

[1]

Hello from Earth

Finn Brunton

Human beings write a great deal about the essence of matter. It would be nice for matter to begin to write about the human mind.

—Lichtenberg

Do Two Tape Recorders Communicate?

J. C. R. Licklider and Robert Taylor coauthored a landmark paper in 1968: “The Computer as a Communication Device.” It was a major public step in shifting the understanding of what computers are *for*: from massive specialized calculators to communications platforms for the interaction of many users augmented by computation. It is part of the same cultural and technological moment as Douglas Engelbart’s *Mother of All Demos*, a theatrical happening (part technology showcase, part live science fiction film) at the 1968 Fall Joint Computer Conference that displayed mice, outliners, real-time document collaboration and word processing, the nuances of linked documents, and other hallmarks of interactive and interpersonal computing (Bardini 2000, 138–42). (It’s part of the same long event of inventing interaction that included Kay, Papert, and Piaget, so elegantly chronicled and analyzed by my colleague Mercedes Bunz in chapter 2 of this book.) Like Engelbart’s showcase, Licklider and

- 2 Taylor's article was only partially about the technology itself—about the metal, glass, and code: it was also a vehicle for communicating a feeling.

With a background in experimental psychology, Licklider was always conscious of the human in the newly emerging loop that Engelbart (1962, 2) called the “whole system” of people and machines. Licklider (1988, 30) documented his thought process, folding himself in as an experimental subject, a test pilot, one of the first people to be sitting at the computer console “four or five hours a day.” He wrote about the feeling of hitting the “brain–desk barrier,” assimilating the new assembly of information pulled together and presented by this networked library-computer (Licklider 1965, 102). He talked about the “motivational trap” of a cunningly built interactive terminal, drawing you deep into the structure of a problem or a concept (Greenberger 1962, 208). “This is going to revolutionize how people think,” he repeated (Licklider 1988, 29). Not individual people, either, but groups, institutions, communities: “a flow of metal and ideas and of flexibility and change,” he wrote, in a single phrase that captures the poetic thrill of engineering not a particular technology but the overarching “system system” (Licklider 1963, 628). Forget processing payroll or running Navier–Stokes equations: this was a change to human *work*, in the deepest sense, both individually and collectively. Engelbart called it “augmentation”; Licklider called it “symbiosis.” “The Computer as a Communication Device” was a path from new communication to new forms of *community*, sharing with “all the members of all the communities the programs and data resources of the entire super community” (Licklider and Taylor 1968, 32).

To make this case, in 1968, Licklider and Taylor first had to clarify a term: “A communications engineer thinks of communicating as transferring information from one point to another in codes and signals.” That’s not what they meant by “communication.” They were trying to get at something else: “our emphasis on people is deliberate” (21).

“To communicate,” they wrote, “is more than to send and to receive. Do two tape recorders communicate when they play to each other and record from each other? Not really—not in our sense. We believe that communicators have to do something nontrivial with the information they send and receive” (Licklider and Taylor 1968, 21). They talked about “the richness of living information.” About being “active participants” whose “minds interact,” about “creative aspects” that “transcend” the transmission of information. What this turned out to mean for them, in practice, is using computers to produce models that people can manipulate in real time over the network. By “communication,” they meant the comparison of mental models.

This may not seem like much after all the talk of transcendent interacting minds, but Licklider and Taylor were dealing with the assumptions of a particular audience schooled in Claude Shannon’s information theory, where “communication” can indeed be defined down to the transmission of information between senders and receivers over channels. By emphasizing the role of interacting humans in the use of computers, they were taking up a novel and potent idea. Licklider and Taylor were trying to counteract the model of communication-as-information-transmission to make a case for time-sharing and better user interfaces. They drew strategically on the deep resonant legacy of the word *communication*. But where does this powerful resonance come from—and what does it actually mean to communicate?

Shannon, approaching it as a telecommunications engineering problem, simplified communication to *information*: any exchange can be understood quantitatively in terms of entropy and probability, in transmissions between senders and receivers over variably noisy channels, and thus the coding, compression, and capacity of channels can be designed appropriately. Warren Weaver, who introduced, popularized, and expanded on Shannon’s work, wrote in the introduction to the landmark *Mathematical Theory of*

- 4 *Communication*, "The word *communication* will be used here in a very broad sense to include all of the procedures by which one mind may affect another. This, of course, involves not only written and oral speech, but also music, the pictorial arts, the theater, the ballet, and in fact all human behavior" (Shannon and Weaver 1949, 3). Weaver was making the classic cybernetic rhetorical move, listing a whole family of seemingly disparate things all linked together by the power of the theory: all can be understood informationally, starting from a minimal state with no particular content beyond the probability of any given bit.

If we squint a little, this approach is similar to very different areas of media and communications studies (each answering the question, as Bunz puts it, of the "force" at work in any act of communication beyond what is conveyed). McLuhan, amid all his Joycean hubbub, proposed a model of media that is not dissimilar: the actual content of a book, a movie, a TV show, is more or less a *distraction* from the medium itself, which is what really communicates. The medium shapes linear print minds who sort the world into taxonomic ontologies, and it shapes "cool" tactile global villagers who listen into the acoustic space of broadcast for distant cultural thunder. The content is not what we should be reading if we want to understand what's going on. McLuhan was the mentor and inspiration to USCO, a new media arts collective devoted to evoking the new consciousness theoretically made available through the immersive experience of electronic media. They built light installations and optical meditation machines and environments like *The World*, a colossal project in an airplane hangar in Garden City with eighteen slide projectors controlled by a repurposed IBM mainframe, 16mm film projection, and cutting-edge real-time analog video (Kuo 2008, 136). McLuhan spent some time in person with USCO, and Gerd Stern and Michael Callahan once had to drive him to the airport from the University of Rochester, in October 1964. McLuhan was getting into one of those now-rare prop planes with a stairwell in the tail. "I remember," recalls Callahan, "Marshall walking up the stairs and us standing below and

seeing him disappear into the plane. But then we saw his legs, his feet came back a few steps, and he leaned out and said, 'Disregard the content and concentrate upon the effect'" (Kuo 2008, 133).

Disregard the content: in McLuhan's analysis, to get at what is happening in the act of communication, we can deliberately ignore whatever is being communicated, which is generally a mere epiphenomenon of the *event* of a particular medium, whether movable type or TV. His famously odd remark about the electric light—that it's a medium, the only medium, that has form but no content—makes sense in the context of his argument: electric light carries no information of its own, beyond off and on, but its presence changes how we live and how we think, "the change of scale or pace or pattern that it introduces," in ways that escape our observation precisely because we focus on what the light falls on, or what the newspaper article is about (McLuhan 1994, 8).

Similarly, in a more nuanced approach, JoAnne Yates (1989) and Cornelia Vismann (2008) understand how communications systems—particularly the tools of bureaucracy and management, files, forms, and paperwork—interpellate people, calling them to account and putting them into all kinds of arrangements and subject relationships. It's not just the policeman Bunz describes, hailing us in the street, but also the citation he issues and the paperwork we must fill out. The preset fields, systems of identifiers, and needle-sort card files *order* us, in both senses of the word, and do so in their structure and not just their written content in ways that exceed the kind of interpretative tools we've developed. Process generated, the universe of memos, forms, circulars, manuals, reports, and tables assembled into "control through communication" constituted a coordination mechanism that used words in enormous volume to increase efficiency across firms. The whole tool kit developed for reading and interpreting written media—hermeneutic approaches, textual analysis, and criticism—falters in the face of the most quantitatively significant written modes that shape our lives: bureaucratic and legal documents and the boxes, cabinets, shelves, and pallets of paperwork.

- 6 Vismann draws on Friedrich Kittler, who most purely exemplifies this strategy of getting to the heart of “communication” and “media” by subtracting what naively seems to be the most important part—the subjective, interpersonal content, the experience of communicating. Kittler (1990, 370) builds directly on his reading of Shannon’s work, with the humans on either end of the line merely distractions, atavistic holdouts whose fixation on meanings and inner experience keeps us from seeing the operation of the system of communication itself:

An elementary datum is the fact that literature (whatever else it might mean to readers) processes, stores, and transmits data, and that such operations in the age-old medium of the alphabet have the same technical positivity as they do in computers. . . . What remains to be distinguished, therefore, are not emotional dispositions but systems.

That parenthetical, with its casual dismissal of most of what we might think literature involves, has the chilling mildness of HAL 9000 locking the human out of the ship in *2001: A Space Odyssey*. Kittler’s move in the media theory of his time was not simply to apply ideas from Shannon, Turing, and sound and image reproduction technologies to get new insights into media as such but to read *backward* from these developments. It’s not that communications media are now different. They have always “determine[d] our situation,” in his famous phrase, from flowing humanist-Romantic handwriting and magic lanterns to ancient Greek music and mathematics (Kittler 1999, xxxix). (In this, he inverts McLuhan’s other key tenet—that media are “the extensions of man,” expanding and externalizing our bodies and senses—by making humans the extensions of media.) Depersonalized mechanical and electronic media just make that determining power more obvious.

If we accept Kittler’s (2010) argument, then Weaver is not wrong to write that the mathematical theory of communication can apply to “in fact all human behavior.” With that theory in mind, Kittler

asserts, we can give a better (truer, more accurate, more useful) account of media than, for instance, “literary scholars” with a “trivial, content-based approach to media” (31). “Let us therefore,” Kittler writes, “forget humans, language, and sense in order to move on to the particulars of Shannon’s five elements and functions instead” (44). (It must be said here that Shannon himself, a humble and clear-eyed scientist, distrusted the hyping of his theory, even within the scientific and engineering community: “It has perhaps ballooned to an importance beyond its actual accomplishments,” he wrote in a 1956 editorial. “Seldom do more than a few of nature’s secrets give way at one time” [3].)

Kittler read Shannon carefully and came out with a model arguing that we miss the main event of communication, the actual operation of the network of discourse, if we are distracted from close attention to the storage and transmission of data by people’s alleged inner lives and subjectivity. Licklider, who also read Shannon very carefully (as well as knowing him personally), came to precisely the opposite conclusion: “A communications engineer thinks of communicating as transferring information from one point to another in codes and signals,” he wrote with Taylor. The danger lay in having too shallow, too *depersonalized*, an understanding of communication. Cutting the humans out of the loop was a design problem, producing models of computer networking that couldn’t enrich human thinking. Licklider was getting at what Engelbart, in 1962, called communication technologies as “a way of life”:

We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human “feel for a situation” usefully coexist with powerful concepts, streamlined technology and notation, sophisticated methods, and high-powered electronic aids. (1)

“Do two tape recorders communicate when they play to each other and record from each other?” No, said Licklider and Taylor: the communicators have to do something with the information they send and receive—something *nontrivial*, they write, in the

- 8 mathematical sense of a trivial proof being easy, obvious, productive of a shallow truth.

