can account for is moment at which the novel's narrative buckles, and we glimpse, however briefly, the nonhuman cognitions that are busy mediating and organizing the world in ways alien to humans.

Roland Feldspath's spirit—an expert on control systems—puts the matter quite bluntly early in the novel: "'A market needed no longer be run by the Invisible Hand, but now could create itself—its own logic, momentum, style, from inside. Putting the control inside was ratifying what de facto had happened—that you had dispensed with God. But you had taken on a greater, and more harmful, illusion. The illusion of control. That A could do B. But that was false. Completely. No one can do. Things only happen, A and B are unreal, are names for parts that ought to be inseparable... .'" (Pynchon, *Gravity's Rainbow*, 30). The illusion of control no longer needs the illusion of willing, acting human being, as it is put into a new, nonhuman body. Feldspath is referring to the new double integrating circuit German engineers designed and built into the V–2, which enabled the rocket to track its own flight and thereby correct its course. It is the same type of integrating automaton that Vannevar Bush strung together to create the Differential Analyzer 2.1, page 25.

As Pynchon notes in the novel, the integrating device senses the rocket's acceleration and then integrates once to determine velocity, and again to determine distance: "To get to distance from acceleration, the Rocket had to integrate twice—needed a moving coil, transformers, electrolytic cell, bridge of diodes, one tetrode (an extra grid to screen away capacitive coupling inside the tube), an elaborate dance of design precautions to get to what human eyes saw first of all—the distance along the flight path. [//] There was that backward symmetry again, one that Pointsman missed, but Katje didn't. 'A life of its own,' she said." (ibid., 301). To acquire this data, the rocket uses mathematical formulae that, as Achtfaben noted earlier, break the flight path into segments that are ideally infinitesimally

small, and then integrates the fragments to produce a new whole. Yet, that whole is a not a narrative whole, for it does not belong to the transductive loop of human bodies and technologies that produces narratives. The rocket controls itself through its integrating circuit and remains completely indifferent to the labeled line segments and paranoid plots of control that humans use to transduce, to narrate this nonhuman cognitive operation. The Rocket is too busy representing its world through circuits that work in the reverse order of human narratives.

This mathematical or statistical loop pulsing through the rocket increasingly intrudes upon the narrative transduction to which Slothrop's human cognition belongs. We can interpret his dissipation as the loss of narrative as a recursive technology, because his human cognition has been overwhelmed by the alien interjection of the V–2 and can no longer self-organize itself as a recognizable self. That is, transduction has ceased to be a border phenomenon (i.e., a process that distinguishes system from environment) and has given way to the colonization of human cognition by another (technological) cognizer that does not need narrative to operate. Hence the increasingly strange personas Slothrop adopts in the Zone that range from a reporter to Rocketman, or *Raketemensch*. Eventually he seems to just dissolve into a wave: "There is also the story about Tyrone Slothrop, who was sent into the Zone to be present at his own assembly—perhaps, heavily paranoid voices have whispered, *his time's assembly*—and there ought to be a punch line to it, but there isn't. The plan went wrong. He is being broken down instead, and scattered" (Pynchon, *Gravity's Rainbow*, 738, original emphasis).

The novel does try again to tame this statistical mode, this nonhuman cognitive order with the bizarre tale of Byron the Bulb. This lightbulb, like Slothrop,

is a statistical fluke, whose existence is so improbable as to be impossible, be-
cause he has been so perfectly constructed that he will never burn out. Thanks
to his immortality, Byron is in the unique position of traveling all around the
Zone—he shines over engineer Franz Pökler at the Mittelwerk;[42] an American
colonel getting a haircut; and over the Preterite world of prostitutes, the desti-
tute, and a man's rectum (Pynchon, *Gravity's Rainbow*, 647–55). How does Byron
synthesize, integrate, or make sense of what he has witnessed? Does he hold the
secrets to the Elect's plans that Slothrop is running all over the Zone to find? Nat-
urally, Byron never reveals what he knows, at least not in a readable narrative. The
best we get is the absurd account of our intrepid Byron trying to evade Phoebus,
the international light-bulb cartel, which monitors the life-span of all bulbs and
plans to retire Byron who has seen, and perhaps knows, too much.

The narrator does, however, tantalizingly suggest Byron transduces his expe-
riences in another way. Powered by Private Paddy ("Electro") McGonigle's turn-
ing of a generator crank (ibid., 641), the bulb only appears to emit a continuous
stream of light, even though it "is really a succession of electric peaks and valleys,
passing by at a speed that depends on how fast Paddy is cranking. It's only that the
wire inside the bulb unbrightens slow enough before the next peak shows up that

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[42] After Allied forces bombed the V–2 research facility at Peenemünde several times during 1943
and 1944, the Wehrmacht relocated the research program to the Mittelwerk (literally, the Central
Works), which was a subterranean factory situated on the outskirts of Nordhausen, a town in
Thuringia. The factory comprised two elongated tunnels, which evoked, as Pynchon reminds
us several times in Gravity's Rainbow, the double integral symbol. The nearby Mittelbau-Dora
Concentration Camp imprisoned the factory's slave labor force. See Neufeld, *The Rocket and the
Reich*, 209, 227, 267.

fools us into seeing a steady light" (Pynchon, *Gravity's Rainbow*, 642). The narrator implies it is indeed the oscillation of the signal, perhaps channeled through Paddy and others, that encodes a comprehensive account of the Zone and the conspiracies filling it. Perhaps all one needs to do is perform a bit of Fourier analysis on Byron. That analysis, however, is only present to human cognition as an abstract mathematical space, not a narrative story world. Indeed, it perhaps unconsciously (i.e., non-narratively) influences Private McGonigle to consider cutting the colonel's throat after Eddie Pensiero finishes cutting his hair. But he does nothing.(ibid., 655) Nonhuman cybernetic devices like the digital computer are far better at manipulating those decompositions and statistical analyses. The conflict between Roger Mexico and Ned Pointsman (as well as other characters like Jessica) exemplifies this tension. The narrative time that we embodied humans occupy does not easily comprehend this statistical and random world whose order is not necessarily linear, spatial, or narrative. My insistence on fractal, rather than emergent or self-organizing, realism lies precisely in how alien the signals of nonhuman cognitions are to humans.

This non-narrative mode that nonhuman cognitive systems begins with the early twentieth century cybernetic automata prefer. Pynchon often invokes metaphors of thermodynamics in his work, which many critics have already noted, and we could indeed see the gradual increase in entropy as the reason for the novel's narrative decay. However, I think we should instead look to how nonhuman cognitive systems present alternatives to those narratives of decay and rebuilding. The novel does, however, use another inscriptional technology to try to capture the order that eludes print narrative: film. I am not referring to the cultural or nar-

rative aspects of film—a topic already covered by others—but rather to the way film technology manipulates time and space in the very act of encoding them as a sequence of still frames. I see this filmic mode as a step toward more statistical and computational modes of nonhuman cognition.

4.3   Flimic Space and Time

Throughout the novel, the narrator and various characters take pains to remind the reader that film and calculus rely on a series of compositions and decompositions. Both decompose a continuous object (the sight of physical motion, and a function) into discrete segments (the cells or frames of a film strip, and line segments), and then use various techniques (the projector, and Riemann sums) to convert the fragments back into a continuous whole. These compositions and decompositions are always relative to some system—film to the human eye, and calculus to another function. Film must present the human sensorimotor system with enough frames per second so that the viewer is not consciously aware of the still frames, even if the brain is filling in, as it were, the gaps between images.[43] Calculus instead relies on the fact that a function broken into small pieces will converge with the initial, continuous function as those pieces shrink infinitely.

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[43] Film theorists frequently describe this phenomenon as "persistence of vision" and consider the eye as a camera that registers images and transmits them to the brain. The enactive approach discussed in the first section contradicts the suppositions of this argument for persistence of vision. Joseph and Barbara Anderson explore the history of this controversy and the psychological research contradicting the persistence of vision theory. See Anderson and Anderson, "The Myth of Persistence of Vision Revisited."

Breaking the smooth function into infinitely small line segments lets us find the function's rate of change (i.e., its slope) at any point. Dividing the area beneath the function into infinitely small shapes and summing them together lets us find the area under the curve. Hence the elongated "S" that represents the integral operation, which the novel mentions on several occasions (Pynchon, *Gravity's Rainbow*, 300–302).

In these examples, however, film and calculus are geared toward transducing some material or function into representations accessible to human cognition, but nonhumans can use them as well. Harold Hazen, Gordon Brown, and WR Hedeman designed a cinema integraph in 1940. By measuring the light that penetrated through successive, moving strips of film, which each represented different variables, the cinema integraph could compute faster but less accurately than Bush's Differential Analyzer.[44] As we saw in the first chapter, the ability to quickly perform these mathematical operations was essential to calculating trajectories, particularly the arcs of weapons. Kittler is therefore not exaggerating when he asserts that the "technological medium that implements motion as calculus [...] is film" precisely because of facility with which film manipulates the time-axis, or more mathematically, the time variable: "Similar to this predecessor of film technology of 1885, the Ascania [sic] high-performance cameras of 1941 were developed not for the imagination of moviegoers but for purposes of slow-motion studies of the V–2 trajectory. Which, of course, does not mean that these techniques should not be extended 'past images on film, to human lives.'"[45] The cam-

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[44]Hazen, Brown, and Hedeman, "The Cinema Integraph."

[45]Kittler, "Reading Matters," 166. The final quotation is from Pynchon, *Gravity's Rainbow*, 474.

era slices time into fragments finer than human senses can perceive as real-time (otherwise called human time), speeds them up, slows them down, or runs them backwards as though "Part of a reverse world whose agents run around with guns [...]—pull the trigger and bullets are sucked back out of the recently dead into the barrel."[46]

The novel similarly reverses the causal chain when it focuses not on how humans develop the rocket by using film and other techniques as extensions of the human sensorimotor system but on how these techniques extend the rocket.

> Engineers sat around looking at movies of dials. Meantime Heinkels were also dropping iron models of the Rocket from 20,000 feet. The fall was photographed by Askania cinetheodolite rigs on the ground. In the daily rushes you would watch the frames at around 3,000 feet, where the model broke through the speed of sound. There has been this strange connection between the German mind and the rapid flashing of successive stills to counterfeit movement, for at least two centuries—since Leibniz, in the process of inventing calculus, used the same approach to break up the trajectories of cannonballs through the air. And now Pökler was about to be given proof that these techniques had been extended past images on film, to human lives.[47]

Ascania manufactured high speed cameras specifically to study fast moving objects like the V–2. The technology would also prove useful when filming the phases of a nuclear detonation.

[46] Pynchon, *Gravity's Rainbow*, 745.

[47] Ibid., 407.

These Heinkels, or Luftwaffe bomber planes, drop models of the "Rocket," not the human pilots.[48] The Rocket's model breaks the sound barrier, but there is no human inside to experience it. Rather than humanizing the Rocket's processes, the nonhuman insinuates itself into the human, so that the narrator will claim that the German mind becomes synonymous with film's rapid, flashing succession of still frames. So Pökler arrives rather belatedly at the realization that these techniques spread from film to human lives, rather than the other way around. Here, film has no need to tell a story or construct a story world, because it transduces the Rocket's experiences, which will always be foreign to humans. The nonhuman Rocket establishes a new transductive loop of materials and technologies from which its cognition organizes itself. Via film, the scientists, the manufacturing plants, and slave labor, the digital transductions of the Rocket's motion feed back into the V–2, and it is this complex recursion that creates a signal that does indeed pass through the human engineers but ultimately concerns the development and experience of the rocket. The V–2 cannot be disentangled from the the chains of mediations and transductions that enabled its design and construction.

Film is at once a representation of reality and also a maker of that reality, as it captures images unavailable to human perception and helps to remake the world according to some nonhuman cognitive order. Consider how Katje and Pökler travel through film as one goes from filmic representation to reality and the other from reality to filmic representation. Katje, for example, believes she has discovered some secret message after viewing films left at the White Visitation.

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[48] *Heinkel* is a metonymy for *Luftwaffe* bombers, because Heinkel Flugzeugwerke manufactured most of them.

