The Historiographic Conceptualization of Information: A Critical Survey

Bernard Dionysius Geoghegan
Northwestern University

The historical pedigree and meaning of ''information'' has been hotly contested since its scientific definition in the 1940s. Scientists have authored very different explanations for the origins of informational research, the scope of information theory, and the historical significance of its findings. This survey classifies the historical literature into genres, offering a view into the changing environment of computer research.

For those interested in ''historiography'' (how methods of evidence gathering, interpretation, and writing inform and constrain the writing of history), Claude Shannon's death in 2001 offered a rich glimpse into the writing of popular computer history. Confronted with the death of an icon, national media and popular attention converged upon unfamiliar traditions of computational research. Eminent science writers responded, serving up stock-and-trade theories of technological change to the press. Writing an obituary in *The New York Times*, George Johnson hailed Shannon for ''giving birth to the science called information theory.''[1] Mitchell Waldrop labeled Shannon the ''reluctant father of the digital age'' who ''gave us the modern concept of information.''[2] James Gleick explained in *The Sunday Times* that

> Shannon is the father of information theory, an actual science devoted to messages and signals and communication and computing. The advent of information theory can be pretty well pinpointed: July 1948, the Bell Labs Technical Journal … Suddenly there it was, full-grown.[3]

Shannon's patrons followed suit. A press release from Lucent Technologies (present-day home of Bell Labs) announced ''Claude Shannon, Father of Information Theory, Dies at 84.''[4] The news office at Massachusetts Institute of Technology mourned the passing of ''the father of modern digital communications and information theory.''[5] Expert commentators and colleagues from both institutes volunteered explanations of Shannon's work. MIT professor Robert Gallagher told *The Times* ''Shannon was the person who saw that the binary digit was the fundamental element in all of communication … That was really his discovery and from it the whole communications revolution sprung.''[6]

In meditating on the death of a researcher, these articles provided the public with curt and precise narratives of historical change in computing. At a time when ''posthuman''[6] scientific, commercial, and technological research distributes agency across innumerable men, machines, and patrons, Shannon's life in these accounts assumed the comfortable, humanist authority familiar to Enlightenment narratives of science.[7] Information theory and the digital age itself sprang fully formed from Shannon's Olympian genius. From these simple, clear-cut origins authors offered a reassuring framework for understanding the World Wide Web and other perplexing digital technologies.[8]

Subtle patterns organized these pat accounts. A small circle of Bell Labs and MIT colleagues provided sound bites on Shannon's importance. Institutional hosts MIT and Lucent Technologies provided these same speakers and forums for reflection. Their massive institutional archives offered additional cooperation. The journalists who wrote these stores came from a small community of popular science writers, among whom Johnson, Gleick, and Mitchell stand out for their writings on chaos and complexity theory.[9] Conventional mourning rituals authorized generous reconciliations between an eminent researcher and the world he now left behind. Through these historiographic alliances, disputed histories of Shannon, computing, and information theory were refashioned into a compelling, authoritative narrative.

 Published by the IEEE Computer Society 1058-6180/08/$25.00

Analyzed collectively, these articles provide insight into how computer history becomes public and topical. "Computer history" does not appear before the public as a convenient, natural, and unmediated accounting of clear-cut facts. Instead, a historically specific organization of experts, research, resources, and interpretive frames emerges in response to present and presumably historical events. This is not the meddling intervention of outside interests and biases upon the neutral labor of historiography; rather, these are the basic conditions for writing computer history. These conditions' appearance prompts questions about how a retiring mathematician, skeptical about his personal acclaim, emerged as a recognizable and heroic subject of popular interest.

A short cultural history

A short cultural history[10] of "the father" of information theory will provide context: Shannon's popular renown originated from a historical moment when the American public put its trust in military-funded computational and communications research after World War II. As a new Soviet threat took form, American policymakers and foundations turned to scientists and engineers for solutions to looming Cold War crises. Confronting massive new industrial systems, prospective global television networks,[11] and new US imperatives for managing global politics at a distance, "communications" emerged as a central social, technical, and scientific concern.[12] Shannon rose to prominence among the nascent postwar scientific elite. For many, his research into communication and computers symbolized the possibility of rationally managing new communications systems vital postwar security.