Again, not to make too much of semantics, but notice the clashing “trivialities” here: for Kittler, the content-based, human-centric approach is a “trivial” one, whereas for Licklider and Taylor, the mere transmission of signals is the trivial part; the “nontrivial” happens somewhere between the interface, the computer, the human mind, and the interpersonal community of collaborators.

What I want to argue for here is a third position that doesn't supersede the prior work but builds on it. It starts not from people nor from media in general but from *computing* in particular. In this, my argument supplements studies of digital formats and interfaces (e.g., Sterne 2012; Bardini 2000; Bunz, chapter 2), protocols (e.g., Galloway 2004; Bratton 2016), and infrastructures (e.g., Starosielski 2015; Edwards 2003; Sandvig 2013)—but it comes to the problem of understanding the effect of digital networks on communication by a different route and with a different destination. I will demonstrate that the concept of trivial or nontrivial communication has become much more ambiguous and complex to discuss in the thirty years since Kittler and the fifty years since Licklider and Taylor's foundational work. I will make the case for this position in three parts: first, by outlining the hybrid, social-technological complexity of the seemingly simple matter of keeping time among networked computers; second, by discussing the limited role played by humans in the communications taking place over the internet and associated technologies; and finally, by presenting the history of formats for communication with alien intelligence as offering useful analogies to our situation. In a mirror image of Bunz's essay, I assert that we can productively reimagine *what we are talking to* when communicating with digital systems and considering their communications with us. This argument does not push humans to the margin, after Kittler—as vacuous metabolic vehicles across which discourse networks transact, like the parasitic typewriters in a William Burroughs story—but neither does it put them at the center of the story, as Licklider and Taylor do. I will start by asking

Mutually Suspicious Clocks

Much of what structures contemporary networked life and digital media is “tape recorders” talking to each other, understood as various forms of addressable data storage, processing, and retrieval. The most active areas of current digital communication—analyzed qualitatively or quantitatively—are almost entirely tape recorders in networks of exchanges, for which the humans are only of third- or fourth-order consequence. (This is another way of phrasing the “layers” and stacks that Bunz describes in detail when we look at digital media in particular.) These are areas where the idea of “triviality” becomes very tricky.

Consider the problem of the clock.

The clock is the very model of dehumanized Machine Age operations, illustrated by the people who embraced it as the new model of work and life, like Alexei Gastev's ultra-Taylorist institutes incorporating clock rhythm into the cyclogram-trained, wordless operation of machine shop labor coordinated by the “electronic beeps of a machine” or Louis Aragon's perfect Modernist line: “In my left pocket I carry a remarkably accurate self-portrait: a watch in burnished steel. It speaks, marks time and understands none of it” (Stites 1989, 154; Ades 2006, 181). What could be more trivial than the working of a clock?

Licklider was one of the main motors, with Robert Fano and others at MIT, of the Compatible Time-Sharing System (CTSS), a multiuser computing project with remote terminals connected to a central mainframe. Licklider and Fano wanted computing to feel like an invisible resource, always on, a daily utility like electricity or water. (One of their great triumphs was the complaints they would receive whenever the system was down—why can't I get access right now? What the hell's going on?—because that meant the users were

10 already taking it for granted as a quotidian faucet of computation [Lee and Rosin 1992, 26].) The tape recorders were there in CTSS, literally: banks of IBM 729 magnetic tape drives, which you can watch spinning back and forth through their address space over the shoulders of scientists being interviewed on television in the 1960s. Licklider, Fano, and the tape recorders were supporting the epitome of the symbiosis-and-augmentation computers-helping-humans-communicate model.

They had a timing problem. The machines didn't have clocks, so if you hit a glitch or a loop, you locked up the whole machine for everybody, and there was no mechanism that could time stamp files or kill a process after a few seconds. To resolve this, they figured out how to hook up a basic time-of-day clock to the machine through the printer port (Waldrop 2001, 234). This seems like the very definition of trivial communication: a simple clock to regulate all those dumb tape recorders, coordinating the most basic form of communication—a statement of the immediate present moment—to aid the nontrivial communication of time-sharing computer network users.

Jump forward to September 1985, to a document called the Request for Comments (RFC) 956, one in the series of coordinating memos for the architects and committees creating the internet and related technologies—the long-term result of CTSS and other experiments. “The recent interest within the Internet community in determining accurate time from a set of mutually suspicious network clocks has been prompted by several occasions in which gross errors were found in usually reliable, highly accurate clock servers after seasonal thunderstorms which disrupted their primary power supply” (Mills 1985, 1). Once you start networking the machines together, the problems of keeping time become far more complex. How do you know which messages come first? What's the order in the queue? How do you make sure data aren't being resent unnecessarily? (The software consultant Mathias Verreaes [2015] captured it with a sardonic joke: “There are only two

hard problems in distributed systems: 2. Exactly-once delivery 1. Guaranteed order of messages 2. Exactly-once delivery.”)

It's one thing to have a master clock regulating all the activities, like the Taylorist tick of scientifically managed factory labor waiting for the shift whistle. This is the clock as understood by Lewis Mumford, the prototype of all other industrial machines and the coordinating center of the humans–tools–processes megamachine, building pyramids and cranking out Model Ts. Network clocks are a very different class of machine. They have to account for transmission lag and mechanical failures and the behavior of many other “mutually suspicious” clocks. The clock protocols have to compensate for the effects of seasons and weather on parts of the network.

The clock is now so big that it has to contain and compensate for Earth's atmosphere, because it interferes with the accuracy of the clock. John Durham Peters (2015) has discussed elemental forms as media; Jussi Parikka (2015) has argued for studying the geological histories embedded in and sometimes expressed by media systems. We don't even have to go as far as artworks or solar energy captured in trees as paper pulp to make their case with this example: lightning will hit high-tension lines in late summer thunderstorms and disrupt the overall temporal picture for the network, so tools are developed to correct for that. At this point, we're still below the level of triviality assigned to tape recorders that “play to each other and record from each other”: these are still just the *clocks* that enabled the tape recorders to play back and forth in an orderly fashion thirty years ago.

As I write this, the current situation is far more complex. It's global, operating across diverse media from undersea fiber-optic cables to microwave relays, satellites, cellular-band radio, and copper twisted pair. It faces signal delays and lag and clock drift from machine to machine (which is affected by the amount of work the machine is doing, and even by heat). To work out the time, it will take a signal that has been time stamped in one location to reach

12 its destination, and we rely on the Global Positioning System (GPS) (whose scale Bunz describes in the context of our overreliance on the voice of navigation instructions). GPS, being satellite based, has to compensate for relativistic problems—the way time passes differently outside of Earth's gravity well. The clock must indirectly incorporate not only the atmosphere but the shape of Earth itself as the "geoid," the subtle undulations of the gravitational field, expressible as a hypothetical ocean surface and perturbing satellites in and out of their true paths.

All of this work to define the machine's time on the network has to function in the context of geopolitics and political economy as expressed in one of their purest forms: time zones. Knowing the time goes well beyond signaling, measuring, and geodesy—and not just for the benefit of the human glancing at her phone's lock screen but for automatically time stamping and logging events, correlating them across borders, accurately representing the hour in the past and the future, and providing data that can account for the national solar time at any given place. Will people be at work? When should alarms be set? Will the stock market be open? Should lights be on or off? There are clock systems particular to computing, like UNIX time, used by many file formats and operating systems, incrementing one second per second since 00:00:00 UTC, January 1, 1970—at this exact moment, 1,456,328,317. ("UTC" is the Coordinated Universal Time standard, mean solar time at 0°, used in aviation, weather forecasting, many scientific applications, and the Network Time Protocol, keeping computer clocks in synch.) On top of these systems runs the stack of Westphalian assertions of identity and human chronotypes concerned with hunger, work, and sleep.

The time zone system can be read as an ongoing, minimalist history of modernity: territorial struggles, global trade, new technologies and forms of work, all embedded as brief lines in computer databases like the "tz" or "zoneinfo" database in UNIX-based systems (Internet Assigned Numbers Authority 2016). Samoa decided to move across the international dateline to be

on the same day as countries to the east (Australia, New Zealand, China) and lost a day in 2011 doing so; those countries had become more important than the ships from San Francisco had once been. Nepal is deliberately fifteen minutes ahead of India; Indiana has a complex, politically fraught relationship with U.S. Daylight Savings Time (itself a matter of issues between agricultural, industrial, and white-collar labor) that puts some counties in the state an hour ahead of others. China went from five time zones to one in 1949, a potent tool for centralization and unity—all the way to the Xinjiang Region is theoretically on Beijing Standard, though Uyghurs also use and maintain their own time. Crimea’s interim government switched to Moscow Standard Time in late March 2014, a gesture of political significance on par with Spain’s adoption of Central European Time in 1940, chronometrically cementing Franco’s alliance with Hitler (and stranding Spain, much of which lies to the west of Greenwich, in a time zone that creates its own daily rhythm of “late” sunrises and sunsets).

All of this and more must be automatically accounted for by the network’s clocks, expressed as code with a laconic history of conflicts, alliances, powerful markets, and subaltern peoples. The clock has become a kind of political appliance, having to incorporate all this complex history to function properly:

```
Rule Libya 1997 only - Oct 4 0:00 0 -
Rule Libya 2013 only - Mar lastFri 1:00 1:00 S
Zone Europe/Simferopol 2:00 EU EE%ST 2014 Mar 30 2:00
4:00 - MSK 2014 Oct 26 2:00s
Zone Asia/Jerusalem 2:20:54 - LMT 1880 2:20:40 - JMT
1918 # Jerusalem Mean Time? 2:00 Zion I%ST
```

Consider our clock at this point. To coordinate interactions between “tape recorders” across the network—all those different points to and from which data are sent, requested, retrieved—it directly and indirectly incorporates millions of global clocks with their various skews and drifts, in the political governance patchwork of dozens of time zones on which both humans and clock-triggered

- 14 events rely, in a network topology in which particular nodes can be congested or completely down and that need to be routed around, which changes the timing on transmissions, with times synchronized over radio and transoceanic cables sunk in pelagic sediment, requested from atomic clocks with reference to satellites and quartz crystals—themselves synched by human labor, with gatherings to monitor the “leap second” transition, including the influence of nothing less than space-time itself. The business of efficiently managing message queues and flows carries us through the step-by-step of pragmatic engineering decisions into the foundations of time and light.