> Out of apparently nothing more than the emptiness of "The White
>
> Visitation," she finds a projector, threads a reel and focuses the image
>
> on a water-stained wall, next to a landscape of some northern coomb,
>
> with daft aristocrats larking about. [...] Katie by now is in a bewildered
>
> state, but she knows a message when she sees it. Someone, a hidden
>
> friend at "The White Visitation" [...] has planted Osbie Feel's screen
>
> test deliberately here [...]. She rewinds and runs the film again. Osbie
>
> is looking straight into the camera: straight at her, none of your idle
>
> doper's foolery here, he's acting. There's no mistake. It is a message,
>
> in code, which after not too long she busts as follows.[49]

A seemingly random assortment of films—some of the octopus Grigori being
trained, some of herself or Osbie—come together in her mind as a narrative, a
code to be deciphered, interpreted, and acted upon. What she fails to notice is
her recursion into the meaning making process. She provides the context and
the narrative trajectory to make the random films make sense, but ignores how
the film's presentation of time and of space is contingent on the technology used
to record and play it. She neglects, that is to say, that the film potentially has a
body and a relationship to the world that has nothing to do with her, the war, or
the intrigues proliferating in the Zone. She indeed assumes that someone, some
human agent has put the films there for her to find, just as Enzian assumed
that some agent had meticulously planned the ruined refinery. The suggestion
here, however, is that a nonhuman cognition is simultaneously using the media

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[49] Pynchon, *Gravity's Rainbow*, 533–35.

technology the encompasses film and its projectors in a different transductive circuit—one that caters to the rocket and its needs.

Franz Pökler, aerospace engineer and designer of Blicero's *Schwarzgerät,* does recognize this possibility, for he begins to see how film encodes and organizes in non-narrative ways, the narrative he projects onto his life's events. He extends film "past images on film, to human lives," specifically his daughter Ilse's life. Sequestered at the secret Wehrmacht research facility located in Peenemünde, Pökler toils on modifications to the rocket with only yearly visits from his daughter to sustain his spirits.

> The years Ilse would have spent between Berlin and Peenemünde were so hopelessly tangled, for all of Germany, that no real chain of events could have been established for sure, not even Pökler's hunch that somewhere in the State's oversize paper brain a specific perversity had been assigned him and dutifully stored.[50]

Her visits are periodic, discrete occasions that Pölker links in time and space, but that have no necessary connection between them. The hope that such a connection exists is indeed the narrative impulse to make sense of all these events, to establish a clean, unbroken chain of cause-and-effect that means each Ilse Pölker sees is the same person but slightly older, that a shadowy Elite control the economy and the V–2, or that the technology itself is the narrator, as Friedrich Kittler seems to suggest.

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[50]Pynchon, *Gravity's Rainbow*, 421.

Yet, the gaps, like those between the frames of a film cannot be ignored, but instead feedback into the system of interpretation, of signal generation.

> The only continuity has been her name, and Zwölfkinder, and Pök-
> ler's love—love something like the persistence of vision, for They have
> used it to create for him the moving image of a daughter, flashing him
> only these summertime frames of her, leaving it to him to build the
> illusion of a single child … what would the time scale matter, a 24th
> of a second or a year (no more, the engineer thought, than in a wind-
> tunnel, or an oscillograph whose turning drum you could speed or
> slow at will…)?[51]

The narrative that Pölker constructs from this flickering image of his daughter like the one that Katje concocts from the reels in the White Visitation is just one recursive loop that makes it impossible to distinguish what is real from what is representation. Ilse and the V–2 rocket's flight through the air belong to vastly distributed transductive systems that translate materials, information, and human bodies into one another. For Pölker the flashing film frames animate the body he associates with his daughter, while for the rocket, the frames are a means of measuring the progress of its flight from Europe to London but not an image or a narrative of events.

Film serves as an interface, then, between narrative ordering and the signals flowing through the nonhuman cognitions. Indeed the V–2 rocket's integrating module measures the rocket's acceleration to calculate its velocity and position.

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[51] Pynchon, *Gravity's Rainbow*, 422.

Using this data, it can guide itself to its target, which is understood as a bearing and distance.[52] What the novel and perhaps the cinema integraph suggest is that film is the best way human cognitions have of understanding just what is happening in this nonhuman cybernetic system. The human body's sensorimotor system renders the gaps between frames imperceptible, completes the arcs between beginning and end despite, like Franz Pölker, missing material in between. It therefore creates a coherent narrative whole from fragments. The V–2 similarly extrapolates representations of its world from the transductions its circuits perform between analog and discrete signals, but the final result is not a narrative in human time.

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[52] Neufeld, *The Rocket and the Reich*, 73, 74, 101, 281. Four external rudders on the tail fins could alter the rocket's trajectory. The LEV–3 guidance system determined their position by using two free gyroscopes and simple analog computers to calculate the rudder adjustments. Flying distance, however, was determined by the time between launch and engine cut-off (*Brennschluss*). The rocket's analog computers calculated that time by monitoring the velocity with a Pendulous Integrating Gyroscopic accelerometer. Remember that integrating acceleration gives velocity, and integrating again gives distance, and so from acceleration the rocket could calculate how far it had traveled.

Chapter 5

The Media of Self Modification: The Fate of Film and Print

When the first electronic oscilloscope and cathode ray tube—Karl Ferdinand Braun's contribution to the evolution of nonhuman cognition—came online in 1897, the electron beam traced not episodes of *I Love Lucy* but the sinusoidal period of the electrical current that powered it.[1] Braun's device contained all the same elements as a contemporary CRT—a cathode as an electron source, control coils (i.e., magnets) to deflect the beam horizontally and vertically, an anode to accelerate and

[1]This electronic version was but the latest in a line of vibration writers, or oscillographs (from Latin *ōscillāre,* to swing, and *-graphus,* Greek *-γραφος,* written or drawn) that inscribed (or transduced) motion through pens to paper or through light to photographic plates. Unlike its predecessors, however, it projected invisible electrons through a near vacuum onto a phosphorescing screen, and therefore took its place among the bevy of other scientific instruments, or scopes, that extended human vision into the microscope world and to deep space. Hence its name, the vibration viewer (again from *ōscillāre,* and *-scopium,* from the Greek *σκοπεῖν,* to look at or examine).

control the electron beam, a focusing slit, and a phosphor screen perpendicular to the beam to trace its path.[2] Hence, Kittler's wry declaration that the first image carried on television was a mathematical function, $\sin(t)$.[3] Braun designed the tube so that he could better diagnose noise and disruptive oscillations in electrical currents, which would improve the performance of telegraphs, help with the development of the telephone, and also give engineers the tools necessary to investigate the increasingly complex electrical circuity in wireless communication systems, e.g., radio. The oscilloscope remains a vital tool in constructing and monitoring electronics. It also gives human eyes a view of the current or signals that machines such as Bush's Differential Analyzer (DA) were using to represent and manipulate reality, or at least other media. Braun saw a visual representation of a statistical phenomenon, or the aggregate behavior of billions upon billions of electrons pulsing through conductive wiring, painted not directly by photons hitting the retina but first by electrons (the parts of the very signal being observed) as they impacted a phosphorous screen.

The oscilloscope CRT is a technical apparatus that makes an electrical signal visible by transducing electrons into photons. Like all transductions, this process generates a new pattern and its accompanying noise, though in this case, the pattern is electrical current's oscillation, rather than a narrative of causes and effects, which is left to the observing scientist. However, Braun designed the oscilloscope not so he could predict the circuit's behavior but so he could ensure the apparatus's parts were properly synchronized. The oscilloscope allowed Braun and

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[2] Keller, *The Cathode-Ray Tube*, 45.

[3] Kittler, *Optical Media*, 191.

his lab technicians to act as regulators or servo-mechanisms for the electronic technical apparatus. It would only be a matter of time, then, before electronic apparatuses, like their mechanical cousins, found a way to auto-regulate, to become automata like the fire control systems being built not long after Braun's experiments. Indeed, the vacuum tube—the same tube on which Braun based the CRT—would eventually become that regulating mechanism with the triode vacuum tube's introduction in 1907.[4] Technical apparatus (the electrical circuit) and technical medium (the oscilloscope) therefore fold into one another in a recursive loop that makes it possible for the signal moving through the apparatus to observe and regulate itself.

This early CRT gives us a glimpse into how early nonhuman cognition diverged from human cognition, and how technical media and apparatuses would remain essential to both. The oscilloscope's vacuum tube core would eventually find its way into the technical apparatus that encoded sound waves on film, and into the now ubiquitous television. That world seems to have little overlap with the story worlds and contextual frames that make the narrative transductive loop so meaningful to humans, except that it would provide a new technical medium to help humans simulate story worlds and construct narratives. In tandem with these new media for story worlds, the transition from mechanical to electrical technical apparatuses would allow cybernetic automata to physically shrink and

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[4]See Forest, "Space Telegraphy." He titled it "Space Telegraphy," because the triode was meant to increase the sensitivity of radio (i.e., wireless) transmitters and receivers. Consisting of a cathode, anode, and grid, the triode was the first significant electronic amplification device that used the grid as a control mechanism.

immensely accelerate their operating speeds. That transition means, however, that technical media like cybernetic automata increasingly operate on themselves and rely less on humans to create representations of reality or of their own circuits. From the human cognition's narrative perspective, the technical apparatus would appear to grow more abstract, less grounded in reality (as human bodies experience it), and more concerned with new patterns, such as fluctuations in voltage and eventually sequences of bits, e.g., binary code. Nonhuman cognitions even get their own technical medium for recording and storing these encoded signals—magnetic tape. The photosensitive emulsions used on film reacted to light, whereas the magnetic tape responds to magnetic charges, like the negatively charged electrons. We then live with the awkward fact that home movies have more in common with first signals of nonhuman cognition traced on Braun's oscilloscope, than with the photographic camera that mimics the human eye.[5]

The V–2's approximately 800 meter per second (1,790 mph) descent onto the

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[5]We may use the words *cinema, motion picture, movie,* and *film* interchangeably, but they refer to slightly different aspects of different technical media. From the Greek for movement (*κίνημα, κινηματ-*) and writing or marking (*-γραφος*), cinematography refers to the movement image or motion picture—in contrast to the still image of photography, or light (*φωτο-*) writing. *Motion picture* and *movie* are therefore close translations of the original and may refer to the many technical media that can produce moving images. Film, however, is a specific medium (a base and photosensitive emulsion) for recording and storing motion images. The first film base was nitrocellulose, but because of its explosive properties, safety film made of cellulose acetate quickly replaced it. This *celluloid* base is still in use today for movie production and editing, though since the 1990s, these production prints have been transferred to the more durable polyester bases. Kodak makes much of this information available in their reference guides for filmmakers. See Kodak Essential Reference Guide for Filmmakers.

Orpheus Theatre at the end of *GR* announces the nonhuman cognition's growing recursivity and autonomy with the appropriately silent but explosive replacement of optical technical media with cybernetic systems of encoding and re-encoding. Mimicking cinematic cuts and montage, the narrative shifts between scenes of the *Schwartzgerät,* into which Gottfried was fused on Easter 1945 plummeting to earth and of the Orpheus in 1970s Los Angeles. The cuts look alternatively to the *Schwartzgerät* reaching *Brennschluss* (or engine cut-off), and an audience gathering in the theater. In the final lines, Gottfried and the rocket become one like Brünnhilde and Siegfried on their funeral pyre, and the audience melts into a mob chanting ""Come-*on! Start*-the-*show!*"[6] Whether or not the show starts is irrelevant because there is nothing to see, except perhaps a sine curve on a CRT. The narrative ends with an em-dash (on the page) and a hallucinated plunge into darkness (in the story world).

> The screen is a dim page spread before us, white and silent. The film was broken, or a projector bulb had burned out. [...] The last image was too immediate for any eye to register. It may have been a human figure [...] coming outside to wish on the first star. But it was *not a star,* it was falling, a bright angel of death. And in the darkening and awful expanse of screen something has kept on, a film we have not learned to see ... it is now a closeup of the face, a face we all know—
>
> And it is just here, just at this dark and silent frame, that the pointed tip of the Rocket, falling nearly a mile a second, absolutely and forever

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[6] Pynchon, *Gravity's Rainbow,* 760, original emphasis.

without sound, reaches its last immeasurable gap above the roof of

the old theatre, the last delta-t.[7]

The book's pages may indeed be contending with the movie for a privileged place in the narrative transductive loop, but they are both being converted into material for the automated technical apparatus that guides the V–2. The preponderance of cinematic references (to classic films and the technology used to produce them) suggests that *GR* sees the writing on the wall, or the light on the screen; rather than disembodied digits writing words on the wall, beams of subatomic particles—first photons, then electrons—write dots on the screen.[8] The automated technical apparatuses of the mid- to late twentieth century, such as the computer, convert the typing of human digits, light, sound, and other media into nonhuman digits encoded as a signal. The encoding and decoding of narrative story worlds is just a subset of what this signal can encode and transmit.