Like the brand names of technological gadgets proliferating in middle-class kitchens, the moniker "Claude E. Shannon" quickly became a fashionable mark of progressive thought.[13] Shannon's article "A Mathematical Theory of Communication," printed in *The Bell System Technical Journal*,[14] was republished as the widely distributed book *The Mathematical Theory of Communication*.[15] A new, populist introduction was added, based on Warren Weaver's musings from *Scientific American*.[16] The expanding market for middlebrow scientific journals and books promoted Shannon alongside promises "to satisfy the curiosity that almost every intelligent American feels about the latest scientific developments."[17] A new educational film—directed by the eminent Charles and Ray Eames, sponsored by influential IBM, and distributed by the prestigious Museum of Modern Art—interpreted Shannon's research for students across the nation.[18] An NBC-produced documentary showcased Shannon as one of the leading mathematicians building "learning machines" that enlightened man and society.[19] At public talks, the erudite mathematician opined on topics ranging from "The Atomic Age—Challenge to Free Men"[20] to methods for communicating with extraterrestrials.[21] Shannon's name was even used to sell the Minivac 601, a 1960s personal computer described as "a private pet project by Dr. Claude E. Shannon" that "introduced teenagers and adults … anyone with an inquiring mind … to the fascinating world of machines that think."[22]

These popular representations, motivated by national security and insecurity, framed by prospects of technological promise and apocalypse, secured Shannon's prominence in the American public's imagination. Through it, obscure laboratory findings of wartime science and nascent digital communications became trendy topics in pop culture.[23] A "father" was born.

Intellectual history

William Aspray's 1985 article "The Scientific Conceptualization of Information"[24] challenged the dominant narratives about Shannon and information theory's invention-discovery. Rejecting technological invention and fathering, Aspray investigated "scientific conceptualization." He portrayed a messy, gestating community of elite scientists who enlisted the diverse resources of mathematics, physics, engineering, logic, biology, and psychology. Together, they strove toward the delineation of a transdisciplinary, quasi-Platonic ideal: "information."

Aspray credited Norbert Wiener, Warren McCulloch, Walter Pitts, Alan Turing, John von Neumann, and Shannon with collectively "conceptualizing information." Bound by wartime imperatives, linked by shared analogies between humans and machines, and united via mathematical logic, they collectively articulated the agendas, assembled the machines, and wove the tropes necessary to articulating a rational, scientific conceptualization of information. In a somber tone, Aspray added that their grand search for information science "formed a more coherent discipline shortly after the war than at any time since."[25] He suggested that the subsequent institutional and academic compartmentalization of information and computer research inhibited "the growth of an interdisciplinary science of information."[25] Instead, the complex, multifaceted field consolidated around Shannon and the discourse he "fathered": "information theory." Technological fathering was not only cliché but also artifact in the contentious reconceptualization of information processing research around a much narrower, restricted field of practices and participants.

Aspray cautioned that his was only a provisional "sketch" of information's conceptualization, a preliminary contribution to an incomplete history of computing. He optimistically hoped that with his own historical notes in place "others will contribute the fine brushstrokes necessary to complete the picture."[26] Successive researchers not only filled-in the information's historical mise-en-scene but also elaborated imaginative alternative panoramas. The history of information, formerly a vanguard topic in IEEE publications, today stands as a topic of general and diverse interest. The tenuous threads of abstract conceptual change have been rewoven into fierce ropes by dozens of historical studies elaborating information theory's place in postwar industry, government, and academics. This robust growth of information-concerned historiography itself constitutes an event in the history of computing, the passing of computers from specialist to generalist interest.

The present article sketches the contours of how the scientific concept of information has been historicized and re-historicized[27] since Shannon's "A Mathematical Theory of Communication." The histories considered fit into a handful of overlapping methodologies, which are neither exhaustive nor mutually exclusive. These include the following:

- popular histories (reportage and histories written for general audiences)
- intellectual histories (a succession of researcher ideas and disciplinary agendas)
- official histories (scientific accounts offered by authoritative researchers)
- institutional histories (institutionally facilitated histories foregrounding the sponsor's contribution to research)
- discourse analysis (how language and research models shape and bind research communities)
- national histories (how national contexts shape scientific research)
- material histories (attention to research cultures' obdurate basis in locally coordinated techniques, machinery, and human-machine assemblages)

These categories provide provisional[28] heuristic bins for grouping and comparing historiographical analyses, and looking at what trends appear in the historiography of information today. Comparing sheds light on the communities, narratives, and cultural concerns animating past and current historiography.