We can go still one step further before returning to the question of the relative triviality of communications: into the *now* of this vast timekeeping process. One of Google’s greatest achievements is a distributed database called “Spanner.” Spanner “shards” data over hundreds of data centers across the planet, maintaining consistency on a global scale. Thus users can see the same text in a collaborative online document; search results can be appropriately ranked, mail sent and received, ads priced and displayed, planetwide and without internal contradictions (Corbett et al. 2012). Data repeatedly requested can be copied to a shard closer to the location of the request, to lower the latency, delivering the next request faster; something can happen on a phone in Kazakhstan, a server in Seoul, and a laptop in Cape Town, simultaneously (or as close to simultaneous as the human mind is capable of observing unassisted), and be reconciled and coordinated; failure of the system in one place is compensated for in another before any human intervention is necessary. To make this possible, Google’s engineers were obligated to develop their own timekeeping system, TrueTime, which uses “time master machines” in each data center, cross-referencing GPS with their own atomic clocks; those latter units have the rather awe-inspiring name of “Armageddon masters.” Even this has uncertainty for which it must compensate, though: TrueTime, constantly correcting itself to account for

drift, uncertainty, and slew, has a real “now” of between one and fourteen milliseconds long.

It does not detract from the achievement of Spanner and the True-Time system to point this out; I bring it up to make clear that there is nothing simple, nothing *trivial* about the act of tracking time for the tape recorders. That is precisely what is happening here: to enable the coordination of the storage, transmission, and retrieval of data, prior to and independent of any encounter with humans, we have built a system that includes late summer storms, the curvature of space-time, and a new, specialized, continuous now, regulated by an arrangement called “Paxos leader lease protocol” (to whom should we listen, all of us tape recorders, when updating the state of our data?). It is a wonder of engineering not least because it vanishes into the background—because we are unaware of the labor of producing *now*. Jimena Canales (2009) has captured the emergence of another new now at the turn of the nineteenth century, a world on the threshold of a tenth of a second and the influence of this new now in domains ranging from experimental psychology and the exact sciences to semiotics and the birth of photography and movies. It was a critical chapter in the story of “measuring, mastering, and disenchanting” in the production of the modern age (207). There was nothing trivial about either the tools or the implications of pushing “now” past a decisecond. Likewise, creating a simultaneous, global, networked now of between one and fourteen milliseconds has implications that cut across media, society, and applied science: it sets up the framework within which what Wendy Chun (2008, 149) calls the “enduring ephemeral” of “constantly disseminated and regenerated digital content” is experienced, the cultural signature of our age.

In other words, Licklider and Taylor’s title “The Computer as a Communication Device” was perfectly accurate, but in the opposite sense: the computer is a communication device, and the communicators are doing something nontrivial with the information they send and receive. It’s just that very, very few of the communicators are *people*.

Telephones Have Conversations

After we have given so much attention to the problems of networked time and timing, of maintaining state and keeping data synchronized across the breadth of the network, it seems logical that we would, at last, turn to the humans who are producing the traffic. All that timekeeping—itself not really communicative, except in the most minimal sense—is the service, after all, of human–human and human–machine interactions. What of the “active participants” with “minds interacting” for whom this whole system was to serve as the platform? It is not mere contrarianism to say that quantitatively and—I argue—increasingly qualitatively, human activities are of less and less significance. In this, I seek not to contradict but to complement Bunz’s essay, which describes the ambiguities (empowering or patronizing?) in how digital technologies talk to us as children. As actual communication on present networks moves away from anthropocentric models, it shifts the “situation” she describes and with it the meaning of those infantilizing forms of interface addressed to us humans. Her study of those modes of interface and address frees me to turn to the nonhuman side of the situation (to paraphrase Licklider and Taylor, my emphasis on machines is deliberate). I will approach this in three parts: that humans are not producing as much of the communicative traffic as we may think; that, in some areas, our activity is not easily distinguished from the activity of machines; and that our communicative activity often has its greatest effect in the aggregate, as data rather than as the expressions of individuals.

First, humans are not producing all of the traffic or even, in some cases, the majority. There’s spam in volumes that dwarfs human–human email exchanges, very little of which human readers encounter: it is generated using templates with “per-message polymorphism” by botnets running on malware-infected computers, sent in million-message batches to automated filtering systems—that is, systems trying to identify human text in an arms race with systems that are not trying to *imitate* humans but to model what the filters think human behavior is (Brunton 2013, 182). On bad

days on the network, upward of 80 percent of all the email sent is spam (again, only a tiny portion of which will ever meet human eyes). This is of a piece with anywhere on the network that human attention pools and aggregates.

Google, maintaining an index of links between sites as a picture of what people consider most important or notable for any given query, has to contend with bot-driven posting activity on social media, pirated wikis, and in the comments everywhere. “Great post, really interesting” writes a commenter, with “interesting” linking to a client’s site or an affiliate scam or a porn-clip landing page. The system of Private Blog Networks has been built solely to establish the appearance of a thriving human community where none exists. Twitter and other social networks regularly have to conduct sweeps to purge the bot accounts from their ranks (bots that follow paying users in packs of thousands to make them look important and popular). The same is true of buying likes on Facebook or YouTube, listens on SoundCloud, clicks on ads, and so on. In a bankable version of Goodhart’s law (“When a measure becomes a target, it ceases to be a good measure”—or, “What gets evaluated, gets gamed”), any metric meant to describe human interest, esteem, or attention more generally will produce purpose-built nonhumans who will take it over for pay (Goodhart 1981, 116). It’s the most perverse version of Licklider’s goal of “man-machine symbiosis,” because the bots and the business models they represent don’t want to overwhelm the system or ruin the arrangement. Sometimes, in some corners of the internet, on poorly secured fora where bots can set up accounts unchecked, you can experience a Philip K. Dick-like moment of existential vertigo: is *anyone* here human other than me?

The second point follows from the second clause of that question. “Other than me”: it may not matter if I or my program is writing, as human and machine communication activities can be indistinguishable in many domains. One of the most telling of the Snowden disclosures was the revelation of the research going into what is called “information-operations” work, “influence or disruption,” in

18 projects like JTRIG in the United Kingdom and OPERATION EARNEST VOICE in the United States (Greenwald 2014). The goal is to “Deny/Disrupt/Degrade/Deceive” online conversations, communities, and movements through the injection of massive numbers of generated “personas” that can engage in online social activity (Fielding and Cobain 2011). They can shift sentiments, quietly spread propaganda, amplify messages, give the impression of trending or significant topics, game online polls, or simply flood a conversation that would otherwise be potentially significant with irrelevancies, noise, and derailing fight starting.

These personas may not necessarily be artificial; they may or may not be conversation engines running on a deep learning feature set. There may indeed be people on the keyboard at the other end—as in the case of Vladimir Putin’s troll factory in St. Petersburg, with coordinated teams at work manipulating conversations about Ukraine and Syria, or gamergate trolls using a mix of bots and their own inimitable human capacity for bullying, harassment, threats, and time-wasting interference to drive women out of gaming and off the internet (Sindelar 2014). There are many significant things to consider about the consequences for political discourse and how we conceive of a public sphere that includes bot-saturated social networks, but the salient point is that, for the practical purpose of excluding messages or kicking bots off the platform, it *doesn't matter* if a human or a machine is communicating. Software development seeks to make them functionally indistinguishable. (Analyzing a study of bots on the side of Labour in the United Kingdom revealed that rules identifying bots were often counting particularly fervid human supporters [Bartlett 2017].) The ultimate goal still involves humans, however indirectly: to polarize their political perspectives, to waste their time, to create an illusion of majority belief, to bury something and keep them from seeing it. The humans matter as an end result, but not as the means. Whether in a messaging app, on the help desk, or attacking an unpopular Twitter user, these systems are meant to erase the distinctions between our potential interlocutors.

We can look, for instance, at Lilly Irani's work on Amazon's Mechanical Turk system. Amazon goes to great lengths to make dealing with the human workers as much like interacting with artificial intelligence as possible, in keeping with the slogan of "Artificial Artificial Intelligence." Irani (2015) calls the broader phenomenon the "digital microwork industry": humans to finesse all the bits of affective analysis that pattern-matching AI still struggles with (an ironic echo of the original human "computers," occupationally producing calculations before their work was mechanized). Beyond the implications for labor, justice, and the organization of society, I want to emphasize how deliberately vague the human and machine work is at the client's interface: provision some capacity and dump modular tasks into it and let the system crunch away. Who knows if there's a sentient consciousness at work? Does it matter? Seen in a certain light, John Searle's Chinese Room looks like a knowledge worker's factory floor.

The gap keeps narrowing between social network bots (and many other kinds of automated work, but this stays with our theme) and what Anab Jain (2014) calls "meatpuppets." This is her term for people who join an internet discussion solely to influence it, and more broadly for how we as communicants on the network can be understood: as livestock for producing information, propagating memes, responding to automated notifications, and generally being a felt glove with glued-on eyes on the limb of a vast and intricate machine. A pack of adolescents activated by text messages or forum posts to attack an individual or disrupt an online conversation are, for purposes of managing the trouble they create, just bots that have easier time passing the various automated tests that try to prove humanness. (This speaks to Bunz's point that it's more important to look at the *situation* of communication than the subjects involved—because who or what the subjects are may be far more uncertain than we'd think.) Meatpuppets carry out tasks and narrow the human-machine gap—like interns at content farms, snorting Adderall and cranking out "content" in response to click rates, competing with software that does precisely the same

20 thing with some occasional textual bumpiness but no need for office space, bathroom breaks, or amphetamine.

This meatpuppet condition is perfectly expressed by the internal structure revealed in the Ashley Madison hack. Ashley Madison, a dating site for married people theoretically looking for affairs, was hacked in purported retaliation for its failure to fully delete the data of users who paid to be erased from the service. What is significant, for our purposes, is what was disclosed when the hackers (“the Impact Team”) dumped user records, corporate memos, and much more onto the public web for scrutiny. There were almost no actual women on the site. The business model was to draw men into loops of interacting with simple chatbot programs, some based on profiles mass created by spammers, to keep them hooked on paying to send messages, “virtual gifts,” “winks,” and the rest of the pixel tat common to dating and social apps. Internal documents refer to this fembot population as the “fraud-to-engager tool,” turning merely curious male users into customers with a credit card on file (Newitz 2015). (Within the company, the bots were called “Angels.”) It is not simply that the men were interacting with procedural systems mistaken for people but that the men were themselves behaving procedurally and reliably as simple stimulus-response, A/B-tested systems that may show complexity in person but in aggregate can be tapped for sap like a stand of maple trees.