The V–2 rocket's guidance system was an analog computer called the *Mischgerät* (mixing device). Helmut Hoelzer designed it while at Peenemünde, as he came to realize he could transform the equations of the rocket's motion into hardware.[9] An electro-mechanical apparatus would record, store, and act upon the data it gathered about the rocket's path, and then use this mechanism to correct

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[7] Pynchon, *Gravity's Rainbow*, 760, original emphasis.

[8] The first such writing reportedly happens during Belshazzar's Feast as recounted in the Book of Daniel 5:1–4 of the Ketuvim in the Tanakh. After Belshazzar uses holy cups to praise the gods of gold and silver, fingers appear and write "*Mene, Mene, Tekel u-Pharsin*" on the wall. It is a nonsense phrase that only Daniel can correctly read as foretelling the fall of Balshazzar's kingdom.

[9] Rojas and Hashagen, *The First Computers*, 324.

its course. It was not any human experience or perception being modeled in the circuity, unlike the images stored on film, but the mathematical description of a nonhuman moving at supersonic speeds. The transductive circuit here requires, by design, no human intervention to regulate it but electron tubes developed by Telefunken. This German communications and electronics company used triode vacuum tubes to create the V–41 amplifier, the first two-stage Hi-Fi amplifier for the German Radio Network in 1928, and to provide the TV broadcasting technology for the 1936 Summer Olympics.[10] Stuffed into the rocket, Gottfried tries to give the human a view of the world behind the CRT screen, unfortunately neither electrons, nor their aggregate statistical behavior is accessible to the senses or to narrative. Hence the narrative ends with a yawning abyss into which text and film descend. A gap, a silence, a dark screen that makes room for the growing cognition and body of the nonhuman. These nonhuman cognitions do not replicate human functions (whether sensory or cognitive) so much as continue by other means the human ability to encode, modify, and interact with a world.[11]

What should concern us then is less the world's growing abstraction, than the intertwining of nonhuman cognitions and the technical media humans use to capture, store, and project narrative story worlds. What appears to us as abstraction is simply the automated technical apparatus's growing ability to execute its recursions and transductions through technical media, rather than through hu-

[10] The V–41 was refined into the V–72S amplifier used in Abbey Road Studios REDD.37 recording consoles in the mid–1960s.

[11] For theoretically oriented studies of the connection of war and technology see Virilio, *War and Cinema*; and DeLanda, *War in the Age of Intelligent Machines*

man cognitions.[12] In the process, the transduced technical medium becomes a set of codes on which the technical apparatus operates. Vilém Flusser schematizes this transduction—though he does not use that term—as a technical evolution that gradually reduces the world's dimensions from four to zero. The anthropocentrism that saw these transductions or encodings as always tied to human cognition was excusable so long as humans were the engines, so to speak, of the transduction, whose latest form was the narrative transductive loop of bodies and technical media like printed texts. Indeed, it allows stories to take as many different forms as there are technologies to capture and project them.[13] This situation, however, changes drastically when technical media gain a degree of autonomy, as the camera and computer do. Their greater complexity and effectiveness rely more on self-regulating (or cybernetic) apparatuses and less on human bodies. The nonhuman cognition system therefore gains a space in which to grow. Fractal realism looks precisely at this situation, especially as it manifests itself in the technical media that make up the world in which human bodies now live.

To better understand these trends, I want to first consider a new history of abstraction or technical evolution that places less emphasis on human bodies and more on the techniques of externalization, recording, and projection. In light of this new history, we can consider how celluloid-based cinema participates in cog-

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[12] Lewis Mumford and Martin Heidegger are two of the most cited thinkers who warn us of the dangers that abstraction poses. See his essay, "The Question Concerning Technology," reprinted in Heidegger, *Basic Writings*, 307–41. The best example from Mumford's work is *Technics and Civilization*.

[13] Ryan, *Avatars of Story*.

nition's narrative and non-narrative modes by simultaneously intertwining the narrative impulse to uncover meaning with the signal synchronization nonhumans cognitions need to function. Michelangelo Antonioni's *Blow-Up* (1966) is a good example, because it pivots on the recursion of this tension into its narrative. Mark Z. Danielewski's *House of Leaves* (2000)—hereafter abbreviated as *HoL*—attempts to recuperate the print book amid this proliferation of automatic technical media and in the process reveals that literature will no longer rely on the novel (or other genres born in print) but on the algorithmic processes of nonhuman cognitions to simulation and augment narrative cognition.[14]

5.1   From Space to Surface to Dust

Each transduction produces a new pattern that must discard extraneous information as noise. In the case of the recursive transductions occurring between technical apparatuses and technical media, we might see this movement as a reduction in dimensions.[15] Each successive re-encoding must discard some information,

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[14]Of the work's form Hayles writes: "In a sense, House of Leaves recuperates the traditions of the print book—particularly the novel as a literary form—but the price it pays is a metamorphosis so profound that it becomes a new kind of form and artifact. It is an open question whether this trans- formation represents the rebirth of the novel or the beginning of the novel's displacement by a hybrid discourse that as yet has no name" (Hayles, "Saving the Subject: Remediation in House of Leaves," 781).

[15]I use the term rather loosely here, but we should keep in mind the sense in which it means a measurement. Mathematically, a system's dimensions are equal to the number of variables needed to adequately describe it. A model of predator prey relations may then use four or more dimensions, even though we think of predators and prey interacting in a three-dimensional spatial world.

some dimensions, as it picks out new patterns in the existing signal. These recursive loops ultimately make it possible for the signal to treat itself as material for further transductions and thus to modify itself—instruction and data therefore cease to be distinct. Discrete state, or digital, computer automata are much better at such self-modification, because they treat the signal produced in an analog machine like the DA as the material to be analyzed and processed. In so doing the signal ceases to be a continuous fluctuation of potentials and becomes a sequence of codes that instruct the apparatus in modifying the state of its circuits. The blank screen or final em-dash of *GR* perhaps shows a "a film we have not learned to see," because this invisible film is increasingly the algorithmic code through which nonhuman cognitions act on themselves.

Vilém Flusser's conceptualization of technical and cognitive evolution as the gradual descent from a four- to zero-dimensional world helps us understand in spatial terms how encodings or representations can become self-modifying and why human bodies are need no longer participate in this circuit of recursions. A four-dimensional world completely immerses animals and other non-conscious (but sentient) life, so that there is no meaningful distinction between self and other. Once early humans gained the ability to grasp objects and pull them out of that continuum, they reduced the world to three dimensions, because now *Homo sapiens* could arrange objects, which were not self, in space. Images or models of these spatial configurations then permitted humans to better understand how arrangements of objects related to one another, but they also further reduced the world to two dimensions. Flusser calls this model or image, the *traditional image* (e.g., cave painting, drawing, etc.). Using the hands to create a medium (or

model) by which objects can be manipulated complicates the situation, because hand, eye, tool, and image enter into a feedback loop. The image or model may no longer refer just to things but also to itself and the tools and humans who create it. Flusser sees the invention of writing as the next recursion that allows the human to manipulate the image and tool, and thereby reduces the two-dimensional image to the one-dimensional "conceptual universe of texts, calculations, narratives, and explanations."[16] We reach the age of the *technical image* when this one-dimensional world finally gives way to the zero-dimensional universe of particles, or binary code. Text and traditional image can only work on themselves by feeding back into the technical apparatuses that produced them.[17]

Flusser's scheme then adds technical media to the co-evolution of human bodies and technologies that Leroi-Gourhan and others have formulated (3.1, page 61). Because human physiological evolution occurs far more slowly than technical evolution, every encoding or transduction from a higher to lower dimension necessitates and is effectuated by the creation of a new tool, which humans must learn how to use. It becomes more difficult to master each one—consider the length and intensity of instruction children require to make reading and writing seem natural. Learning the mathematics and programming languages needed to manipulate a computer requires even more time and educational resources. The solution to this problem is not genetic engineering but rather the construction of technical apparatuses that perform the encoding and decoding autonomously. The cybernetic automata we examined in Chapter 1 were an early

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[16] Flusser, *Technical Images*, 9.

[17] For a complete account Flusser's history of media, see Flusser, *Technical Images*, 6–10

permutation of these automated technical apparatuses, and as we saw there, the growing distance from the human led to a more complex world than had previously existed. This dimensional reduction then opens rather than closes possibilities. We do not open ourselves to reality by moving from the shadows cast on the cave's wall into the sun's light—as Plato would have us do. Escape from illusion means learning to see the cave wall's particulate dust as data.

We can understand how technical media participate in a feedback loop with technical apparatuses and marginalize human cognition by looking at photography's break from painting. Because the human hand created the painting, it was possible for human cognition to intervene in the representation, to alter the appearance of whatever object was being painted. In its infancy, photography, however, guaranteed a level of mimetic realism and verisimilitude that painting suffused with human intention could not. As Rudolf Arnheim remarked about photography: "It [i.e., photography] is not only supposed to resemble the object [as in all representational arts], but it is supposed to guarantee this resemblance by being the product of this object itself, i.e. by being mechanically produced by it—in the same way as the illuminated objects in reality mechanically imprint their image onto the photographic layer."[18] Not only is veracity guaranteed but the object itself is somehow responsible for the generation of its mediated representation. The light the object reflected only succeeded in producing an image thanks to the technical apparatus we call a camera. Arnheim assumes that the photographic camera is technologically continuous with the *camera obscura* and

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[18]Arnheim, *Kritiken und Aufsätze zum Film,* Ed. Helmut Diederichs (1977): p. 27. Quoted in Kittler, *Optical Media*, 40

laterna magica, but the new camera partially automated the image production process, and so did not just extend the hand in the way the painter's brush does. The camera requires precision equipment from highly polished and delicate glass lenses to precision mechanical parts to focus photons onto a photosensitive base (initially a metal or glass plate and then an emulsion on film). The finger needed only to press the button that triggered the shutter mechanism. Kittler provides an excellent account of how different chemical processes, bases, better lenses, and automated exposure mechanisms helped improve image quality and expand the lighting conditions under which the camera could operate.[19]

That technical apparatus and its growing level of automation belies Arnheim's implication that photography and motion pictures simply record and project but do not modify reality. The long history of photographic tricks, such as double exposures and slicing together negatives, makes this point quite clear. As photography develops, the two-dimensional *tradition image* that it is supposed to perfect gradually reveals itself as an image that the photographic camera simply simulates. The camera apparatus and the film negative instead make it possible to treat the image as a new pattern to be altered, recombined with itself, and fed back into the technical apparatus for further development. The traditional image now enters a phase that puts it between surface and line, between the two and one dimensional worlds. With the traditional image's trasduction and re-encoding into the camera's technical apparatus, it gains a fractal dimension, which is neither one nor two but somewhere in between.[20]

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[19] Kittler, *Optical Media,* 129–33.

[20] Mandelbrot defines this term in "How Long Is the Coast of Britian? Statistical Self-Similarity

The photograph shifts closer to the one dimensional world of concepts and calculation with the cinematograph's invention in the late 19th and early 20th centuries. While photographs travel quite easily, because humans only need their eyes to view them, movies require a complex projection apparatus capable of running the film a high enough frame rate (or Hertz) to make the still images appear to be moving. The sender and receiver of the film need a projection apparatus made to the same standards and specifications as the camera used to create the film roll. Cinema, in other words, requires a vast industrial process that is capable of producing precision, preferably interchangeable, parts. Film as technical medium then requires the same precision engineering of mechanical parts as Charles Babbage's Difference Engine and the US military's mass-produced arms.[21] The military pushed for precision, interchangeable parts, so that weapons would be easier to manufacture and repair; but Babbage and other cyberneticians needed them, so that physical mechanism—whether the oscillation of electrical current or the gears grinding—would introduce as little noise as possible into the signal they were using to encode data. The desire for precision, replicability, and minimal noise meant isolating the human from the technical apparatus. In

and Fractal Dimenson." The fractal dimension, or Hausdorff dimension, is a statistical index that characterizes a fractal set's complexity as a ratio between, roughly, changes in detail, and change in scale. Unlike the topological or Lebesgue covering dimension with which we are most familiar, fractal dimensions may take non-integer values. For example, a fractal curve composed of what appear to be one-dimensional line (i.e., their topological dimension is one) segments may be embedded in a two-dimensional plane, and yet be neither one-, nor two-dimensional. For example, the Sierpinski triangle's fractal dimension is approximately 1.5849.