Such a critical review is not a supplement to computer history. Historiography and historiographic reevaluation plays a basic part in organizing and building the research, industries, institutions, and professions that make up "the history of computing."[29] From Norbert Wiener's vision of the computer as great mathematical marvel to the gendering of computer professions, from Bill Gates' "paperless office" to the repurposing of computers for biological research, the practices of computing are inseparable from histories built around it.[30] In adducing historiographical perspectives on computers, we gain insight into the changing fortune of information processing industries and professionals. The varieties and methods of telling computer history document ephemeral hopes, fears, and aspirations professionals and the public harbor for computers. They also reveal historians' intimate and historical relationship with their objects of study. No longer scribe or dispassionate observer, historians emerge as participants caught up in the historical forces they help others imagine, conceptualize, and explore.

Official histories of information

Claude Shannon and Norbert Wiener, information's most eminent researchers, also served as its most eminent historians. Through the conventions of scientific exposition and research, both provided historical precedents, trajectories, and contexts for historicizing early informational research. Shannon and Wiener offered directions for understanding the history of the concept "information," as well as the place of information and transmission research within history. Yet their historical portraits diverged sharply, as Shannon addressed a narrow technical community while Wiener solicited an interdisciplinary community of scientists.

Shannon's classified, wartime Bell Labs report "A Mathematical Theory of Cryptography"[31] was his first lengthy treatise on the transmission of "information."[32] This report provided major concepts, equations, and prose passages for Shannon's postwar articles "A Mathematical Theory of Communication" and "Communication Theory of Secrecy Systems."[33] It also provided rudiments for information's historiographical assignment. Scientific precedent, attempted or intended informational applications, and influential colleagues are cited throughout. However, the shift from a private paper circulated among colleagues and friends to a public article tailored to general professional interests also entailed a shift in intellectual genealogy and historical emphasis. Particularly striking were Shannon's passing philosophical framings of information theory, absent from subsequent articles in professional engineering journals.[34]

In the publicly distributed "A Mathematical Theory of Communication,"[14] Shannon abstracted his research from its singular, local, historical context of production. Replacing the wartime concerns animating earlier papers, an entrancing aura of ahistoricity surrounded Shannon's discussions;[35] historical specificity expunged, unmediated truth seemed to emanate from the hand of a mathematician-supplicant. But the citations of Shannon's articles comprised specific, historically rooted, intellectual architectures. His citations from "A Mathematical Theory of Communication" reconstructed his previous institutional environs—MIT, Princeton University, and Bell Labs. Shannon credited Harry Nyquist and Ralph Hartley, both of AT&T, with outlining the basic principles for measuring information.[36] Princeton mathematician John Tukey, a wartime consultant on fire control, was recognized for conceiving of the bit ("binary digit"); Princeton legend John von Neumann's contributions to ergodic theory are also noted. MIT graduate students are throughout cited for complementary work.

Shannon reserved the most personal and generous recognition for Wiener, writing, "Communication theory is heavily indebted to Wiener for much of its basis philosophy and theory."[37] Providing hints to the political and laboratory origins of their present work, Shannon added that "[Wiener's] classic [National Defense Research Committee] report, *The Interpolation, Extrapolation and Smoothing of Stationary Time Series* (Wiley, 1949), contains the first clear-cut formulation of communication theory as a statistical problem, the study of operations on time series."[38] This generous salute, however, served to foreground Shannon's historical distinction. Wiener's paper, he explained, was "chiefly concerned with the linear prediction and filtering problem," and *Cybernetics* focused on "the general problems of communication and control."[38] Isolating these precedents brought Shannon's novel contributions into relief: his were rigorous mathematical formulations of discrete, informational transmissions.

Other shared experience and work between Shannon and Wiener might have been included. Both developed their most lasting theories of communication while working for the National Defense Research Committee. Both developed important aspects of communication theory on their overlapping research in artillery fire control. During the war the two met and shared research.[39] But none of this fit the historiographical dictates of scientific exposition. Instead, Shannon's account suggested a series of stable research findings emerging in the abstract, transmitted and verified through a series of ingenious equations and publications.

Shannon's presumed assumptions about his readers provide a proximate and concrete explanation for his terse, sober historiography. History, particularly "social history" and "cultural history," serve the purpose of making facts intelligible in context; Shannon presumed his audience already possessed the contextual knowledge necessary for apprehending his work. Readers of the highly specialized *The Bell Labs Technical Journal* would likely be advanced researchers in engineering and mathematics, familiar with aspects of Bell Labs culture. The coordinating role played by government, the close-knit cadre of scientific elites, and the merger of science and techno-science taking place there were familiar trends among electrical and communication engineers. By eliminating cultural contexts from representation, Shannon signified his confident belief that his readers were advanced researchers in mathematics and engineering, sharing the training, methods, tools, and work routines for producing, interpreting, and validating his own findings.