As the consequences of the hacked data dump played out, even the blackmail was mostly automated: clever extortionists set up sites where the curious (spouses, coworkers, the general public) could type in a name to see if someone was present in the Ashley Madison database as a customer—which would trigger an email to the name’s email address, threatening to reveal all the person’s Ashley Madison activities to his social network contacts unless blackmail was paid (in Bitcoin, no less) (Krebs 2015). A user of Ashley Madison could have a complete, personal, Dreiserian tragedy play out—curiosity, temptation, flirting, offers and promises,

exposure, shame, and secret extortion—that never once involved direct communication with another human being.

This brings me to the third point in my argument: the utility and significance for many purposes of aggregate data over individual expression on the network. The human contributions are often more useful in volume, as fodder for deep learning systems, predictive text algorithms, and translation engines, than as the outcome of any individual activity: not as much for what they tell us about you as for what they tell us about people like and unlike you. McKenzie Wark has discussed the unexpected side of the collapse of privacy on the network: not just the terrifying, targeted, Orwellian violations of personal autonomy for small numbers of dissidents, activists, and minorities worldwide—which was to be expected, tragically—but the *indifference* with regard to everyone else as individual identities (Gregg 2013). Your individual identity is in many ways the least interesting thing about you for purposes from advertising to social segmentation to assessing credit ratings to targeting a particular mobile phone signal for a drone strike: the ability to *address* and target you and others like and unlike you is more significant than your evaluation of what about you matters.

The common, lazy defense of surveillance—if you have nothing to hide, you have nothing to fear—is a useful illustration here because of how it misses the point: if you have nothing to hide, you are much more useful to a surveilling adversary because you help to distinguish those who *do* have something to hide. Your visibility probably does not matter (no one cares) but is helpful in how it informs the analysis of others. Your good credit aids in the identification of potential bad credit risks for discriminatory pricing. Individuals are merely biography; groups and social graphs are demography and Big Data, something far more useful. In other words, even when we are communicating with other humans (“directly,” as mediated and managed by the network), the content of our communication is of consequence well beyond any particular *meaning* it may have for us, as Big Data—data at a scale that calls into question any personal self-evaluation of their significance.

22 These aggregate data produce rapid improvements in the experience of communication with machines. Human-machine communication is becoming a rich, coherent, ubiquitous part of everyday life, exemplified by the proliferation of “conversational user interface,” where all three of the points made so far in this section can be discerned.

“Saying that cultural objects have value,” wrote Brian Eno (1996, 81) with a crisply aphoristic turn of phrase, “is like saying that telephones have conversations.” Of course we have conversations over the telephone, *using* the telephone, with other people, as we transact value across cultural objects; but the implicit logic has begun to break down. Telephones, particularly mobile devices like smartphones, have conversations, and we have conversations with them. Phone and interphone conversations happen constantly—handshake check-ins about location, transmission of carrier information, Wi-Fi requests, and pushing and pulling background information—though that stretches the definition of “conversation” too far. We also have more direct and apparent conversations with telephones and with the systems doing voice recognition on telephones; think of Siri, Cortana, and customer service.

As digital platform interaction moves from computers to mobile devices, the trend is clear: many systems converge on one interface, and that interface is texting. It mediates interactions with services through the same messaging modes we think of as texting with humans, making it a perfect platform for increasing human-machine engagement, side-stepping the challenges of extracting human voices from ambient noise and accounting for accents and the diversity of speech. (As it happens, Licklider’s career began in psychoacoustics, working on the problem of verbal communication in a mechanically noisy environment like the cockpit of a plane under fire.) From fitness (Lark) to personal finance (Digit) to personal assistants (Magic) to games (Lifeline) to logistics (Taobao’s 阿里小蜜) to news (Quartz) to payment (many) and customer service (Rhombus and more), whole categories of media activity that would once have implied custom software platforms, tools, or

programs instead work through messaging. In those environments, the handoffs between humans and machines can be seamless. An exchange that triggers an automated response and one that pops up as a thread on a person's desktop or device, eliciting his response, are indistinguishable. As the most practical, quotidian matter, the easy binary split between people and machines that comes out in our prepositions—that we have conversations *with* people *over* telephones—is blurring.

All this contemporary activity may seem like rather old news to readers who recall Turing's (1950) rebuttals to the "arguments from various disabilities" against the possibility of artificial intelligence in his landmark paper "Computing Machinery and Intelligence." Turing's argument in favor of the possibility of computers having minds can be crudely summarized: if you think the machines are dumb, you should see the *people*. The argument builds on the assumption that machines can't be thinking because thinking is a special property of humanness, to which Turing responds, well, in what ways do you evaluate whether other people—or indeed you yourself—are thinking? Take that set of criteria and apply it to everything else, and see what passes; this is a way of eliminating what Reza Negarestani (2015) has called the "straw machine argument." Hence the Imitation Game, also known as the Turing test, which we pass in limited forms in the field constantly now—and here we touch closely on Bunz's half of this book, with the modes of address that are coming to typify that exchange. People give their credit card numbers away to seductive interaction designs; the programs that need to distinguish human users from all kinds of bots are in difficult straits; and even a living, breathing human user can effectively be a bot, or functionally indistinguishable from one. This boundary promises to become still more permeable now that so much of the research initiative is moving toward abstracting the most subjective, intimate areas of communication, from facial expressions to sentiment analysis to "interestingness."

In light of this, I argue that we are in the process of building deeply inhuman (which I do not mean in a pejorative sense)

24 architectures and systems on a vast scale, whose content we partially constitute, and it is in the *context* of those systems that we now communicate—"the computer as a communication device." "In thought and political analysis, we still have not cut off the head of the king," Foucault (1990, 89) famously wrote; I'm worried that I still habitually think the king has a head. We did not make humanlike interlocutors, just humanlike interaction and interface designs that sit atop an infrastructure that has nothing whatsoever to do with the anatomy, physiology, or even cognitive processes that define the shifting borders of humanness. Then, as Bunz describes, we made it talk to us as if we were children, complete with cute animals. It is this infrastructure that we communicate through and, more and more often, *with*. We have theories about how we communicate with nonhumans of all kinds, from Lucy Suchman's situated actions to Donna Haraway's companion species to anthropological studies of humans in natural environments to theories of biosemiotics. I wonder if we could push them further: to think about exchanges with things that are alien to us in a different sense.

As it happens, another area of human imagination and scientific research is concerned with logical formalisms, binary pulses, and the communication of language and images to a "missing subject." It closely tracks and in some cases overlaps with the history of electromagnetic and computational communications media, and it shares a great deal with them. I believe it offers a useful analogy for our current situation: a series of examples of extraterrestrial media formats in which we as humans have attempted to communicate with the truly alien, in experimental arrangements we are now in the process of re-creating on our own planet.

Hello from Earth

Consider this thought experiment: we want to communicate with a potentially habitable planet. Therefore we send a signal that will take decades or centuries to reach a distant star, with no prior

understanding of the biology or sensory anatomy of our communicants, much less their symbol systems or their technical instruments or the nature of their cognition. What to send? The work of communicating with aliens is the work of communicating with an entity that is for present purposes almost entirely unknowable—an entity that the anthropologist Klara Capova (2013), in her study of extraterrestrial signal work, calls the “missing subject.” What, then, do we communicate?

This is a useful question to ask for two reasons.

The first is that the process of trying to develop formats, rules, systems, and messages for communicating with other entities that are fundamentally unknowable turns out to be very closely connected with many historical and contemporary problems in computing and telecommunications. The theoretical problem of communicating with aliens turns out to share a great deal with the practical problem of communicating with computers.

The second reason cuts a bit deeper: studying formats for extraterrestrial communication is a useful starting point because it necessarily forces a reevaluation of our human biases—bodily assumptions, cognitive habits, arrangements of language and what constitutes meaningfulness—that shape our concepts of what communication is. We have to carefully consider our assumptions about the other elements of the situation of communication that Bunz breaks apart in looking at how we are hailed and addressed. My hope is that these formats open dimensions of analysis that might otherwise escape us, which will apply to understanding communication over and with networked computers.

I focus on the act of communicating—broadcasting radio waves, flashing lights—precisely because it is the most demanding case. The Search for Extraterrestrial Intelligence (SETI) is usually divided into so-called passive and active SETI, where passive is listening: the fields of radiotelescopes scanning the skies for anything out of the ordinary. It is the search for potentially meaningful events, like the “Wow!” transmission from 1977—named for the remark Jerry

26 Ehman wrote on the printout next to the code representing the intensity of the signal (Gray and Ellingsen 2002). It's a fascinating and important process, but more pertinent are the projects in which we try to figure out how to *address ourselves* to our unknowable interlocutors—when we don't just look for regular or unusual patterns that could be meaningful to us but try to create *formats* that will be meaningful to an unknown and unknowable subject.

Mirrors and Morse Code:

A Clear Suggestion of Number and Order

Early attempts at an “interstellar language” are abstract more in an artistic than a mathematical sense, reading like proposals for vast Land Art initiatives and minimal sculptures on an enormous scale. Their components (mirrors, trenches, agriculture) suggest Robert Smithson with the resources of the U.S. Army Corps of Engineers. Robert Wood, a physicist who made major contributions to both ultraviolet light and ultrasound research, proposed a system of black cloth baffles, miles on a side, built in the desert and opened and closed by motor—a grid of pixels that could send “a series of winks” to observing Martians (*Popular Science* 1919, 75). Camille Flammarion argued for vast tracts of electric lights built in the Sahara, shining upward when Mars was in opposition. An A. Mercier, a colleague of Flammarion's, proposed constructing an enormous mirror or electric light in the heart of Paris (on the Champ-de-Mars, no less) (Frollo 1899). Alternatively—assuming that there might be some conservative opposition to constructing the brightest light on the planet, at the scale of the Brooklyn Bridge, in the heart of a densely inhabited metropolis—he suggested installing two mirrors on a mountain so that sunset light would reflect onto the shadowed side oriented to flash up at Mars, taking advantage of the dark background to use the light for better effect (Crowe 1986, 397).

Over the course of decades, two recurring landscape-as-medium proposals, generally but apocryphally attributed to the astronomer Joseph von Littrow and the mathematician Carl Friedrich Gauss,

kept reappearing: to dig canals in the Sahara (circles or squares), fill them with kerosene, and set them on fire at night or to plant agricultural tracts in Siberia laid out as the square of the hypotenuse (the “windmill” diagram) (Crowe 1986, 205). Konstantin Tsiolkovsky, the great pioneer of rocketry (and advocate for the cosmic future of the human species), envisioned yet more tracts of mirrors (Crowe 1986, 397). Had there been a bit more free capital around for the turn-of-the-century “Mars mania,” we might have some vast field of dusty, angled mirrors abandoned and reflecting the empty sky on a desert plateau somewhere, a Ballardian monument to the void.