[21]Kittler, *Optical Media*, 146.

the case of cinema, human could not reliably and quickly produce the projector's parts in mass, feed film through the machine, or synchronize audio and video.[22]

Cinema brings together the encoding and re-encoding of technical media into other technical apparatuses with the transductive loop of narratives and story worlds that we saw in the previous chapter. Human brains need no longer integrate a narrative into a visual and aural hallucination when they can watch and hear the events unfold on screen. Human cognition in the narrative mode then ceases to reside only in the brain-hand-writing circuit and blends with a feedback loop of technical apparatuses. We will see that these technical apparatuses include the vacuum tube and the solid state transistor derived from it. With the introduction of computing machines, light, sound and their various encodings become the medium and material that carries a new encoding, a new signal. Automated technical apparatuses perform this recursion of the traditional image and the narrative story world into themselves and bring about the transition from the one-dimensional to the zero-dimensional universe of the *technical image*. Even texts (i.e., the one-dimensional universe) are inaccessible,[23] because they, like visual images, are now computed from vast zero-dimensional particle seas: "The gesture of tapping with the fingers on the keys of an apparatus can be called 'calculate and compute.' It makes mosaic-like combinations of particles

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[22] Before the invention of sound-on-film technology, an usher had to start the sound track, probably recorded on a gramophone, at precisely the right moment to synchronize it with the motion picture. Failure to do so would especially noticeable if an actor's lip movements and words did not correspond.

[23] Flusser, *Technical Images*, 8.

possible, technical images, a computed universe in which particles are assembled into visual images."[24] Statistics, not cause-and-effect narratives, now explain them.

These particles are not the silver halide grains in photographic film, but the pixels on the CRT (and later LCD), the sequence of charges on the magnetic tape's surface, and later the binary code the microprocessor sorts among its memory registers.[25] The movement from celluloid film, to video tape, and to the digital computer entails a parallel evolution of technical apparatuses that can transduce each technical medium into the next. These technical apparatuses need humans less and less to perform the transductions, and the technical media themselves become vehicles not just for narrative story worlds but for the signals that nonhuman cognitions process. Kittler deplores user interfaces, because they perpetuate the illusion that the computer is just a sophisticated camera or video tape player. He wants to delve into the supposedly raw manipulation of data occurring inside

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[24]Flusser, *Technical Images*, 10.

[25]The term *microprocessor* refers to an integrated circuit that contains a computer's central processing unit (CPU). The CPU consists mostly of transistors, which before the advent of integrated circuits were composed of vacuum tubes and electronic relays. The development first of integrated circuits and then solid-state transistors like the metal–oxide–semiconductor field-effect transistor (MOSFET) in the 1960s and 1970s made CPUs significantly smaller, more reliable, and faster. See Orton, *The Story of Semiconductors*. Nearly all CPUs fetch, decode, execute, and writeback instructions to and from memory. These instructions make the form of binary code and therefore take the same form as data. Indeed, all the separates the two are yet more special control code sequences that mark some data as executable. The still classic book on computer architecture is Hennessy and Patterson, *Computer Architecture*.

the microprocessor but that will always remain beyond human representation.[26] On the other extreme, Mark B. N. Hansen proclaims the "impossibility of representing the digital"[27] and reasserts the human body's role in constructing text, image, and information.[28] We are interested neither in raw computation, nor human interpretations of data, but in the nonhuman cognitive processes unfolding in those abysses, or the "black hole of circuits."[29]

5.2   The Invisible Film

The black hole only prevents light from escaping by transducing it from photons into encoded analog or digital signals. To follow that transductive pathway into the computer, we must first look more closely at the technical medium that straddles the traditional and technical images—cinematography. Because it must present a sequence of images, cinema must deal with visual images and sound waves not as things to be seen and heard but as information to be shunted from one part of

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[26]The clearest statements of this view are in "Protected Mode" and "There Is No Software." The English translations are printed in Kittler, *Literature, Media, Information Systems*.

[27]Hansen, "The Digital Topography of Mark Z. Danielewski's House of Leaves," 618.

[28]See Hansen, *New Philosophy for New Media* in which Tim Lenoir succinctly captures the thrust of Hansen's project in the Forward: "Hansen aruges that media convergence under digitality actually increases the centrality of the body as framer of information: as media lose their material specificity, the body takes on a more prominent function as selective processor in the creation of images. [...] Hansen's 'Bergonist vocation' asserts that there is no information (or image) in the absence of the form-giving potential of human embodiment" (xxii).

[29]Kittler, *Optical Media*, 225.

the apparatus to another.[30] Cinema therefore depends upon the control and amplification techniques so crucial to the development of the cybernetic automata we examined in Chapter 1. The images threaded through the projection camera are not just images but one part of a technical apparatus that encodes the images as sound and motion. We therefore need to focus more intently on the technical rather than narrative aspects of film for the moment, for the major concern in this evolution is not mimesis but synchronization. This shift has important consequences for narrative cognition's quest for meaning and cause-and-effect. Flusser's perceives this consequence rather grandly as the end of history, because he intimately connects logical thinking, linear writing, and calculation with historical consciousness.[31] Perhaps it is a sign of history's end, but more importantly, it means we can no longer pretend that narratives always refer back to some traditional image that in turn refers back to the external world as our human bodies perceive and act in it.

While humans might busy themselves with interpreting these images and putting them in order as though they were still linguistic and linear, early motion pictures demonstrate how preoccupied these automated technical apparatuses were with the production and reproduction of image streams. Movies such as the Lumière brothers' *La charcuterie mécanique [Mechanical Delicatessen]* (1895),

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[30]While we could also think of photography as the problem of optimizing channel bandwidth (i.e., light through the aperture), the technical apparatus still treats the light as light, which is to say, it is designed to record one of light's physical properties. The same is not necessarily true for cinema.

[31]Flusser, *Does Writing Have a Future?* 5–9.

and Georges Méliès' *Escamotage d'une dame au théâtre Robert Houdin [The Conjuring of a Woman at the House of Robert Houdin]* (1896) demonstrate this preoccupation. *La charcuterie* depicts the journey from pig to pork chop in reverse—a sequence of events it would be impossible for a human perceive (and perhaps even imagine) but the film maker easily achieves the effect by reversing the projector's gears.[32] Méliès' movie demonstrates that the continuity displayed by the projector's playback is an illusion, for he succeeds in making the eponymous but anonymous *Dame* vanish—courtesy of the stop trick. The operator pauses the recording camera, changes the arrangement of objects in the scene (in this case the *Dame*), and then resumes recording. Because the gap was not recorded, the theater projector cannot communicate it to the audience, which remains oblivious to it. Hence, the scene changes, but without continuity or obedience to the laws of physics and common sense. The woman (or rather her projected image) vanishes before their eyes.

These cinematic tricks remind us that motion pictures only appear realistic because the director and projectionist have synchronized the technical apparatus with the human senses. Without that synchronization, it would not be able to fool the human perceptual system into thinking that still images were in motion, that the world in the frame moved at the same rate as the universe outside the

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[32]The projector can also accelerate the film or slow it down to provoke the audience, or simply to reduce the movie's running time. Doing so, however, would alter the frame rate, which was not fixed at 24 fps until 1924. While human eyes could still interpret sped up or slowed down images, human ears, as we will see, proved less tolerant of the synchronization problems these various frame rates caused in sound films.

theater, and, later, that the separately recorded sound matched the actors' lips. That synchronization with the human perceptual system requires that the apparatus's parts be probably synchronized with one another. The reverse, however, is not the case. In the previous chapter, we already touched upon some of time-axis manipulation's ramifications beyond the audience, particularly how useful it was to capture, store, and play back events that occurred too fast or were too dangerous for humans to observe, such as the V–2's supersonic flight or the atomic bomb's denotation. One could also imagine manipulating the time-axis so that data recorded on the film moves at speeds more suited to another technical apparatus rather than human eyes. Light could just as easily encode sound, as sound-on-film technology did, or mathematical functions, as the photoelectric integraph did (4.3, page 127).

Sound-on-film technology may have offered early twentieth century audiences a more realistic and immersive story world by reliably synching the actors' voices with their lips, but more importantly, it demonstrated how easily technical apparatuses could use technical media to generate and work on signals, which were invisible to humans. Doing so required more transductions and greater automation. Like its fire control system and analog computer relatives, sound-on-film promised accurate and reproducible synchronization, since the projector apparatus would necessarily advance the literal soundtrack and image tracks at the same rate (Hz). The technology evolved nearly in parallel in Germany and the United States after WWI with the Tri-Ergon (Josef Engl, Hans Vogt, and Joseph Massolle) in the former, and Phonofilm (Lee De Forest) and Movietone (Theodore Case and

his assistant, Earl I. Sponable) in the latter.[33] Getting the sound waves onto film required microphones that could transduce sound waves with minimal noise, and vacuum tube amplifiers to strengthen the electrical signal transduced from the sound waves, so that it could power the encoding automata.[34] To encode the sound on celluloid then required transducing the electrically encoded sound into light, so that it could expose the film's photosensitive emulsion. The electrically encoded sound powered a glow-discharge lamp whose flashes the motion picture camera could record. The process then had to be reversed during playback in the theater.[35] Not long after this triumph it would occur to technicians that images

[33]The two American technologies actually relied on the same patents, as Case's lab provided De Forest with the equipment he needed to create the Phonofilm system. De Forest's failure to acknowledge the contribution or reward Case's lab financially led to several law suites. William Fox, of Fox Films, bought Case's patents as well as those of the Tri-Ergon inventors and then sued users of Movetone claiming that technology was entirely based on the Tri-Ergon team's work. See Sponable, "Historical Development of Sound Films"

[34]First, a microphone needed to transduce the three-dimensional vibrations called a sound wave into an electrical circuit. The carbon (button) microphones that Edison invented in 1877 output a (relatively) powerful signal but had limited frequency response and produced unacceptable levels of noise. AT&T's manufacturers were furiously at work on refining and mass producing E. C. Wente's condenser microphone—which was patented as a telephone transmitter and used electrically charged capacitors rather than plates separated by carbon, such as the earlier carbon button microphones—so that a greater sound frequency range could be recorded with significantly less noise. It, however, could not produce as strong a signal as the carbon microphone. For more information on the original microphone design see Edison, "Speaking Telegraph," (graphite microphone); Berliner, "Electrical Contact Telephones," (carbon diaphragm with carbon contact pin).

[35]See Kittler, *Optical Media*, 196 His source is Vogt's *Die Erfindung des Lichttonfilms,* Munich:

could also be electrically encoded, or transduced from a two-dimensional to a one-dimensional medium.

Michelangelo Antonioni's *Blow-Up* (1966) arrives after the maturation of sound-on-film technology and while the motion image is undergoing its transduction from celluloid surface to analog video transmission. Though sound was farther along this path, the two-dimensional image surface was beginning its journey into the black hole of integrated circuits and computational algorithms. Signs of the image's encoding reached the masses, however, with the aforementioned live transmission of the 1936 Olympic games.[36] *Blow-Up* enacts this impeding transition by reflecting back on the recursion of previous technical media and technical apparatuses, specifically the photograph. Antonioni's film poses so many interpretative dilemmas for the viewer, because it is well aware that photographs—and now even films—belong to a complex chain of transductions that marginalize the recording of reality, story worlds, or human cognition. Interpretations of the film's events multiply profusely, because we are trying to use narrative cognition to understand a technology that need not simulate narratives.[37] The viewers' in-

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Deutscges Musem, 1964.

[36]The transmission had to be live as there was yet no efficient way of storing video signals.