The specific bearing audience had upon Shannon's historical styles in "Mathematical Theory" is suggested by its stark contrast with Wiener's *Cybernetics: or Control and Communication in the Animal and the Machine*.[40] Seeking to create new interdisciplinary science, Wiener could not rely on present, existing, and shared research frame research interpretations; instead, he sought to manufacture such contexts. Through a more ambitious, robust historiography, Wiener guided his readers toward attaching different import to his accomplishments and the status of information generally. "The thought of every age is reflected in its technique,"[41] Wiener instructed. "If the seventeenth and early eighteenth centuries are the age of clocks, and the later eighteenth and the nineteenth centuries constitute the age of steam engines, the present time is the age of communication and control."[42] In this way, "cybernetics" was not only defined *in* the sequence of history, but also for its ontological status as an exemplar and engine of historical spirit.

Wiener situated his research as a confrontation with the historical state of modern scholarship. "Since Leibniz," he explained, "there has perhaps been no man who has had a full command of all the intellectual activity of his day."[43] Faced with the proliferations of disciplines, subfields, and jargons throughout the academy, Wiener argued that cybernetic information flows provided a unified theory of animal, machine, and social systems. Wiener's contemporaries sometimes dismissed such claims as intellectual onanism. Such critiques obscured his practical and productive historiographic labor. Wiener resituated trends in technology, computation, and communication within a kind of Hegelian historical spirit. His history brought social, ethical, and political import to the use of technology, recruiting acolytes from across the academy. Out of this discursive ebullience, Wiener constructed a new and diverse community for cybernetic research. Finally, in his capacity as ad hoc historian, Wiener could assign an especially rosy portrait of cybernetics' historical importance.

Both Shannon and Wiener produced insiders' accounts of the rational, mathematical principles inherent in their emerging methodologies. Despite different rhetorical styles aimed for different audiences, both their works carefully authorized proper methodologies, devices, and interpretations. These narrowly constructed histories and citations established eminent scientific genealogies. Accepting this mantle and proposing their own extensions to these traditions, both authors took the liberty of proscribing what they regarded as inappropriate understandings or applications of their work.[44]

However, other "official" histories also appeared. Researchers from different traditions and national contexts wrote alternative histories where Shannon's and Wiener's research appeared to be specialized instances in a much broader field of practices producing and distributing "information." British cognitive scientist Colin Cherry offered one of the most widely read, alternative[45] official histories of information.[46] Like other eminent British information theorists, Cherry proposed more expansive definitions of information, its origins, and its applications.[47] In "A History of Information Theory" introducing the 1953 inaugural issue of *IEEE Transactions on Information Theory*, Cherry found the findings of modern information theorists borne out in the ancient writing practices of Roman shorthand, Ancient Hebrew, and Slavonic Russian. Philosophers Descartes and Leibniz were cited as philosophical precursors, and he credited behaviorists Ivan Pavlov and J.B. Watson with discerning the informational basis of animals and machines. Reviewing the articles in that first *Transactions on Information Theory*, it is clear Cherry's history had much to recommend it: within a relatively slim volume, Shannon, Denis Gabor, and Donald MacKay each offered competing theories of information. Phonetician Donald Fry mused on the parallels of Shannon and linguist Ferdinand de Saussure. Other articles treated computers, automata theory, physiology, and mechanical brains. Cherry's introduction offered the only unified field theory through which these disparate methods appeared to have something broadly in common.

In subsequent decades, information theory consolidated around the work of Shannon, pushing the histories by Wiener, Cherry, and others into the margins. J.R. Pierce's 1973 essay "The Early Days of Information,"[48] published in the *IEEE Transactions on Information Theory*, offered a history appropriate to this new disciplinary formation.[49] Explaining his decision to reject Cherry's earlier histories, Pierce wrote "With 20-20 hindsight it is easy to pick out the earlier work most contributive to *Shannon's* synthesis."[50] A hatchet job in the best sense, Pierce cut away what he regarded as aberrant earlier claims for information theory's broad relevance. Discussing Wiener's ambivalence toward Shannon's narrower informational measure, Pierce wrote:

> Wiener's head was full of his own work and an independent derivation of [some of what was in Shannon's work] ... Competent people have told me that Wiener, under the misapprehension that he already knew what Shannon had done, never actually found out.[51]