All of these were more or less *visual* media projects, expressions of an era devoted to the idea of a crowded and lively solar system with canals on Mars, cloud forests on Venus, and underground populations of selenites on the moon. Franz von Paula Gruithuisen thought the famous “ashen light” sometimes observed on dark Venus was the product of “general festivals of fire given by the Venusians,” with the forty-seven years between observations reflecting “the reign of an absolute monarch” before “another Alexander or Napoleon comes to supreme power on Venus.” (Gruithuisen is sadly but accurately described by Crowe [1986, 204] as “a man of vast energy, extensive learning, excellent eyesight and instrumentation, and little sense.”) Perhaps, speculated Mercier, the “flashes” observed on Mars were a response to the dazzling lighting of the Universal Exposition of Paris in 1889 (Crowe 1986, 397). When A. E. Douglass noted a “projection” on the Martian surface, which was reported in the press as another attempt at communication with Earth, he received theories as to the architecture of the population that could create such an effect: “Suppose the people of Mars have built a monument 10 miles square and a hundred miles high, covered exteriorly with polished marble” (Crowe 1986, 398).

If the populated universe were so neighborly, surely we could build tools by analogy to the Chappe semaphore telegraph, using basic visual symbols to convey the fact of existence and perhaps more complex information. Contacting the moon or Mars this way would be of a piece with broader technological transformations of the

28 media apparatus, wrote Flammarion: “it is, perhaps, less bold than that of the telephone, or the phonograph, or the photophone, or the kinetograph” (Crowe 1986, 395). Even Gauss, much less prone to flights of fancy like his colleague Gruithuisen’s “mad chatter,” considered the use of the heliotrope—the mirror apparatus for reflecting sunlight over long distances to mark positions for surveying—for signaling: “This would be a discovery even greater than that of America, if we could get in touch with our neighbors on the moon.” (In March 1822, with some back-of-the-envelope estimation, Gauss envisioned a hundred sixteen-square-foot mirrors used together—which would have been a splendid object, a fit companion to the Jantar Mantar architectural-astronomical buildings in Jaipur [Crowe 1986, 207].)

The visual component of these early projects tended to duck the follow-on question of what, precisely, was to be signaled and how it would be conveyed. All we could do was provide some evidence of our existence—a flashing light—and then presumably the acknowledgment would set the terms of the conversation. When the issue of the identity of our interlocutors was raised at all, it was understood that they would be more or less like us: after all, did they not dig canals and irrigation trenches? For purposes of communication, we could assume they were further along our inevitable historical and technological trajectory, “far superior to us” as Flammarion put it (Crowe 1986, 395). “Perhaps we will learn from an older and wiser planet how we ought to run the Earth,” as *Popular Science* (1919, 74) had it with reference to telling the Martians about the just-concluded First World War. Only a few would-be stellar communicants consider the possibility of an alien biology. Francis Galton (1896, 661) has a hypothetical Martian transmission cracked by a little girl who points out that it’s in base-8, not base-10, because Martians count with six limbs and two antennae, like “highly developed ants,” rather than ten fingers and toes. Gauss, rigorously imaginative as ever, “considering the universal nature of matter,” hypothesized life on the sun with its massively higher gravity to consist of “only very tiny creatures . . . whereas our bodies would

be crushed" (Crowe 1986, 208). Guy Davenport once described how seventeenth-century English translations of ancient Greek make Achilles into a contemporary gentleman, always on the verge of taking snuff; likewise, despite these steps away from anthropomorphism, the assumptions of those plotting miles of mirrors on mountain slopes are that Martians will be, more or less, as we are—that we are addressing advanced Kants whose study windows happen to look out on canals at the foot of Olympus Mons. The conversation will be "begun by means of such mathematical contemplations and ideas, as we and they have in common," suggested Gauss (Crowe 1986, 206).

Even here, though, a more specific and abiding problem is becoming apparent: How are we to communicate anything more complex than a flash of light or a right triangle? What does "communication" mean, in this instance? Once we build those grids of electric lights in the high desert, we can't just use "the Morse Code for it were idle to suppose the Martians are familiar with this" (Crowe 1986, 400). In a problem with echoes of the Turing test or the Imitation Game, cruelly inverted, how do we distinguish human activities and attempts to communicate from the effects of natural events for an unknown observer—volcanoes, auroras, bioluminescent seas, and the radio hubbub of the universe at large?

That remark about Morse code is pertinent, because it is at this point that the project of alien communication begins to shift from the kinds of signaling techniques familiar to lost campers and marooned sailors—flash a mirror, light a signal fire, arrange rocks in a geometric shape—to richer, more abstract problems of communication that speak to the challenges of digital systems. As with schizophrenic-paranoid anxieties, our models for human-alien communication closely track developments in media technology. Just after the turn of the century, Tesla (1901, 5) reported picking up signals from Mars (or possibly Venus) while building his experimental wireless transmission apparatus in Colorado Springs, with "a clear suggestion of number and order." He announced the dawn of this new age in an article, "Talking with the Planets,"

30 which included a few lines that perfectly capture the combination of cosmic grandeur and can-do pragmatism that would come to characterize many of these communication projects: “with an expenditure not exceeding two thousand horsepower, signals can be transmitted to a planet such as Mars with as much exactness and certitude as we now send messages by wire from New York to Philadelphia” (4). The astronomer David Peck Todd, in 1909, proposed lifting “the most sensitive wireless telegraph receiver available” into the upper atmosphere with a balloon to pick up extraplanetary signals (Crowe 1986, 399). Through all of this, the problem of *what* to communicate—indeed, how to appear as a communicative act—remained uncertain. Tesla (1901, 5) breezily confirmed that communication, initiated by “a mere interchange of numbers,” would rapidly move to “more intelligible” forms.

Part of the answer begins with the challenges presented by communicating using the new technical media themselves. There was a kind of symmetry between the two different forms of nonhuman communication.

Cros’s Étude: Designs as Number Series

Charles Cros is now known—if he is known at all—as one of media history’s also-rans, or as the author of some delightfully frustrating poetry. He invented techniques for three-color photography and a version of the phonograph, both of which he registered more or less immediately contemporary to other, more successful projects. (His phonograph—called, beautifully, the paleophone, *voix de passé*, the “past’s voice”—was in many ways an Edisonian foil phonograph, not quite at the prototype stage, just as Edison was rolling out his first model.) He was one of the circle of *hydropathes*, artists and writers who shared a *fumiste* attitude combining outrageous subject matter with deadpan style, the result of a mocking, cryptic, too-cool sensibility that throws up a smokescreen and baffles outsiders—much of Erik Satie’s dry amusement, his piano pieces played “like a nightingale with a toothache,” is very *fumiste*—and specialized in grating nonsense poetry, like “The Salt Herring,” to be

read aloud to restive audiences. (The very model of a nineteenth-century inventor-dilettante, he also spent time on a project to manufacture fake jewels [Cros 1970, 541].) When not engaging in acts of deliberately failed communication with other humans, Cros was petitioning the French government to construct a huge and technically infeasible Archimedean burning mirror to etch shapes onto the deserts of Mars as a communications initiative. Concealed within the work of a man seemingly custom built for a cabinet of historical curiosities, however, was something far more profound.

In “Étude sur les moyens de communication avec les planètes,” Cros (1970, 519) begins to seriously consider the challenge of reciprocal communication with an alien intelligence. He takes up the basic concept now well established—an enormous mirror flashing light to be seen by an observer on another planet—but asks how information is to be conveyed once the lines of communication have been opened. He considers, first, how a sequence of rhythmic flashes could be used to encode numbers but then takes up the question of whether those numbers could in turn encode *images*. A series of digits could communicate binary pixels—spaces black or white, off or on—in lines on an ordered grid, in the style of “6-1 2-0 3-1 7-0” for

XXXXXX00XXX0000000

using integers rather than having to flash all those signals one by one. (Cros devotes some time to how exactly this message-sending protocol would be initially communicated.) As he outlines his project, it becomes clear to the modern reader that he has developed a version of what is now called “run-length encoding,” an image compression and transmission technology akin to that used in fax machines, early digital bitmap images, and some of the very first television technologies collected by Siegfried Zielinski. There would need to be encoding systems for turning images—and, potentially, other kinds of media—into materials for this notation-transmission apparatus: “analogous notation procedures for rendering designs

32 as number series are used in various industries, including weaving and embroidery.”

At this point, the ears of historians of computing might prick up: what kind of industrial weaving machines, pray tell? “There is, in [Jacquard weaving], a whole science that, as so often happens, was practiced before it was theorized. From it will emerge a new and important branch of mathematics, and eventually a new classification of these primordial sciences [i.e., the sciences of information and data storage]. The study of rhythms [patterns and encoding systems] will take its place alongside that of figures” (Cros 1970, 534). In context, Cros’s “study of rhythms” means a set of instructions to be carried out in a particular order on the machine’s material: what we would now call an algorithm. What we have here is a project to turn Earth into a graphics card, encoding images and eventually other data for transmission to be rendered and displayed elsewhere. The project of developing nonhuman communication, with its problems of abstraction, encoding, compression, error correction, and display, turns out to be analogous to the problem of developing computable media—to “what we now call programming.”

Astraglossa: How to Point at Things

“What we now call”: it was new then, in 1952, when the zoologist and medical statistician Lancelot Hogben wrote “Astraglossa,” a lighthearted but extremely thorough and detailed study of the format of potential extraterrestrial communication. During the Second World War, Hogben (1943) had published “Interglossa,” a proposal for an auxiliary language with an inventively simple structure—a kind of international argot of science and technology inspired by the complexities of teaching biology to a cosmopolitan student body. Astraglossa is something else entirely: not a language as such but an analysis of what it means to communicate with a nonhuman, unknowable interlocutor. Prior to meaning as such, prior to language, Hogben—who in his working life was occupied with hormonal signals of African clawed frogs and color-

shifting reptiles and amphibians—was interested in the most minimal order of signaling: “a technique of how to point at things” (Hogben 1963, 126). If we assume (and this is already a large and complex assumption) that those we seek to contact share a sense of *time*—and with it number, interval, and the stars—then we can produce what for Hogben constitutes the fundamental structure of this most minimal nonhuman communication: rank order, gaps, and iteration. That is, if all you can communicate are sequences of electromagnetic pulses, dots and dashes, you rely on order in *time*. A shorter time interval separates a chunk of pulses meant to be taken conceptually together, and a longer interval marks the conclusion of a linked series of such chunks—*gaps*. Their sequence in time establishes the role of different sequences of pulses—*rank order*. One follows another, with the same or different operations executed repeatedly to arrive at a result—*iteration*:

1 .. Fa .. 1.1 .. Fa .. 1.1.1 .. Fb .. 1.1.1.1.1.1

or one plus two plus three equals six, with the periods standing for units of time between pulses. The *Fs* in Hogben’s notation refer to “flashes,” sequences of pulses with distinctive properties whose placement by gaps and rank order suggests the operation of addition and identification or equality.