[37]Peter Brunette reminds us that Antonioni's rather popular (at least among the critically and philosophically inclined) film imposes on the characters the same interpretative and hermeneutical dilemma that novels, films, and other avatars of story impose on readers and viewers. This reflection on reflection renders the movie's events so ambiguous that possible interpretations (whether on the characters' or viewers' parts) multiply infinitely: "[The] very ambiguity of these films causes them to become vast blackboards on which individual critics scrawl their own desires and obsessions." Brunette, *Films of Michelangelo Antonioni*, 5.

terpretations seem just as arbitrary and violent as the way the Hemmings character poses female models throughout the film.[38] We should see this assertion of will for what it is: nostalgia for the creative individual who speaks the narrative into existence, now that this individual requires a vast network of technical and industrial systems to make and show his or her film.[39] Our task will therefore avoid the anthropocentric approaches of other critics to focus on the nonhuman cognition evolving through the film's technical apparatuses. The camera will be less an extension of the director's will than a means to look at how cybernetic automata correct celluloid's technical problems and in the process move us closer to nonhuman cognitions.[40]

The problem of synchronization and cinematic technology makes the final scene—the mimed tennis match—a *mise en abîme* in which cinema looks at the technical media that make it possible.[41] Hemmings' character comes upon the

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[38] For example, the scene in which he poses Jane Birkin for a solo shoot (beginning around the 5 minute mark), and his meticulous and violent composition of the female models that he treats like objects (beginning around the 11 minute mark).

[39] Seemingly oblivious to this fact, marketing departments have, since the film's release, plastered an image of Hemmings and his camera looming over Jane Birkin's anorexic body on the movie poster and then DVD cover.

[40] Antonioni's anxiety about his will being expressed anonymously by the camera has been the subject of much criticism about the movie. The intensity with which the Hemming's character poses

[41] Much of the extant criticism on *Blow-Up* from scholars of film, literary, and philosophy, and various other fields attends to the epistemological or perceptual aspects of the camera. Others choose instead to concentrate on the gender dynamics between the Hemmings character and his various models. The final scene of the tennis match usually becomes the occasion for a rumination on the nature of reality vs. its aesthetic representation. See Brunette, *Films of Michelangelo*

same grassy field and mime troop that appeared in the movie's opening credits and first scene, except that this time two of the mimes are playing at playing tennis, or rather simulating the game for their gawking colleagues. In complete silence (save for some white noise), the David Hemmings character stands apart from the other spectators and watches them watch the game. He is at first befuddled and then amused by the apparent earnestness with which the mimes follow the invisible tennis ball. The camera cuts continually from the players, to the spectators, and back to Hemmings to reveal that the mimes, unlike Hemings, are turning their heads to follow the ball. In imitation of their head movements, the camera switches back and forth from the male to female mime player as they exchange volleys. Following this sequence comes a complex nesting of observation as the mimes watch the match, Hemings watches the match and the mimes' watching of the match, and the camera watches both watching. Suddenly the camera from an indeterminate person's (or no person's) vantage point follows the imaginary ball's parabolic trajectory until one of the players eventually launches it out-of-bounds, and it rolls to a halt on the grass. Coaxed into joining their communal hallucination, the Hemmings character runs to retrieve the ball and throws it back to the court, as the camera and audience watch his eyes follow the descent and the resumption of game play (all of which occurs outside the frame, or rather in the theater audience). Suddenly we hear the sound of the ball hitting the rackets—the first sounds, other than background noise, we hear since the scene's opening moments. The camera pans out to reveal Hemmings alone

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Antonioni.

on the field, the noise fades into jazz, and suddenly he vanishes—like the *Dame au théâtre Robert Houdin*—as the end credits play.

The mimed tennis match requires the same contextual frames and shared embodiment that the narrative transductive loop presupposes. In this case, however, a set of self-regulating technical apparatuses overlay and make possible key elements of that transductive loop. Those apparatuses belong to a distinct set of transductive loops that link analog and digital technologies such as the camera, microphone, projector, and loudspeakers. These loops encode and decode the technical media for the human audience as well as for themselves. The continuity of visual images and motion so important to maintaining a consistent and coherent story world that follows the same laws of cause-and-effect (and physics) as the one human bodies inhabit is a contingent convergence of the Hz in the sampling rate (i.e., the frame rate), and film editing techniques. Without the apparatus's automated amplification, transmission, and storage of these technical media, the image and sound would be out of synch. The technical media on which film rest can break those synchronizations at any moment, especially as they begin to participate more and more in nonhuman cognitive loops.

By turning to the contingency of this synchronization and its reliance on encoded signals that need not align with human perceptions, *Blow-Up* motions toward the electrical encoding of the image that TV has already made a reality. It looks toward the end of film, just as the technical image looks toward the end of history. The movie contemplates the image's recursion into itself by turning back to the technical image's photographic origin. The movie camera takes the photographer's role during the montage of blow ups, or photographic enlarge-

ments, near its mid-point (around 58 minutes). Wishing to develop some of the photographs he snapped of Vanessa Redgrave and her mysterious gentleman in the park, Hemmings uses the silver gelatin process. He steps his way through a series of dark rooms in his development lab to prepare the negatives, uses a light table to select a frame, and then enlarges (i.e. amplifies) the image with the aptly named enlarger,[42] which projects the picture onto a much larger piece of photosensitive paper. Repeating this process, he creates a sequence of photos that he hangs in his living room. In relative silence the camera (and presumably the Hemmings character) pans from one photo to next. Antonioni takes some pains to establish the analogy between these cells from the negative roll and the frames of celluloid flashing through the projector apparatus. Besides the analogy between the succession of photos and the film's frames, we get a view from behind the suspended pictures that reveals Hemmings' shadow as he examines them, which further establishes them as screens onto which the projector focuses light.

Blow-Up performs this recursion not only in the narrative transductive loop but by previewing what the technical image fed back into itself will look like. Like a sequence of words on the page, the parade of images and images within images can indeed form a narrative once we viewers integrate them into the growing contextual frame and story world that the narrative transductive loop is so

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[42]The enlarger is a specialized transparency projector consisting of a light source, a condenser (to concentrate the source's divergent rays into parallel ones), a holder for the negative, and a lens apparatus to focus the light on a screen. Changing the distance from the larger to the screen shrinks or enlarges the image.

good at constructing. Unfortunately that integration is a rather delicate process, for the images are not immune to the noise present in the channels that store and carry the audio track. The very noise that drives the creation of a clearer and more distinct signal in cybernetic automata infects the celluloid. The enlargements that Hemmings performs would necessarily be limited by the size of the silver halide crystals in the gelatin, which coats the negative and the photographic paper (i.e., the film grain). The fact that Hemmings at one point generates the enlargement from an already exposed photographic print rather than from the negative compounds the noise interference by adding the negative's film grain to the one already present in photographic paper's emulsion. The narrative transduction can ignore this actuality by using contextual frames to fill the gaps, but the automata at work in the technical apparatus do not have the same access to those contextual frames and story worlds, since they lack human bodies.

Channel noise and physical materials constantly undercut the narrative transductive loop's attempts to generate a murder plot out of the fairly bland and poorly framed pictures of Redgrave's assignation with the mystery man. No sooner has Hemmings found the corpse his enlargements revealed, than it has disappeared when he returns later in the evening. Did the murders remove it? No, the noise subsumed it. Narrative does not describe that noise so well as the Poisson distribution that also modeled the density of V–2 rocket strikes on London in *Gravity's Rainbow*. The random variations in grain density throughout the image closely resemble those of shot noise in electrical currents. First described by Walter Hermann Schottky in 1918—who incidentally patented several key semiconductor technologies—shot noise refers to infinitesimal variations in electron or photon

energy that deviate from the average energy of particles traveling through the channel. As with tossing a coin, the results seem to vary wildly if the coin is tossed a few times, but the longer the flipping continues the more the results average out to a roughly 50% chance of heads or tails. Film grain and shot noise then point directly to the discrete nature of the materials or media that constitute film and electrical currents—silver halide in celluloid emulsions, and electrons or photons in currents and light rays. In the aggregate, they appear as a coherent whole, but they actually consist of innumerable particles that behave statistically, not narratively.

Unlike the pages of a print novel, then, film as a technical medium has at best an ambivalent relation to the narrative transductive loop. The narrative loop that makes use of the celluloid and projector cannot penetrate to the randomly distributed grains in the emulsion coating the film's surface, because a technical apparatus must encode and decode the image. The film image is a technical image being transduced through a technical apparatus whose growing cognition operates according to statistical and probabilistic principles. Those principles make the conversion of these particles from silver halide to electrical current far more easy and inevitable than human narrative cognitions might imagine. Film's contemplation of its own technical media comes at the time when it is already being replaced by the technical media of electrically encoded signals for television and later computational automata. Film turns to its transduction into a new technical medium just as it becomes clear that the mathematical function displayed on Braun's CRT is indeed the image's fate, as it was already sound's.

The technical medium of film gives way to that of the vacuum tube, CRT,

and its later progeny—the transistor, LCD, and digital computer.[43] This transition should not surprise anyone given that all these technologies—film, vacuum tube, and computer—were present at the V–2's birth in Peenemünde. Before closed circuit television (CCTV) was ever used to deter crime or record the puerile antics of Hollywood's vast seas of aspiring actors, Walter Bruch, working for Siemens AG, designed and installed a CCTV system at the principal V–2 testing site—Test Stand VII.[44] By using the first TV camera—the Iconoscope, which he had field tested at the live broadcast of the 1936 Berlin Summer Olympics—Bruch's CCTV system enabled Nazi engineers to observe the rocket's launch in real time from the safety of a distant bunker.[45] Perhaps it was simply a matter of time before the historical accidents that brought these technical media and cybernetic automata together in war also fused them together in algorithmic codes. Now images, like cybernetic automata, could modify themselves.

5.3 RECURSIONS OF TEXT AND IMAGE

Throughout technical media's changes, narratives and story worlds have remained. Notwithstanding the changes in motion picture recording and projection technol-

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[43]I do not want to write *digital* computer, because the distinction between analog and digital is not a matter of less and more advanced, but rather of how and by whom the signal is interpreted.

[44]Dornberger, *V-2*, 14.

[45]Based on Zworykin's US Patents 1,691,324 and 2,022,450, the Iconoscope swept the image plate with an electron beam, so I suppose it was only a matter of time before a similar beam in Steven Lisberger's *Tron* (1982) would scan Kevin Flynn and convert him into a computer program rather than an analog signal.

ogy, for example, movies still can have plots the audience may follow and interpret. Despite the transition from oral storytelling to offset lithography, stories as related through language persist. We should remember, however, that the fact narrative emerges from a transductive loop between human body, a medium (now a technical medium like computer layouts and lithographic prints), and story world means that each shift in medium changes how we experience and interpret the narrative. We have seen how the introduction of autonomous technical apparatuses into cinematography influenced the construction of cinematic narratives, and now we must think about how these apparatuses and nonhuman cognitions will affect the print book's place in the narrative transductive loop. To the extent that print books belong to the narrative transductive loop and therefore to human cognition in the narrative, I have also been exploring how these cognitive fictions, as Joseph Tabbi calls them, are also, in a strange way, nonhuman cognitive fiction.[46] Nonhuman cognition's infiltration into narrative through technical media, however, means the age of print like that of film is definitely over, as Flusser realized in the 1980s.[47]

The end of print, like the end of film, entails not just a shift in medium—like that from handwriting to mechanical printing—but the introduction of a nonhuman cognition that treats the text as codes to be further encoded and processed. Printed books are therefore static instantiations of the simulated book that exists in the computer, which can simulate the technical media that preceded it.[48]

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[46] Tabbi, *Cognitive Fictions*.

[47] Flusser, *Technical Images*, 8.

[48] Kittler declares "People will be hooked to an information channel [i.e., optical fiber] that can

The print book and narrative—just like film in *Blow-Up*—has already begun to recognize its growing dependence on the ways nonhuman cognitions transduce and operate on codes. *House of Leaves* acknowledges the print text's transduction into the nonhuman cognitive signal, while reminding us that the printed page as material artifact does not survive the transition from linear text to digital code. The text explores this situation by traversing the history of technical media from the photograph and film camera to analog and digital video. To claim that Danielewski's work reasserts humanity's unique, unrepresentable experiences, as Mark Hansen does, misses the point: *HoL* reasserts the uniqueness of ink infused into cellulose fibers.[49] Like celluloid film bases, the recursive encoding and re-encoding of media throughout *HoL* (and the history of technical media) discards the cellulose by amplifying the code printed on its surface; the code that eventually becomes capable of transforming itself into commands that modify other codes. The concern in *HoL* would seem to be not what is unique about experience but what, if anything, is unique about the printed page and whether it is worth preserving in light, so to speak, of the nonhuman cognitions on which even the printed page must now rely. It is an open question whether this transformation represents the rebirth of the novel or the beginning of the novel's dis-

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used for any medium—for the fist time in history, or for its end" (Kittler, *Gramophone*, 1). See also Manovich, *Language of New Media*, 20.