An unalloyed Shannon-chauvinism stemming from their many years of collaboration hardly explains Pierce's harsh dismissals of alternatives. He himself had prominently participated in "Project Troy," one of the government's largest and most outlandish mergers of mathematics, engineering, and social science through information theory.[52] But by 1973 an enlivened field of information theory, on the cusp of implementing Shannon's most robust theorems, had officially disavowed such earlier experimental alliances. With strong funding coming from NASA and industry, such support of earlier "diversions" was unneeded and unwanted. By drawing information into broader, less practicable reflections, alternative histories threatened an ongoing and lucrative consolidation of information theory around emerging governmental and commercial priorities.[53]

Pierce's history was strongly reinforced by successors, and particularly the dominant *IEEE Transactions on Information Theory*. Exemplary is a recent article by *Transactions* editor Sergio Verdú, entitled "Fifty Years of Shannon Theory."[54] The very first sentence declares "A Mathematical Theory of Communication" as "the Magna Carta of the information age."[55] Verdú offers a literature review of "the main achievements in Information Theory." This is confined to "Shannon theory," that is the disciplines "spawned"[55] by Shannon. An embittered Wiener or Cherry might imaginably lament this narrowing of the field. But neither malice nor rivalry explains Verdú's account. As with Shannon's early and original account, "information theory" is here conceived for an assumed audience, sharing a unique and narrow common set of assumptions. Verdú offers a carefully constructed scientific tradition consolidating communities and disciplinary power within dominant practices of the present (in which sense it is methodologically in harmony with the implied goals of Wiener's and Cherry's histories). In short, the "official history" provides the most certain, narrow, and secure "rationalization"—which is to say support, justification, and consistency—to present practice: information theory narrowly conceived as the optimalization of discrete transmissions.

Institutional histories

"Institutional histories" are variations upon official histories. Like the official histories, they offer privileged insiders' account of research. Often these histories are written by, or feature extensive interviews with, researchers at host institutions. These histories treat the discovery or construction[56] of research results as a tribute to the practice, community, and ethos of sponsoring institutions. Written to bring prestige and recognition to its sponsor, the institutional history often adduces contingencies, cultural milieus, and research contexts familiar to mainstream scholarly histories (e.g., social and cultural histories written by professional historians). By documenting institutional mediations among political dynamics, the market, researchers, and ephemeral winds of technological change—which all tend to be ignored within official histories—these institutional histories illustrate the institutions' agency and largesse on behalf of researchers and scientific, technological, and cultural "progress."

The epic seven-volume *A History of Engineering and Science in the Bell System* aptly illustrates the peculiar interests of the history-writing institutions. Bell Labs researcher and IEEE columnist Robert Lucky once warned an interviewer:

> I edited one of the volumes, and I can assure you it's complete bullshit. The corporate view of how things happen is absolutely myopic. The corporations like to think things were planned and charted and went according to management plans, but of course that's not true at all.[57]

Such myopia served especial tactical value at American Telephone and Telegraph. As a governmentally sanctioned monopoly, carrying on vast commerce with the government, supporting its Bell Labs with a so-called R&D tax on all national calls, AT&T's fortunes were closely tied to staying in the public's good offices. Conceived shortly after the US government filed an antitrust lawsuit against AT&T,[58] these histories' documentation of AT&T benevolence were, at the least, of fortuitous timing.[59] As one of the history's editors recalled, "[AT&T] recognized very early on that, you know, the Bell Labs had contributed a great deal to national goals and things like that."[60]

It is through this nationalist, militarist, and self-interested historiographical drive that Bell Labs makes its greatest contribution to information theory history.[61] Although the *Communications Sciences (1925–1980)*[62] volume offers a relatively unremarkable account of Shannon's research, *National Service in War and Peace (1935–1975)*[63] fits Shannon's research squarely within the narratives of American science at war. There is no radical invention or fathering here, but rather a historically and politically specific shaping of research questions. Bell Lab researchers Nyquist and Hartley and Shannon's training at MIT are cited. A surprising and lengthy discussion of the "X

System," Shannon's team-project in World War II cryptography, illustrates crucial steps toward conceiving information theory. Through this documentation, Shannon's research no longer appears a natural link among great ideas, but instead one fortuitous result of mid-century mobilization within one of the nation's largest and most reliably patriotic commercial firms. Perhaps for the first time in the historiography of information theory, the decidedly political dimensions and conditions of its research appeared.