We have pulses and the time between pulses, some of which we can arrange into operations—addition, subtraction, identity, affirmation and negation, and so on—and we can then, given enough time, stack the operations into “flashes” that constitute *rules*: apply the set of operations collected by this rule to the following string of numbers. Followed by silence. Which thus becomes the framework for a signal, a flash, corresponding to elicitation or a question—awaiting the product of an operation performed. All of this should begin to sound rather familiar: “The only unmentioned clue that I regard as specially relevant to our theme I shall merely refer to *en passant*, viz. what we now call programming, i.e. the syntax of the language in which we transmit orders to the new electronic computing machines.”

34 The parallels that Hogben (1963) draws are illustrative not only of his thinking about this subject but of the larger challenges of finding the edges of the concept of communication—the places where we enter and leave the communicable, what he calls the “common field of semantic reference” (124). He draws on the history of interpreting the Mayan glyphs—which, in 1952 as he composed these ideas, had only encompassed the numerical and astronomical and calendrical systems present in the language. He compares the project to the universal visual languages of Otto Neurath’s ISOTYPE and Charles Bliss’s semantography (or as it is now known, Blissymbolics)—both of which build symbolic vocabularies that don’t correspond to sounds but instead express concepts wholly through visual objects and abstract operators. He plays at length on the theme of childhood, infancy, and education: how do we try to teach shared symbol systems to children? He compares the puzzles of establishing concepts like antitheses, interrogatives, and assents to “a fuller case history of Helen Keller” (131). All of these analogies are laden and complex, and it would be very interesting to consider the different models of “communication” they imply—but most interesting for our purposes is the challenge of alien communication expressed as an essentially *computational* problem.

All of his other comparisons rely on human commonalities, from the shared sky over Mayan Mesoamerica to the silhouettes and color codes of ISOTYPE to Keller’s understanding and Anne Sullivan’s hands, making this computational aspect stand out all the more. The challenge of establishing a shared binary symbol system and logic of operations, predicated on gaps, rank order, and iteration, closely resembles the work done by Turing, Tom Kilburn, Freddie Williams, and others to build Turing-complete electronic computers in Manchester and London contemporaneously with Hogben’s talk. (Manchester happens to be the city where Hogben sets his fictional classroom of analogical Martian pupils.) Finding the minimal fundamentals necessary to express more complex ideas has parallels with Boolean algebra and logical processes like

Charles Sanders Peirce's (1989) demonstration that NOR gates, properly arranged, can produce the functions of all logic gates and therefore of a functionally complete logical system (what came to be called "Peirce's arrow").

Finally and crucially, however, this is not the full extent of Hogben's ambition. He does not want to establish logic for its own sake, to produce "a monologue of simple assertions," but as a step toward a rapport. The later parts of his study playfully but carefully analyze how he could establish pronouns (*your* and *our*, *it* and *they*, *I*-ness); terms of assent, denial, and doubt; conditionals and assertions; causes and consequences, entirely within a system of binary pulses and "flash" operators with reference to time and stellar objects. The ultimate goal is to use the framework of this logic for "reciprocal communication" with the unknown, as "our Neolithic forebears . . . can communicate with us" through numerical and calendrical relics like notched bones and standing stones, or as we "transmit orders to the new electronic computing machines."

Of course, even this elegant attempt at a minimal set of communication components relies on some necessary assumptions as to how it will be interpreted and understood.

"How does it come about that this arrow >>>--> *points*? Doesn't it seem to carry in it something besides itself?" So asks Wittgenstein (2001), in section 454 of the *Philosophical Investigations*. Why, when someone points, do we assume that the direction runs from elbow to fingertip and not the other way around? (Or, as Laurie Anderson [1983] asked of the waving man depicted on the Pioneer Plaque, the engraved plates of aluminum mounted on the Pioneer spacecraft in the hope of being intercepted by extraterrestrials: "Do you think that they will think his arm is permanently attached in this position?") Wittgenstein notes, "Perhaps a Martian would describe the picture so." How would our unknown audience *listen* to something, for instance? Again, the challenge of formatting extraterrestrial conversation takes us directly to the puzzles of communication in technological media.

- 36 Set aside, for a moment, the complexities entailed by establishing the primitives of formal logic using only radio pulses beamed to some corner of the sky with decades-long time lag. Instead just imagine a record—an analog LP. Take it for granted that the recipients will be able to decipher the instructions for building the player or will invent their own. What do we put on the record to express our experience?

Voyager and Arecibo: A Martian Would

Describe the Picture So

That's the most common question for such a project: we jump to the content of the communication—the usual Bach-or-Fela Kuti-or-a-child's-laugh debate about which object could stand in for many objects, which unit expresses a category. More difficult and much more profound, however, is the question of *format*: what about this groove etched in an anodized disk conveys that this is “our” “experience” prior to any particular chunk of that experience? Just as conducting even the most minimal conversation about astronomical states requires us to reinvent time and spatial notation, *we-you* pronouns, direction, and ordinality, so the commonsensicality of sound demands deep consideration, one which echoes Kittler's work.

Imagine two records, then. One is made of gold-plated copper from 1977, currently in interstellar space outside the heliosheath. The other is a dictation cylinder produced in 1900. Kittler has written about the latter, emphasizing one of the most significant and least obvious things about it: that it records the *voice*, not just “the words.” It is a mechanical process, transforming what is said not into words, as a scribe would, but into data storage—the stylus records the voice aspeak but also the birds singing outside, the creaking of the floorboards underfoot, and of course the mechanical noise of the recording medium itself. It shifts the boundaries of what can be inscribed and recorded—what becomes part of the record, part of discourse. Along with other novel media technologies, it creates a new form of human expression that

sounds familiar to our present data-driven order: that we expose what is most personal and individual to us not through what we deliberately *say* but through what the machines pick up about us. We are our fingerprints, unconscious microexpressions captured on film, our tone of voice and mistakes of speech and background sounds. (From *Blow-Up* to *Blow Out* to *The Conversation* to *The Girl with the Dragon Tattoo*, a new genre has come into being based on the tales told by machines recording events whose significance at first escapes their human users.) “Only the phonograph can record all the noise produced by the larynx prior to any semiotic order and linguistic meaning” (Kittler 1999, 16). And only for humans would all that extraneous noise be so *invisible*: the gray velvet mounts on which the gleaming jewelry of spoken language is displayed, when we encounter it through the mediation of tinfoil and shellac, nails and needles and resonant cones.

Jon Lomberg, reflecting on the production of the Voyager “Golden Disk” in 1977, articulated the problem (Lemarchand and Lomberg 2011). The record was to include music, human speech, technological sounds, animal sounds, and natural sounds produced by the planet, addressed to unknown alien listeners. Within the format of the recording itself, Lomberg and his colleagues wanted to convey a set of profound and subtle distinctions. First, there were distinctions in “nature of the sound” between the music and the other sounds. The music was to be *experienced* and analyzed for its structure, but the other sounds were to be *identified* for their informational content. Music expresses subjective states; the other sounds are objective conditions. (I ask the reader’s indulgence in these deep waters about the questions already raised—that human sounds, music included, are not a product of nature—just to consider the format and communication problems.) Furthermore, and still more delicately: how to communicate that the speech (greetings in different languages, children talking, party noise), technology (hammering nails, engines turning over), and music are all “our” sounds and birdsong, bees buzzing, a roll of thunder, dogs barking, and whalesong are *not*?

38 Lomberg sought to connect human activities with the sound of a heartbeat, running it as a backing track to distinguish “our” sounds from all the others—and to produce a kind of sequence, a variant of Hogben’s use of rank order and gaps, with the technological sounds as a series of acoustic narratives that would build from running feet through internal combustion to a jet engine and a rocket launch. Indeed, Lomberg exploited the very property of audio recording that Kittler emphasizes: that the voice as inscribed is no longer a matter of words understood, interpreted, and written but a bodily event of moderated breath in the larynx. The recordings of speech should be made “so that an intake of breath before syllables could be heard. This would link breathing with speech, and perhaps give a clue as to the respiratory nature of speech, and link the sounds of speech with the heartbeat” (Lemarchand and Lomberg 2011, 379). The heartbeat was a kind of metadata about a particular set of sounds. Given the fearsome complexities and challenges in interstellar linguistics, perhaps the most important and salient component of our recorded speech is precisely that it is anatomical first and foremost.

Every extraterrestrial communication project forces *two* assertions: the minimal requirements for communication and the most significant matter to be communicated. With a few exceptions, like the Voyager record, the minimal requirements are *pulses*, binary strings of energy encoding different kinds of messages or representational schemes—in other words, systems more or less directly inspired by or in dialogue with computing and telecommunications projects. Cros was a forerunner, well ahead of the state of the art in adapting notation from Jacquard looms to produce a celestial fax machine; by the 1970s, with the famous Arecibo message, Frank Drake (1992) had worked out a string of 1,679 bits (on and off pulses, repeating) to be sent from the radiotelescope of the same name in Puerto Rico. The number 1,679 is semiprime, the product of the primes 23 and 73, and if you arrange the on and off signals in order in a grid of twenty-three columns and seventy-three rows, you have a picture—with the pulses as the pixels.

And what content? What is the substance of communication with unknown and unknowable interlocutors to be? A minimal set of facts, almost always: a numbering system, a set of stellar coordinates, a few facts of chemistry, a human silhouette. Arecibo, read top to bottom, provided numbers in binary, the atomic weight of the basic elements in our biology and the chemistry of DNA, our population and physical shape (the wavelength of the message itself provides the scale), the arrangement of our solar system, and finally the antenna itself. Most such messages are necessarily humble, primarily concerned with the structure of their own decoding—after all, the simple, phatic fact of a *we are here* statement is itself of enormous consequence. Successful use of the medium, with a signal distinguishable from the electromagnetic activity of the universe in general, is the event. The content can be more or less of the “Watson—come here—I want you” / “What hath God wrought?” / “This has been a day of solid achievement” variety (for telephone, telegraph, and hard drive, respectively).