[49] "In an age marked by the massive proliferation of (primarily audiovisual) apparatuses for capturing events of all sorts, from the most trivial to the most monumental, House of Leaves asserts the nongeneralizability (or nonrepeatability) of experience—the resistance of the singular to orthography, to technical inscription of any sort" (Hansen, "The Digital Topography of Mark Z. Danielewski's House of Leaves," 606).

placement by a hybrid discourse that as yet has no name."[50] Fractal realist novel might just be the most appropriate name. Works like *HoL* are not print fictions sitting at the margins of the contemporary media ecology, as Joseph Tabbi argues, so much as they are humanity's attempts to simulate the ever more recursive and complex nonhuman cognition forming around and through technical media.

HoL explores its fractal realist aspects by splitting the narrative into at least three threads that interlock and compete with one another. One is "The Navidson Record," a documentary of the poltergeist happenings at the house on Ash Tree Lane into which the Navidson family (Will, Karen, and their children Daisy and Chad) has recently moved—the house, it turns out, is larger on the inside than the outside. Navidson and Karen supposedly splice the movie together from footage he shot with an eclectic mix of amateur videotape-based recorders and professional grade motion picture (celluloid-based) cameras. Of course, the printed text does not provide us with the actual motion picture (if it were an e-book, perhaps it could contain embedded video) but with the blind Zampanò's pseudo-academic (summary heavy) analysis of it, which is typeset in Times. Another thread contains the aspiring tattoo artist and Hollywood drifter Johnny Traunt's account, typeset in Courier, of how Zampanò's mysterious death brought the manuscript and typescript of "The Navidson Record" to him and his attempts to stitch together the fragments. The third comprises the letters, typeset in Kennerley Old Style, Johnny's mother Pelafina ostensibly wrote to him from the Whalestoe—the mental institution her husband committed her to. In addition, the work contains

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[50] Hayles, "Saving the Subject: Remediation in House of Leaves," 781.

transcripts of interviews, appendices of pictures and sketches, and an index.

These distinct narrative threads all unfold through supposedly different media and technical media: film cameras and Hi 8 video cameras record most of "The Navidson Record"; Zampanò dictated his book to various typists; and Johnny Traunt uses a combination of typewriters and handwriting. All these wind up on the printed page and therefore prove how resilient the narrative transduction can be in bracketing as noise such things as the celluloid film, ink, images, or pencil on which the narrative in *HoL* purports to depend. However, some of those media rely on technical apparatuses that are increasingly recursive and therefore cognitive in nonhuman ways, and as a consequence, the narrative signal that transduces itself between these media is partly a simulation that nonhuman cognitions have generated. Just as the text on the page re-encodes (or remediates) different media and story worlds as printed language, the nonhuman cognitions are working on the text and page itself as material to be encoded into signals that nonhuman cognitions can process. *HoL*'s pages are partly physical artifacts and partly screens that nonhuman cognitions can scan—they are like cinema screens on which ink rather than light does the writing, but also CRTs on which electron beams sometime write narratives and sometimes write the signals that only nonhuman cognitions can interpret.

We should then begin our journey into *HoL* in the same way the Navidson family does, through the TV CRT and the literally empty space it contains. The first hallway into that labyrinth appears in the living room, precisely because that is where most American households keep a TV. In this case, the TV's electric circuits produce the images and sounds recorded by the Hi 8 video cameras Navidson in-

stalled throughout the house on Ash Tree Lane; but they could as easily draw the A/C current's sinusoidal oscillation. Triggered by motion sensors and originally intended to document the family's transition from city to country life, the Hi 8s actually capture the family's descent into the darkness seeping back from the living room wall.[51] This record exists not as a mosaic of the celluloid gel's exposed silver halide crystals, but as variations in magnetic polarity and intensity that follow helical patterns across a slender tape—video tape.[52] Magnetic tape allowed images and sounds to exist on the same medium (i.e., the tape) and in the same encoding (i.e., magnetic polarities). Even though Bing Crosby's voice was the first time the masses heard sounds that had been recorded on magnetic tape, the technology has its origins in Germany during the interwar period.[53] Were it not for the significantly higher bandwidth that a multidimensional image required, Crosby's audiovisual technical image might have been encoded in that first time-delayed recording. For tape, unlike film, the technical apparatus required a codec that

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[51]The Hi 8 video format belongs to a host of invisible (to humans) signals and transductions. While Hi 8 offered better resolution compared to its predecessor (560×480, or 420 scan lines for Video 8) and VHS (330×480, or 250 scan lines), it continued to use the analog video formats NTSC and PAL, which were developed for TV transmissions.

[52]"Tape Recording Used by Filmless 'Camera'," New York Times, Nov. 12, 1951, p. 21.

[53]A collaboration among BASF (Badische Anilin- und Soda-Fabrik), AEG (Allgemeine Elektricitäts-Gesellschaft), and RRG (Reichs-Rundfunk-Gesellschaft) converted Fritz Pfleumer oxide power infused paper tape into the world's first usable magnetic tape recorder, the K1, in 1935. In a coincidence worthy of Pynchon's paranoia, BASF founded IG Farben in 1925. It's invention helped Bing Crosby avoid a nervous breakdown from live radio performances in 1947, when NBC used a later version of the machine to record Crosby's voice. Get references from "History of Tape Recording Technology."

could encode and decode a signal as information. For example, the codec would have to transform analog light and sound into analog or digitally encoded magnetic charges on the tape.

Video tape and TV transmission no longer carried images and sounds so much as encoded units only comprehensible to another technical medium, or apparatus on the receiving end. A vast chunk of the narrative transductive circuit then depends as much on nonhuman cognitive systems as it does on human bodies. These encoded signals might be radio waves propagating through the atmosphere or electrical currents moving through metal wiring. The relatively low bandwidth required for analog video also made it relatively easy to transmit via radio waves. This signal encoded in an electromagnetic wave is perhaps what flows through *GR*'s Private Paddy ("Electro") McGonigle and what Johnny Traunt hears while looking at images: "Of course these are only images, my images, and in the end they're born out of something much more akin to a voice, which though invisible to the eye and frequently unheard by even the ear still continues, day and night, year after year, to sweep through us all."[54] It sweeps through us all so long as we have a radio receiver, or better yet, a television set in our living rooms. Zampanò's blindness is therefore hardly an impediment to him watching "The Navidson Record." He does not need to see the light streaming from the surface (whether CRT or LCD) but only to receive the encoded signal that configures that surface. Sound and image exist as a stream of codes that might as easily wind up on a page as text or on a magnetic tape.

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[54]Danielewski, *House of Leaves*, 518.

Because technical media, like video tape, are closer to those regimes of coding and encoding, they do a better job at capturing the house's transformations. The Hi 8s only missed the hallway's first appearance in the living room, because the motion sensors that triggered them were attuned to human movement. "The Navidson Record," however, does provide footage of such a transformation as the camera watches Karen (and the bedroom wall) as she watches segments of Navidson's farewell tape.[55]

> The angle from the room mounted camcorder does not provide a view
> of her Hi 8 screen. Only Karen's face is visible. Unfortunately, for some
> reason, she is also slightly out of focus. In fact the only thing in focus
> is the wall behind her [...]. The shot lasts an uncomfortable fifteen seconds, until abruptly that immutable surface disappears. In less than
> a blink, the white wall [...] vanishes into an inky black. (*HoL*, 417).

A human eye's blink rate is approximately 2 to 10 Hz while a CRT's refresh rate is upwards of 50 Hz, so it makes sense that the technical recording apparatus might record what the human eye may fail to notice and then project it onto a screen for humans to view. The "immutable" surface, however, is not a wall but only a series of magnetically encoded variations in light frequency and intensity. Perhaps it eventually gets transferred over to celluloid for large-screen projection, but even then, the so-called wall is a technical image. The viewer participating in the narrative transductive loop imagines or hallucinates it as the same sort of wall he or she could touch in reality, but on the screen, and especially the

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[55]Danielewski, *House of Leaves*, 416.

CRT, it is the result of algorithms (whether transduced into hardware or software) sorting codes instead of light, plaster, paint, or whatever atoms make up a wall. The labyrinth's "inky black," then, only appears as the absence of light and sound, because whatever operates there does so in media other than light and sound, and at speeds far in excess of what human eyes and even the technical media that emulate them can record. Once the technical media cut out the human and begin operating on themselves, they re-encode the already encoded reality into a form that human cognition and even older technical media can barely grasp.

The re-encoding of the already encoded signal—this recursion—truly brings us to the zero-dimensional world Flusser wrote about. By bracketing out most of reality (even light) as noise, this signal must operate at higher and higher frequencies to re-encode the noise of the higher dimensional worlds it has left behind. As an example, consider the transition from fixed tape to helical scanning systems. In fixed tape systems, the mechanism draws the tape over the head at a constant rate and leaves magnetic impressions in a linear sequence. The faster the tape, the higher the frequency, and therefore the greater the channel bandwidth that the tape can store. Audio, whether analog or digital, requires a relatively small bandwidth compared with the two dimensions video tape had to encode. The added bandwidth of even analog video means the tape would have to move past the head so fast that it would have to be too long to store in the video cassette housing. The higher speed would also potentially damage the tape or the read mechanism during encoding or decoding. Helical scanning methods solve this problem by rotating the tape and heads so that the magnetically encoded data would

lie on diagonal paths.[56] This space-saving method opened the way for encoding higher density digital information on magnetic tape.[57] Despite those advances, magnetic tape's speed would not be able to keep pace with the higher frequencies at which solid-state microprocessors (introduced in the 1970s) could process signals.[58] The magnetic tape would eventually pass into memory, quite literally as a long-term storage medium, and lose its role as a medium from which audiovisual signals could be encoded and decoded in real time—a capacity it shared with now obsolete celluloid film.

Not surprisingly, then, the Hi 8s fail to capture the climactic moment when the house implodes upon itself and takes Navidson's twin Tom into its inky depths, the walls transform at a rate that faster than the 48 or more frames per second (fps) of a motion picture camera (the same or greater refresh rate as the CRT): "In less time than it takes for a single frame of film to flash upon a screen, the

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[56]This technology originated around in the mid–1950s through Alexander Maxey's work for Ampex and many Japanese engineers working for Toshiba and Sony. See Abramson, *History of Television*, 87 and Maxey, "Assembling a Helical Scanning Assembly"; Maxey, "Helical Scanning Assembly" for descriptions of the video tape recording systems that would use helical scanning methods.

[57]See Buslik and Pennington, "Track Following System."

[58]The rate at which a signal can flow through an integrated circuit, for example, is usually measured in Hertz. When manufactures assign a clock rate to their microprocessors, they are not indicating how fast electrons physically move through the channels, but how many cycles of computing instructions (bits of data, which are encoded in the signal) the CPU can perform in a second. The first IBM PC had a clock rate of 4.77 MHz, or approximately 4,772,727 cycles per second. Contemporary CPUs have clock rates measured in GHz and usually execute multiple instructions per cycle.

linoleum floor dissolves, turning the kitchen into a vertical shaft."[59] The problem here is not the sampling rate but the fact that it would need to far exceed what humans and even the technical apparatus, like the video camera, can register. Rather than continuing to manipulate and tweak the image or the sound itself, we must instead turn to the algorithms that encode and decode them. It is this recursion of the encoded technical image into itself that forever removes it from human perception and the grasp of earlier technical media like the celluloid camera. Navidson supposedly returned to get better pictures of the house (and its vast interior), ordering substantial and expensive new recording equipment such as "high speed film, magnesium flares, powerful flashes, and [...] a thermal video camera."[60] All that equipment either reacts to or produces light, and therefore cannot capture or comprehend the nonhuman cognitions that utilize electrical impulses or light itself to encode information about light's intensity and wavelength.