Even here though, beaming minimal signals to distant stars and “missing subjects,” we find ambitious projects to expand on what the format is capable of—and we reconnect completely with the question of rethinking “communication” in terms of our own nonhuman and alien media technologies. What can we communicate using this set of binary pulses and logical primitives? What are the limits? People have built everything from more complex Arecibo-like messages, with new pixel arrangements (Zaitsev and Ignatov 1999). The “CosmicOS,” a “self-contained message” made of four symbols that account for binary code and brackets, acts as a kind of computer program to be executed. (It looks like this: $\diamond | \diamond \diamond \diamond \diamond || \diamond [\square] . . .$) This last example, while also playful, is exact and thorough and speaks directly to the challenge of thinking past our own biology in our communication efforts. One of the goals of CosmicOS is

to avoid making too many assumptions about the perceptual abilities of the non-human intelligence; for example that they make sense of 2D images in the same way we

do. While some arguments can be made for this, as a machine vision researcher I am very skeptical that we really understand the variability possible here. (Fitzpatrick, n.d.)

It is through thinking about how machines can “see”—or can use novel techniques to do something like seeing—that we can also understand how different forms of life might see, or sense, or otherwise interact with visible light.

CosmicOS builds on another, earlier experiment in pushing the limits of possible extraterrestrial communication: the constructed language Lincos. It is one of the most rigorously eccentric intellectual projects of the twentieth century, to put “in principle the whole bulk of our knowledge” into a form communicable to any possible intelligent life, and we will close this chapter with it.

Lingua Cosmica: Human, or at Least

Humanlike

“He begins with elementary mathematics,” writes Marvin Minsky (1985) of the Lincos project, “and shows how many other ideas, including social ideas, might be based on that foundation.” Minsky, one of the major figures in AI research—cofounder of MIT’s AI laboratory, author of *The Society of Mind*, advisor to Clarke and Kubrick in the production of *2001*—is describing the work of the mathematician Hans Freudenthal. The lingua cosmica, or Lincos, is a language that begins with “peeps” of discrete radio pulses for the natural numbers and ends with relativistic mechanics. On the way, it includes set theory, cardinality and ordinality, assertions (“Future events *cannot* be perceived”), a “short history of Fermat’s theorem,” “examples of polite speech,” bets and gambling, the act of wishing, points and vectors, and “whistling for one’s dog.” (“The dog refuses.”) And this was to be only part one of a projected two, with the second including chapters on “Matter,” “Earth,” and “Life” and an additional supplement on “Behavior” to build on the first book (Freudenthal 1960, 23). All of these contributions are rendered in an increasingly complex formal notation, express-

ing how they would be transmitted as radio pulses. It looks like this:

↔PauAnt•HeDatHd.Den0, 101■

Once we are past the same basics touched on in one way or another by every broadcast concept more complex than Arcibo—numbers, spatial coordinates, timing, basic logical and mathematical operations—Freudenthal, like Hogben, wants to do something far more ambitious than simple declarations about the nature of things. He establishes a set of human actors and embarks on a series of logical-minimalist playlets. These conversations and events between *Ha* and *Hb*—described entirely in Freudenthal's formal notation—establish stories about the nature of the world and, more to the point, about the nature of human experience in its most austere form. *Ha* throws a ball farther than *Hb* can catch it. *Hb* knows something but does not say it, which means that *Ha* does not know it; *Ha* can try to guess what it is that *Hb* knows. *Ha* and *Hb* know what happened in the past but not what will happen in the future, and they bet on an outcome together. *Ha* didn't see something and therefore asks *Hb* about it. Together, they live in a world, and there are many other things that live in the world with them with whom they can't communicate in the same way, even though those things can also see, hear, move, know the past, and chase a ball. They can die, *Ha* and *Hb*; so can all the other things with which they share the world. They can wish that things were otherwise than they are. When one of them dies, they can no longer talk.

It in no way diminishes Freudenthal's strange achievement—an attempt at formalizing human life in the universe into a basic set of electromagnetic signals—to question its fitness for purpose: the nearest possible life is so far away that years or decades would separate each exchange confirming receipt and understanding with reciprocal signals. Some of Freudenthal's dialogical units are hundreds of steps long, with multiple points needing confirmation; simply at the level of back and forth, this would be a millennial project. What he has produced in fact seems much closer—much

42 more appropriate—to formulating properties of human experience not to communicate with aliens but with machines.

George Boole, walking across a field at seventeen in 1832, was struck by an idea that led to his book *An Investigation of the Laws of Thought*, a model of logical reasoning using a symbolic calculus built on what he called “the Universe” and “Nothing”—or 1 and 0 (Boole 2009). What he produced was not an accurate portrait of the process of human reasoning, but it was, a century or so later, perfectly suited to performing complex mathematical and logical operations on electrical relays and vacuum tubes. Likewise, Freudenthal’s project is filled with striking insights, and many of them seem less applicable to broadcasting to Alpha Centauri than to explaining what it is to be a person in the universe to an entity that lacks anything but a memory and the input of a very limited set of electromagnetic symbols. No wonder Marvin Minsky, who constructed the first neural network simulator, was drawn to this research: it shoots for the stars and lands in the AI lab.

Indeed, one of the persistent challenges of AI has been precisely in recognizing the particular biases and tendencies in human cognition that would not be shared by a machine—no more than the way we think that we see is shared or modeled by a sensor picking up photons. “I shall suppose that the person who is to receive my messages is human or at least humanlike as to his mental state and experiences,” writes Freudenthal (1960, 14). “I should not know how to communicate with an individual who does not fulfill these requirements.” Now we do so all the time: by voice, text, image, and the indirect production of data.

We have established rapport with an alien planet that we build and maintain around us, teaching its population to make spatial sense of the world, keep secrets, recognize faces, hear and compress and filter voices, make conversation, and interpret a far broader range of electromagnetic radiation than just radio waves or the visual spectrum. We have done all this with binary pulses, logical operations, and encoding and decoding schemes.

The informational commerce and exchange of the world take place in the dense network of Martian canals that we've dug for the last sixty years, and we communicate in ways that embody the problems and solutions of Cros and Gauss, Hogben and Lomberg and Freudenthal. Like fantastical narratives that act as accounts of our society alienated and rendered strange—from *Gulliver's Travels* to *Animal Farm*—the three centuries of projects for communicating with unknowable, nonhuman interlocutors chronicled here can be rearranged (*Erewhon* becomes Nowhere) to be our most ordinary present: reacting to automated alerts, talking with customer service, solving CAPTCHAs to log in to Facebook.

This is our present state of mediated communication. What is our future?

The Light Cone

Hogben was not alone in this conceptual move, but he put it most eloquently: "Though we cannot communicate with our Neolithic forbears, they themselves can communicate with us through the mists of time"—with "astrocalendrical" hieroglyphs and number systems. Many extraterrestrial communication projects make reference to the case of our distant ancestors and their notched bones and standing stones marking, or appearing to mark, lunar sequence and equinoctial sunrise. With a basic vocabulary of forms, used to track regular cosmic patterns, they were able to establish a one-way communication channel over thousands of years. It seems similar, in some ways, to a message broadcast out into the void. But this position is riddled with problems if it is taken any more seriously than a straightforward statement on the value of numbers and astronomical events as points of common reference. After all, we enjoy anatomy, fundamental cognitive and social traits, and a planet in common. Why do we use ourselves in the past as a way of analogizing communication with alien life in the future?

This chapter has been concerned with the idea that, in considering communication in digital media, we should account for how alien,

44 and how ubiquitous and invisible, the interlocutors and mediators we built have become. This corresponds to a dehumanization—again, not in a pejorative sense!—of contemporary digital media. I find the analogy of extraterrestrial communication useful in seeing this problem, because it forces questions about the anthropocentric sense of communication on digital networks and acts as a kind of parallel history of digital networks themselves and the formats we've developed to make use of them. Toward the end of the first section, I asserted that we could move beyond the models of Kittler and Licklider and Taylor to look at communication with the future as well as past and present—a future defined by communications media that are not just digital but *alien*. Rather than hiding their profound strangeness behind carefully designed interfaces and media that, to quote Bunz, “address us as if we were children,” complete with cartoon characters, bright flat design, and tinkly-tonkly toy instrument sound tracks, we should expose and explore—and even embrace—their alienness and, with it, the future.

We have talked about theories defining the limits of information, like Claude Shannon's, but there is one more limit to communication: a temporal one. The light cone is the theoretical description of an event—a flash of light, a signal—propagating through space-time. What lies within the cone could have been influenced by the signal in some way. What lies within the *future* light cone, and could therefore receive a signal from a present moment, is the set of all future events that could be causally influenced by it. It's a steadily expanding zone of possible causality and a way of understanding the temporality of information and communication. You can understand an event taking place here and now as being within the light cone of many remote objects in the universe, to the edge of observation itself—but as they were, of course, at the moment of an equally remote event, and not now. We are in their (far, far) future.

“To get information about the life and times for some inhabitants of a planet outside the Solar system, say, the fastest way that we

can get such information is by means of light signals," write Grøn and Hervik (2007). "The light-cone tells us what region of spacetime we can get information from" (221). Both the way light moves and the speed at which it moves are hard limits on what can be known. All the emissions of attempted communication with alien life—the mostly hypothetical flashes of light, the bursts of radio signals—are light cone events, utterances in space-time. That is, they are communications not simply with a distant exoplanet but with our future.

If they are intercepted at all, these messages will arrive years—or more likely decades, millennia, or eons—later. Given time for interpretation and response, that almost unimaginable conversation will likely take place after the original human speakers are dead. We likewise address ourselves to our present, in the act of communication, but also to a future likely populated with far more, and more diverse, varieties of alien interlocutors—the "missing subjects" who await our signals and whose predecessors we are programming, building, and installing on Earth at the moment.

I would like to end on this note of depersonalized optimism: that our present communicative acts on and with digital infrastructure put us in conversation not only with one another, or with our current machinery, but also with far stranger communicants that will have as little resemblance to our media experience as Spanner does to the CTSS. Future technical infrastructures are what we digitally communicate with now, infrastructures far more alien in their likely operation, and in the place they occupy in the future itself. This is how we can retrospectively understand ourselves and our communication using contemporary digital media: messages formatted and transmitted to our alien planet to come, a little way down the light cone, close enough to guess at but unimaginably far away.

Note

I owe many thanks for this project, starting with Wendy Chun's invitation to join the Terms of Media II conference. The question and discussion session during

that event was invaluable. This piece was informed throughout by the work and conversation of Mercedes Bunz and Sara Dean. My thanks in particular to Boris Traue for a thoughtful, informed, and thorough editorial reading of the manuscript, which improved it significantly; to Paula Bialski for analysis, suggestions, and the introduction; and to the staff of meson press and the insights of the peer reviewers. My fond gratitude to you all.

References

- Ades, Dawn, ed. 2006. *The DADA Reader: A Critical Anthology*. Chicago: University of Chicago Press.
- Anderson, Laurie. 1983. "Say Hello." *United States Live*. New York: Warner Brothers Records.
- Bardini, Thierry. 2000. *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing*. Stanford, Calif.: Stanford University Press.
- Bartlett, Jamie. 2017. "Can You Distinguish between a Bot and a Human?" *Spectator*, November 20.
- Boole, George. 2009. *An Investigation of the Laws of Thought on Which Are Founded the Mathematical Theories of Logic and Probabilities*. Cambridge: Cambridge University Press.
- Bratton, Benjamin. 2016. *The Stack: On Software and Sovereignty*. Cambridge, Mass.: MIT Press.
- Brunton, Finn. 2013. *Spam: A Shadow History of the Internet*. Cambridge, Mass.: MIT Press.
- Canales, Jimena. 2009. *A Tenth of a Second: A History*. Chicago: University of Chicago Press.
- Capova, Klara. 2013. "The Charming Science of the Other: The Ethnography of the Scientific Search for Life beyond Earth." PhD diss., Durham University.
- Chun, Wendy. 2008. "The Enduring Ephemeral, or the Future Is a Memory." *Critical Inquiry* 35: 148–71.
- Corbett, James C., Jeffrey Dean, Michael Epstein, Andrew Fikes, Christopher Frost, J. J. Furman, Sanjay Ghemawat et al. 2012. "Spanner: Google's Globally-Distributed Database." In *Proceedings of OSDI 2012*. Accessed March 25, 2016. <http://static.googleusercontent.com/media/research.google.com/en//archive/spanner-osdi2012.pdf>.
- Cros, Charles. 1970. *Oeuvres complètes*. Paris: Pléiade.
- Crowe, Michael J. 1986. *The Extraterrestrial Life Debate 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell*. Cambridge: Cambridge University Press.
- Drake, Frank, and Dava Sobel. 1992. *Is Anyone Out There?* New York: Delacorte Press.
- Edwards, Paul. 2003. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems." In *Modernity and Technology*, edited by T. Misa, P. Bray, and A. Feenberg, 185–225. Cambridge, Mass.: MIT Press.
- Engelbart, Doug. 1962. *Augmenting Human Intellect: A Conceptual Framework*. Report to the Director of Information Sciences, Air Force Office of Scientific Research. Menlo Park, Calif.: Stanford Research Institute.

- Eno, Brian. 1996. *A Year with Swollen Appendices*. London: Faber and Faber.
- Fielding, Nick, and Ian Cobain. 2011. "Revealed: US Spy Operation That Manipulates Social Media." *Guardian*, March 17.
- Fitzpatrick, Paul. N.d. "CosmicOS." CSAIL. Accessed March 4, 2016. <http://people.csail.mit.edu/paulfitz/cosmicos.shtml>.
- Foucault, Michel. 1990. *The History of Sexuality: Vol. 1. An Introduction*. New York: Vintage.
- Freudenthal, Hans. 1960. *Lincos: Design of a Language for Cosmic Intercourse*. Amsterdam: North-Holland.
- Frollo, Jean. 1899. "De la Terre a Mars." *Le Petit Parisien*, May 10.
- Galloway, Alexander. 2004. *Protocol: How Control Exists after Decentralization*. Cambridge, Mass.: MIT Press.
- Galton, Francis. 1896. "Intelligible Signals between Neighboring Stars." *Fortnightly Review* 60: 657–64.
- Goodhart, Charles. 1981. "Problems of Monetary Management: The U.K. Experience." In *Inflation, Depression, and Economic Policy in the West*, edited by Anthony S. Courakis, 91–121. Lanham, Md.: Rowman and Littlefield.
- Gray, Robert H., and Simon Ellingsen. 2002. "A Search for Periodic Emissions at the Wow Locale." *Astrophysical Journal* 578, no. 2: 967–71.
- Greenberger, Martin. 1962. *Management and the Computer of the Future*. Cambridge, Mass.: MIT Press.
- Greenwald, Glenn. 2014. "How Covert Agents Infiltrate the Internet to Manipulate, Deceive, and Destroy Reputations." *Intercept*, February 24.
- Gregg, Melissa. 2013. "Courting Vectoralists: An Interview with McKenzie Wark on the 10 Year Anniversary of 'A Hacker Manifesto.'" *Los Angeles Review of Books*, December 17.
- Grøn, Øyvind, and Sigbjørn Hervik. 2007. *Einstein's General Theory of Relativity: With Modern Applications in Cosmology*. New York: Springer.
- Hogben, Lancelot. 1943. *Interglossa: A Draft of an Auxiliary for a Democratic World Order, Being an Attempt to Apply Semantic Principles to Language Design*. New York: Penguin Books.
- Hogben, Lancelot. 1963. *Science in Authority*. New York: W. W. Norton.
- Internet Assigned Numbers Authority. 2016. "Time Zone Database." Accessed March 25, 2016. <https://www.iana.org/time-zones>.
- Irani, Lilly. 2015. "Justice for 'Data Janitors.'" *Public Books*, January 15.
- Jain, Anab. 2014. "Valley of the Meatpuppets." Superflux. Accessed March 25, 2016. <http://superflux.in/index.php/work/valley-of-the-meatpuppets/#>.
- Kittler, Friedrich. 1990. *Discourse Networks 1800/1900*. Stanford, Calif.: Stanford University Press.
- Kittler, Friedrich. 1999. *Gramophone, Film, Typewriter*. Stanford, Calif.: Stanford University Press.
- Kittler, Friedrich. 2010. *Optical Media*. Cambridge: Polity Press.
- Krebs, Brian. 2015. "Extortionists Target Ashley Madison Users." *Krebs on Security* (blog). August 15. <https://krebsonsecurity.com/2015/08/extortionists-target-ashley-madison-users/>.

- Kuo, Michelle. 2008. "Special Effects: Michelle Kuo Speaks with Michael Callahan about USCO." *Artforum*, May 2008.
- Lee, John A. N., and Robert Rosin. 1992. "The Project MAC Interviews." *IEEE Annals of the History of Computing* 14, no. 2: 14–35.
- Lemarchand, Guillermo A., and Jon Lomberg. 2011. "Communication among Interstellar Intelligent Species: A Search for Universal Cognitive Maps." In *Communication with Extraterrestrial Intelligence (CETI)*, edited by Douglas A. Vakoch, 371–95. Albany: State University of New York Press.
- Licklider, J. C. R. 1963. "The System System." In *Human Factors in Technology*, edited by E. Bennett, J. Degan, and J. Spiegel, 627–45. New York: McGraw-Hill.
- Licklider, J. C. R. 1965. *Libraries of the Future*. Cambridge, Mass.: MIT Press.
- Licklider, J. C. R. 1988. "Oral History Interview by William Aspray and Arthur L. Norberg, 28 October 1988, Cambridge, Massachusetts (OH 150)." Charles Babbage Institute, University of Minnesota.
- Licklider, John, and Robert Taylor. 1968. "The Computer as a Communication Device." *Science and Technology* 76: 21–31.
- McLuhan, Marshall. 1994. *Understanding Media: The Extensions of Man*. Cambridge, Mass.: MIT Press.
- Mills, D. L. 1985. "RFC 956: Algorithms for Synchronizing Network Clocks." Network Working Group. Accessed March 25, 2016. <https://tools.ietf.org/html/rfc956>.
- Minsky, Marvin. 1985. "Communication with Alien Intelligence." In *Extraterrestrials: Science and Alien Intelligence*, edited by Edward Regis, 117–28. Cambridge: Cambridge University Press.
- Negarestani, Reza. 2015. "Revolution Backwards: Functional Realization and Computational Implementation." In *Alleys of Your Mind: Augmented Intelligence and Its Traumas*, 139–54. Leuphana, Germany: meson press.
- Newitz, Annalee. 2015. "How Ashley Madison Hid Its Fembot Con from Users and Investigators." *Gizmodo*, September 8.
- Parikka, Jussi. 2015. *A Geology of Media*. Minneapolis: University of Minnesota Press.
- Peirce, Charles Sanders. 1989. "A Boolean Algebra with One Constant." In *Writings of Charles S. Peirce*, vol. 4, 13–18. Indianapolis: Indiana University Press.
- Peters, John Durham. 2015. *The Marvelous Clouds: Toward a Philosophy of Elemental Media*. Chicago: University of Chicago Press.
- Popular Science Monthly*. 1919. "Hello Mars—This Is the Earth! Will the Martians Answer Us?" September.
- Sandvig, Christian. 2013. "The Internet as Infrastructure." In *The Oxford Handbook of Internet Studies*, edited by William Dutton, 86–106. Oxford: Oxford University Press.
- Shannon, Claude. 1956. "The Bandwagon." *IRE Transactions on Information Theory* 2, no. 1: 3.
- Shannon, Claude, and Warren Weaver. 1949. *The Mathematical Theory of Communication*. Chicago: University of Illinois Press.
- Sindelar, Daisy. 2014. "The Kremlin's Troll Army." *Atlantic*, August 12.
- Starosielski, Nicole. 2015. *The Undersea Network*. Durham, N.C.: Duke University Press.
- Sterne, Jonathan. 2012. *MP3: The Meaning of a Format*. Durham, N.C.: Duke University Press.

- Stites, Richard. 1989. *Revolutionary Dreams: Utopian Vision and Experimental Life in the Russian Revolution*. New York: Oxford University Press.
- Tesla, Nikola. 1901. "Talking with the Planets." *Collier's Weekly*, February 9.
- Turing, Alan. 1950. "Computing Machinery and Intelligence." *Mind* 59: 433-60.
- Verraes, Mathias. 2015. "There Are Only Two Hard Problems . . ." Twitter. Accessed March 25, 2016. <https://twitter.com/mathiasverraes/status/632260618599403520>.
- Vismann, Cornelia. 2008. *Files: Law and Media Technology*. Stanford, Calif.: Stanford University Press.
- Waldrop, M. Mitchell. 2001. *The Dream Machine: J.C.R. Licklider and the Revolution That Made Computing Personal*. New York: Viking.
- Wittgenstein, Ludwig. 2001. *Philosophical Investigations*. London: Blackwell.
- Yates, JoAnne. 1989. *Control through Communication: The Rise of System in American Management*. Baltimore: Johns Hopkins University Press.
- Zaitsev, Alexander, and Sergey Ignatov. 1999. "Broadcast for Extra-Terrestrial Intelligence from Evpatoria Deep Space Center": Report on Cosmic Call 1999." Accessed March 19, 2016. <http://www.cplire.ru/html/ra&sr/irm/report-1999.html>.