Yet the page is neither a technical media nor a technical apparatus, and Navidson's final excursion into the labyrinth, "Exploration #5," brings this distinction to the fore. He takes the ubiquitous Hi 8s into the labyrinth, since they are the technical apparatuses that have replaced human eyes and ears throughout *HoL*—Navidson needs them in the labyrinth if he is to see and hear anything. Unfortunately, he depletes the batteries. He turns to a microcassette recorder "to collect his thoughts and a 16mm Bolex" motion picture camera "to capture the sputtering bits of

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[59] Danielewski, *House of Leaves*, 346.

[60] Ibid., 418.

light."[61] Video tape gives way to silent celluloid film (here it is 16mm, probably Super 16mm, Kodak or Fuiji film) and audio tape. These older technical media, however, cannot adequately record the labyrinth, which Hayles and Hansen rightly equate with the digital realm,[62] because the motion picture camera now works uses light directly rather than as an encoded signal. Indeed, ensuring that there is sufficient light suddenly becomes a problem for Navidson, as he must start throwing out flares to illuminate the labyrinth and exhaust flashlight batteries as he attempts to navigate. The text attempts to compensate for this decoding by re-encoding the motions the camera would have recorded as spaces on the page—a procedure we might call *kinomimetic* typography. The direction and rate at which the flare falls into the void becomes the spacing and density of words per page. This kinomemetic typography, however, takes the words out of the narrative transductive loop and repurposes them as codes for regulating the technical apparatus's signals.

These printed letters still take the form of words and complete sentences, rather than the aggregated statistical masses that Claude Shannon used, for example, to calculate the entropy of *Finnegans Wake*.[63] Humans, not technical apparatuses, read and interpret them. Having run out of technical media, Navidson therefore turns to a book called *House of Leaves*.[64] His eyes like the camera ap-

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[61] Danielewski, *House of Leaves*, 465.

[62] See Hayles, "Saving the Subject: Remediation in House of Leaves," 781, and Hansen, "The Digital Topography of Mark Z. Danielewski's House of Leaves," 607–8.

[63] Weaver and Shannon, *The Mathematical Theory of Communication*, 56.

[64] Danielewski, *House of Leaves*, 465.

paratus need light to read the words on the page, but the labyrinth's blackness provides none because like the CRT, it relies on electrons (not photons) carrying encoded signals. Eventually Navidson must burn the book's pages to provide the light he needs to read it. The printed text cannot provide the synchronization as the encoded signals that pulse through the technical apparatuses, for the narrative transductive loop relies on human not nonhuman embodiment for its contextual frames. In a footnote marked with a leftward point arrow, Zampanò remarks on the absence of coherence.[65] "Exploration #5" therefore ends with "nearly six minutes of screen time [that is] black."[66] Light, the essence of photography and cinema, no longer shoots from the projector because the labyrinth owes its existence not to light but recursions of code.

Even when optical fiber can transmit digital information, the reintroduction of light does not bring back the camera or tape recorders. Besides moving at the cosmic speed limit, the light jetting down the fiber is worked on by computers that see not the light but only instructions for the algorithms that reconfigure the computer's memory and circuits. Light ceases to be meaningful in any contextual frame that cognition in the narrative mode might craft for it and instead becomes the raw material into which nonhuman cognitive signals can imprint and propagate themselves. This process is invisible (like the labyrinth) to human eyes and is indeed potentially hostile to human attempts to enter, catalog, and explore it. This hostility does not manifest itself as body-shredding violence. Instead, we see friction between human narrative cognition using technical media to construct

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[65]Danielewski, *House of Leaves*, 468.

[66]Ibid.

a plot, to understand the labyrinth, and, at the same time, nonhuman cognition using the same technical media to form themselves.

Narrative itself becomes less important as a topic of the print book under these conditions. Hence the fixation in Chapter 9, "The Labyrinth,"[67] on the how text is laid out on the page's surface. Notes run along the margins from top to bottom and in reverse; and a blue framed note runs through the chapter that reads forward on the recto side but backwards on the verso, as though the page were transparent but the text was not. Much of the text in that chapter appropriately covers topics related to mazes, landscaping, and, of course, measuring and laying out architectural spaces. How one prints and orients the text on the page relies on a host of traditions and conventions that are part historical contingency (the use and placement of footnotes) and part technical necessity (the high contrast between ink and page). However, these constraints do not necessarily apply when the text is being encoded and decoded as an electrical signal with statistical not narrative organization. While this kinomemetic typography and self-referential page layout makes extracting any definitive meaning—narrative or otherwise—from *HoL* difficult, it shifts the active dimensions of the text away from the *deep* meaning and significance provided by the narrative transduction and toward the *surface* encoded in the electrical signal.

This situation is an excellent opportunity for print texts, because photographs and even motion pictures can no longer claim to record, store, and project reality. Those technical media can therefore no longer use their verisimilitude or

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[67]The titles are given in Zampanò's Appendix A, p. 540.

mimetic realism to claim any ontological priority over printed text. Indeed, the very technical apparatuses that now encode images and sounds treat those multi-dimensional phenomena as one-dimensional sequences of many zero-dimensional particles—almost like words aligned on a page. *HoL* does not hesitate to draw attention to this situation. The academic commentators on Navidson turn their attention to the undermining of veracity that first staged photographs and now "electronic manipulation"[68] afford whomever or whatever creates images. Gone is Arnheim's praise that the reality it captures also produces the photograph, as is even McLuhan's warning that "to say [...] 'the camera cannot lie' is merely to underline the multiple deceits [...] now practiced in its name."[69] Now that the image derives from a series of encodings and decodings overseen by technical apparatuses, we can no longer speak of a direct correspondence between the camera's and the human's eye. The photograph and motion picture are equally capable of existing as a data streams awaiting processing through the microprocessor's transistors and registers. The computer can interpret these digital codes either as instructions for executing commands or as data. By entering this nonhuman transductive loop, the image becomes not a record or registration of something physical that exists independently but a stream of bits that may modify themselves irrespective of whatever real object they were intended to represent.

HoL responds to these possibilities, which it cannot explore, by returning to the very cellulose fibers of the page itself. These fibers' physical properties cannot make the transduction into the computer or the blackness of the labyrinth.

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[68] Danielewski, *House of Leaves*, 141.

[69] See McLuhan, *Understanding Media*, 192, which Danielewski also cites on p. 141.

Johnny Traunt and the editors transcribe ink spills, whether by them or Zampanò, as X's across printed page,[70] thereby drawing our attention to the fact that the page in the bound book resting in our hands is the product a complex mechanical process that converted the manuscript and typescript into a form that a lithographic press could print as a book. Perhaps like the desolate Navidson burning the very pages he reads, Zampanò may have accidentally scattered hot ashes on his typescript and manuscript, leaving minute holes in the page, which Truant decides to remediate as "[ ]" with the space between the brackets presumably being analogous to the hole's size.[71] Photographs reproduced in Zampanò's Appendix display these ink spills and burn marks in yet another mediated form.[72]

This intense attention to the page's physical material, however, cannot obscure the fact that *HoL* owes its very existence (even as printed artifact) to the conversion of the printed page into a technical image, into a digital construct. Despite his claims during an interview of only needing a pencil to create the novel, Danielewski in fact needs quite a bit more.[73] Besides the time that page layout software like Adobe InDesign saved him, it also signaled a shift in the

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[70] See *House of Leaves*, 38 for the first example that Truant attributes to Zampanò, but he later admits to accidentally covering entire pages in ink (Danielewski, *House of Leaves*, 376).

[71] Johnny explains his typographical convention for representing the burns on *House of Leaves*, 323 and then we see the results on *House of Leaves*, 327–38.

[72] Danielewski, *House of Leaves*, 550–552.

[73] In an interview he proudly proclaims: "I wrote out the entire thing in pencil! [...] You hear a lot of people talking about how computers make writing so much easier because they offer the writer so many choices, whereas in fact pencil and paper allow you a much greater freedom." McCaffery and Gregory, "Haunted House: An Interview with Mark Z. Danielewski," 117.

publishing industry toward a much larger economy of scale. Computer set books significantly reduced the time and cost of codex printing (whether through lithographic or other processes) than during the mid-twentieth century.[74] *HoL*'s text pays homage to this transition from mechanical to digital typesetting in its use of nonprinting characters. Small rectangles appear on pages 359 and 360 to indicate that the font software did not contain the required glyph, because the designer did not create one, or because it represents a control character. Used for in-band signaling, these characters control or regulate the how the signal is processed. Control characters might include "backspace" (BS, \b, ^H), "line feed" (LF, \n, ^J), "form feed" (FF, \f, ^L), "carriage return" (CR, \r, ^M) or "escape" (ESC, \e, ^[), whose function varies with the device.[75] While the human reader might see them as characters among others from the alphabet, for the computer they are also instructions. Page 360 even contains mock code for an embedded equation to be rendered later by software such as LaTeX: "equation: 1/a =□ EMBED "Equation"* mergeformat □ □ □."

This so-called text was not meant for human consumption but as instructions for the nonhuman cognitions that would process the technical image from which the text we read and hold in our hands has been structured. The labyrinth at the center of Danielewski's *House of Leaves* is the recognition and representation of the nonhuman cognition that operates beyond human awareness and is only

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[74]Various methods exist to transduce a digital page layout to a cylinder, drum, or press. See Chapter 4 of Kipphan, *Handbook of Print Media*.

[75]"Form feed", for example, might cause a printer to eject the current page or a video terminal to clear the screen.

revealed by the mediating interfaces responsible for its creation. In so doing it demonstrates a path forward for the print novel—one that will implicate it in nonhuman cognitions just as film has been with digital cinema and streaming content. It does, however, signal that the realist novel—whether social, historical, or psychological—is over and that fractal realist one has begun.

Chapter 6

Conclusion

To point out that the age of print or film is over may be accurate but also neglects the larger shift from human to nonhuman forms of cognition. From a human perspective, the medium of print and the technical medium of film were the vehicles to help carry on the narrative transductive loop, and so they augmented whatever cognition the brain performs in concert with the rest of the body. The obsolescence of one medium in the face of another is scarcely a surprise and hardly something to mourn. While the new technical media necessarily entail changes to the way human bodies produce, participate in, experience that narrative transduction, the overall pattern or signal—if you will—that we recognize as a narrative continues. More important than the technology that carries narrative is the fact that the narrative transduction can alter its embodiment with such relative ease; that it can re-encode itself for a new media and technical media.

Once we automate the encoding and re-encoding process in cybernetic automata like calculating machines and technical media like the photograph, and

motion picture projector, the automated technical apparatus becomes so implicated in some aspects of human cognition that it gains its own form of cognition—one that operates by means that are foreign to human cognition in the narrative mode. The novels, movies, photographs and other media that we think of as simply telling stories and extending our cognition, then lead a double life. They are on the one hand, tools to assist and store human thought, and the other, the components of a cognition that cares very little for and has no significant need for narrative—even if it excels at simulating it. The effects on literary fiction, for example, are neither negligible nor worth resisting, for the more scholars and authors resist in word and argument the presence of a nonhuman cognition operating through their work (or the encroaching of the technical image, to use Flusser's elegant term), the more they contradict themselves. How many people compose linear text by hand either initially or entirely? Even if we write notes or paragraphs with pen and paper (themselves just the technical innovations of a more distant time), we nevertheless re-encode them in a text editing computer program, because no publisher would accept a handwritten submission

As scholars such as Jonathan Crary, Katherine Hayles, and even Friedrich Kittler have argued over the years, the very technical media we use to augment our senses and aid our thinking enters into a feedback loop with us. The humans become more like machines and the machines more like humans—the distinction becomes less ontological and more the marker of a historical period that has now passed. Whether it is the tide washing away the human at the end of Foucault's *The Order of Things,* or the recognition that the distinction between Nature (human bodies) and Culture (human technology) was always an illusion, albeit a pro-

ductive one for those people (and things) who invented it.[1] Human bodies were always technical, and therefore so was the cognition that hovers around them. It is this bio-technical cognition and the phylogenetic and ontogenetic co-evolution of human bodies and techniques that makes a re-examination of what we mean by the term *cognition* necessary. I have approached this point by showing how the terms cognition, mediation, and technology blur together—a blurring that appears all the more obvious in the twentieth century as nonhuman systems exhibit all three.

We cannot talk about cognition, then, as either present or not present, as though it were a thing, or an object, to be handled, analyzed, or otherwise isolated. Simondon's concept of transduction offers a way of reconceptualizing cognition as the successive and recursive activity of a system on itself and its products. In this way, the parts of the system or its environment cease to be things in themselves and become media that can transmit or convey something else, like a code. The mRNA, for example, of a prokaryotic or eukaryotic cell ceases to be a chain of nucleic acids when it enters the endoplasmic reticulum, bonds with a ribosome, and provides the template for a protein. This new molecule created not from the nucleic acids themselves but from the sequence they encode can then either be the building material for new cells or perhaps an enzyme that itself operates on other proteins or mRNA itself.[2] While some may not consider this an in-

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[1] I am thinking specifically of Bruno Latour's argument in *We Have Never Been Modern* that the division modernity draws between Nature and Culture was an illusion—one we must now do away with.

[2] An enzyme called RNA polymerase is responsible for transcribing messenger RNA from stretches of DNA. The same DNA it reads encodes RNA polymerase's amino acid sequence. Bacteria, animal

stance of cognition, I can only say that not acknowledging the cognitive aspects of such recursive activity sets the bar too high and treats cognition as an all or nothing phenomenon. We should instead see cognition as a continuum of increasing complexity that simultaneously points to the obvious difference between a cell's protein synthesis and human consciousness's introspection and self-recognition, while also showing the continuity between them. The connection being the ability of both processes to treat one medium as the material or ciphers for a new system or code.

Technical media, which we usually think of as mechanical and electrical apparatuses, now exhibit the same recursive behavior when they transduce one medium (e.g., electricity, or gears) into another, and thereby create a new system. In their case, it is the signal that encodes information, whether for human operators or other systems in the machine. Electricity ceases to be a stream of electrons and instead regulates the systems' operations or encodes instructions that perform the regulatory function. In effect, the components are no longer mere parts, for they convey energy and material that informs, quite literally, the system. It is then the action that defines the system as functioning or not functioning, rather than the presence or absence of individual pieces or materials. It is this conversion of materials into media through which action occurs that constitutes the beginning of cognitive and technical activity (whichever term one prefers). The recursions of these actions in themselves adds complexity and the possibility for transformations that simpler systems could not have effected on

cells, and even some viruses encode for this essential enzyme. See Hurwitz, "The Discovery of RNA Polymerase."

their own.

The increasingly complex systems that transduction makes possible are then cognitive to the extent that they enact Flusser's scheme of dimensional reduction. Each recursion of the system into itself, of the conversion of one medium into the activity of another brings with it the encoding of the previous medium. While this code necessarily simplifies or leaves out all aspects of the predecessor, it also makes new configurations possible. We saw this type of filtering at work in the activity that separates pattern from noise during transduction. The transductive process creates the pattern that distinguishes itself from noise, and in so doing re-encodes the former system into a so-called pattern that is useful to and constitutive of the new system. Flusser's scheme looks specifically at the transductions among different technical regimes that at first congregate around the human and then migrate to the nonhuman cognition. The three-dimensional universe analyzes the world into subjects and objects; the two-dimensional image or model, re-structures that world in relations among objects; the one-dimensional text encodes those relations into logical, historical, or narrative sequences; and finally, the zero-dimensional particle, or computer algorithms re-encodes the line as just one option in a universe of possible configurations whose structures are statistically rather than logically or narratively articulated.

We are justified in calling these nonhumans who manipulate and exist in the zero-dimensional universe cognitive precisely because they have generated a signal that carries information that is meaningful, i.e., actionable, to them and not necessarily to humans. It does not matter whether the signal exists as variations in an electrical or optical current, but only that the technical apparatus can use it

to execute an algorithm. The signal is meaningful in itself and operates on itself. Technical apparatus and media evolve partly to better transmit that signal, to meet its demands, and the signal in turn changes according to the capacities of the technical apparatus carrying it. The best example of this co-evolution and mutual reconfiguration is currently the computer in which nonhuman cognitions shift bits among memory addresses and reconfigure their circuits to execute whatever algorithms have bee programmed into them.

Any part of the encoded signal in the nonhuman cognition is potentially instruction or data. This distinction is only relevant to the algorithms at work in the circuits not the human user. To understand how it is possible for a number that exists as variations in a current, we need to remember John von Neumann's early computer architecture decisions.[3] Every computer consists of a processing unit (i.e., the arithmetic logic unit and processor registers), a control unit (i.e., the instruction register and program counter), main memory, and mechanisms for input and output (to the human user). Binary numbers point to memory addresses, which themselves hold binary numbers. These numbers in memory may be either instructions or data, for all the control unit does is load the number stored in memory into the instruction register which they feeds them to the processor. These instructions tell the processor how to change the numbers stored in main memory or where to relocate them. Indeed, computer programming would not be possible without this inherent ambiguity of instruction and data. When a contemporary computer programmer sits down at a keyboard and types some-

[3] Neumann, "First Draft of a Report on the EDVAC."

what English-looking commands into a file, he or she is actually typing a script that another program, the compiler, will process into the instructions hardwired into the processor, i.e., convert the text into machine code. Human programmers do not write computer programs, other computer programs do.[4] Computer programs may therefore be self-modifying, and a relatively recent trend allows the computer to modify its programs in a way that emulates the natural selection pressures exerted on biological organisms.[5]

Kittler's disdain for user interfaces, "protected modes," and other systems that impose a strict division between instruction and data reflects the ease with which we may ignore how alien the computer is to our modes of thinking and perceiving. We simply throw a coat over the parts we would rather not see, or, more appropriately, cannot comprehend with text or narrative.[6] He ignores, however, the possibility that the computer is the site for a nonhuman cognition that continues neither human desires nor the supposedly inexorable logic of information optimization. Indeed, Geoffrey Winthrop-Young, one of Kittler's primary exposi-

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[4]Though they may be unaware of it, the ambiguity of instruction and data makes it difficult to defeat many viral programs and malware. What computer security experts call *arbitrary code execution* makes it possible to trick the operating system into marking data containing memory addresses as executable. Though a PDF, for example, may not be an executable file, a malicious user might be able to trigger an error in an email program or viewer that temporarily executes some code stored in the file.

[5]Genetic programming, for example, allows the computer to alter and design its own algorithms to better suite whatever problem or data it is presented with. See for example, Koza, *Genetic programming IV*.

[6]"Protected Mode" and "There Is No Software" printed in Kittler, *Literature, Media, Information Systems*.

tors in English, speculates that the media theorist wants "somebody who [...] has such mastery over the machine code that he can directly interact with basic operating levels of digital systems without any need for intermediary software".[7] Aside from Neo in *The Matrix* no human will soon come close to achieving such a lofty union with hexadecimal computer code.

I do not mean to be too hard on Kittler, because my proposal and his are not very far apart. His research program essentially calls for the removal of humans from history in favor of various technologies of information processing. Indelible human traits, like the soul, are simply the result of inscriptional technologies (or programs), like language or writing, imprinting themselves on humans. The computer optimizes those technologies and largely removes humans from the loop. Like used up husks, they can just be discarded. My insistence that cognition be seen as the transductive recursions of media into one another, as the conversion of one system into information for another, does not seem to disagree with Kittler's scheme so much as call our attention to what he forgets—that systems of enciphering and encoding are always producing and using media, and that human bodies remain an integral part of that system. I would also add that transduction, unlike Kittler's Foucaultian history of discourse, gives a sense of how these codes, technologies, or active assemblages of material come to define themselves. Human bodies are just as important to the evolution as mechanical or electrical ones.

Indeed, it was human arousal—in the sense of any elevated emotional state,

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[7]Winthrop-Young, *Kittler and the Media*, 77–78.

whether induced by fear or sex—and imagination that help propel the development of the media and technical media necessary for the nonhuman cognitions discussed in this work. The pursuit of better technologies—novels, photographs, movies, video games—to capture, store, and project story worlds and narratives was just as important to the development of cybernetic automata as war or previous technical developments. Kittler is fond of pointing to the importance of the war in the evolution of the computer and other technical media, but we must also remember that the surprise, anxiety, sexual desire, bloodlust, and other irrational desires that accompany all war belong decidedly the human brain's origins in a highly competitive, quickly changing ecology. Nonhuman cognitions remain just as precariously situated in that ecology as the humans who build and support them.

Fractal realism acknowledges the complicated interrelations of these divergent cognitive transductive loops, for we now live in a world where human cognition in the narrative mode and nonhuman cognition work upon one another. Because narrative and nonhuman cognitions rely upon the same technical media, we must relocate the discussion of the literary to this new domain in which the narrative mode competes with and relies upon the statistical (or fractal) operations of the nonhuman cognition. This attention will be particularly necessary as written texts increasingly incorporate into themselves the very data structures that nonhuman cognitions use to produce human-readable forms of those texts, whether books printed from digital files, or text drawn on computer screens. Human cognition in the narrative mode will simply be one of many participants in the production of literary works.

Appendix A

Hello World Code

Hello World!

A.1 Python

```
print "Hello World"
```

A.2 Java

```
//Hello World in Java

class HelloWorld {
 static public void main( String args[] ) {
 System.out.println( ''Hello World!'' );
 }
```

```
}
```

A.3   C++

```
//Hello World in C++


include <iostream.h>


main()
{
 cout << "Hello World!" << endl;
 return 0;
}
```

A.4   x86_64 Assembly code

```
[bits 64]
global _start


section .data
message db "Hello, World!"


section .text
```

```
_start:

mov rax, 1          ; write(int fd, const void* buf, size\_t bytes)

mov rdx, 13         ; the value of size\_t in bytes

mov rsi, message    ; the value of int fd

mov rdi, 1          ; the value of const void*

syscall             ; tell the system to execute write(1, message, 13)


mov rax, 60         ; exit(const void*)

mov rdi, 0          ; the value of const void*

syscall             ; tell the system to execute exit(0)
```

A.5   HEXDUMP

```
0000080 0001 0000 0001 0000 0003 0000 0000 0000

0000090 0000 0000 0000 0000 0200 0000 0000 0000

00000a0 000f 0000 0000 0000 0000 0000 0000 0000

00000b0 0004 0000 0000 0000 0000 0000 0000 0000

00000c0 0007 0000 0001 0000 0006 0000 0000 0000

00000d0 0000 0000 0000 0000 0210 0000 0000 0000
```

A.6   A Word on CPU Operation

Contemporary microprocessors differ greatly from the early CPUs of the 1950s, so we should understand the CPU as referring to a general structure. Regardless of whether they use vacuum tubes or transistors, CPUs execute a sequence of stored instructions, otherwise called a program or algorithm. A control unit fetches instructions and data from memory, and translates them into a form that the Arithmetic Logic Unit (ALU) can process. The ALU performs addition and substraction as well as logical functions like AND, OR, etc. Contemporary microprocessors also include a Floating Point Unit to perform calculations with real numbers beyond the integers handled in the ALU.

The CPU typically cycles through four steps when executing an instruction: fetch, decode, execute, and writeback.

Fetch

True to its name, the fetch command fetches an instruction (or data, they are basically the same thing) from memory. Which memory address to fetch, however, is determined by the value stored in the CPU's program counter (or instruction pointer on the Intel platform) register. This value effectively indicates where the processor is in the program sequence. Once fetch executes, it increments the program counter register.

Decode

Decode indicates which command the CPU will execute by breaking the instruction into an opcode, which indicates the operation to perform, and the arguments that operate needs, such as a numerical constant, a register, or main memory address.

Execute

As the name implies, this step executes the operation specified by the opcode that the decode step extracted. Each CPU's components (or microarchitecture) are configured to perform the various operations specified in its instruction set architecture.

Writeback

This final step, simply, writes the result of the execute step to memory—either a processor register or a main memory address. The output of some operations modifies the program counter, or instruction pointer, and therefore is not so much a result written back to memory, but a program jump. These jumps are crucial for algorithms that require loops (e.g., for and while loops), conditionals, and calls to other functions.

A.7   Processor Registers

Registers are relatively small amounts of memory integrated into the cpu. Since they hold working instructions and data, it is vital to have them as close to the alu as possible. Since most cpus operate much faster than main memory and the system bus, this proximity eliminates the lag associated with fetching instructions from main memory. The most common registers are: data registers, address registers, general purpose registers, and control and status registers.

- Data registers hold numeric values (such as integers and floating point values), characters, and arrays.
- Address registers store addresses of locations in memory.
- General purpose registers store either data or addresses and are therefore combined data and address registers.
- Control and status registers include the program counter, instruction registers, program status word, which gives the status of an operation.

Programming in assembly language involves manipulating these registers.

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