A Century of Electrical Engineering and Computer Science at MIT, 1882–1982,[64] by MIT-affiliated engineers Karl Wilde and Nilo Lindgren, offers a very different, and much more personable history of informational research. Its account of the postwar Research Laboratory of Electronics (RLE) portrays a lively research lab peopled by a young cadre of future luminaries in information and communication theory. Wilde and Lindgren write that these young researchers focused on "translat[ing] the ideas of Norbert Wiener and Claude Shannon into new forms of equipment."[65] MIT personalities such as Yuk Wing Lee and Jerome Wiesner, marginal or absent from official histories of information, play a starring role as mentors and champions in the MIT informational community. Wiesner, who later became MIT's president, fondly recalled the diverse personalities and disciplines surrounding 1950s and 1960s information research at MIT:

> … we explored the far-ranging implications of the concepts of information and communication theory; our interests ranged from man-made communication and computing systems to the sciences of man, to inquiries into the structure and development of his unique nervous system, and the phenomena of his inner life, and finally his behavior and relation to other men … Wiener was the catalyst. He did his job almost without recognizing his role, for his interest was in ideas.[66]

Alex Bavelas (social psychologist associated with Project Troy and the Macy Conferences), Noam Chomsky (founder of modern linguistics), M.P. Schützenberger (French mathematician and an erstwhile collaborator with Claude Levi-Strauss), and others also earned Wiesner's admiration, suggesting the peculiarly personal inflection of this MIT engineering history. One might suggest that where the Bell Labs histories outline inventions and their researchers, the MIT history outlines researchers and their inventions.

The contrast between Bell Labs and AT&T historiography may find its origins in the traditions and financial motivations of the respective institutions. As a modern research university, MIT belongs to a tradition based on freely cultivating and distributing research, and competing with other universities by cultivating the renown of its researchers and their communities.[67] Bell Labs, by contrast, was a private research institution without peer. Its unusual economic and legal place in postwar American life made exhibition of contributions to consumer markets, technology, and national well-being more tactically important. Highlighting eminent researchers contributed to this, but was secondary to delineating concrete research findings and inventions. From these vying interests, two distinct historiographical cultures emerged.

Most important is what the two histories share: by representing science in a field of massive institutional support, the AT&T and MIT institutional histories reflect and document the development of "technoscience" and "big science" within modern scientific research. They make tangible the indispensability of institution, industry, politics, and research communities in the construction of modern scientific research. Particularly in the cases of Bell Labs and MIT, these histories keep in mind the well-being and interests, and perhaps the readership, of a taxpaying public funding large aspects of institutional research. More generally, we might observe that the institutional history promotes and inaugurates the conceptualization of "information" and "computation" as public benefits, produced through public-private collaboration, indissoluble from social concerns, and supports making this work possible.

Discourse analysis

In the years following World War II, science and technology emerged as the standard-bearers of political, national, and academic hopes. Lavish support from the US government and innumerable private foundations widely promoted rational technological research as the key to freethinking progress. This politicization of science and technology recruited informational imitators from across the human sciences; it also invigorated new varieties of technological skepticism.

As a broader range of citizens, scholars, and political agents faced the promise and perils of the military-industrial complex, the interpretive schemas applied to science and technology multiplied. In the wake of Ronald Reagan's

1980s Star Wars proposals, information technologies became a topic of particular interest and scrutiny. Gradually but surely a new genre of analysis that focused on "informational discourse" emerged and proliferated. These studies examine how quasi-scientific, ostensibly apolitical language of information theory embodied, promoted, or masked more contingent and contentious political interests. Often these studies suspiciously regard science's discreet alliances[68] with industry, government, and other entities that contribute to their work of making scientific facts, scientific knowledge, and to some extent public culture.[69]

Donna Haraway, author of early and influential studies of the informational discourse,[70] locates not only her research, but also her historiographic methods, in the heart of postwar American technopolitics. The Yale-trained biologist explained:

> I am conscious of the odd perspective provided by my historical position—a Ph.D. in biology for [myself] an Irish Catholic girl was made possible by Sputnik's impact on U.S. national science-education policy. I have a body and mind as much constructed by the post-World War II arms race and Cold War as by the women's movements.[71]

Critical historiography was not a way of objectifying or distancing herself from the sciences, but rather part of investigating her—and our—belonging to these fields. Haraway's "The High Cost of Information in Post-World War II Evolutionary Biology: Ergonomics, Semiotics, and the Sociobiology of Communication Systems"[72] offered an early, exemplary study of the social and political factors shaping informational research. As she explained it, the paper tried

> to call attention to the kinds of objects of knowledge which historically can exist and are made to exist by the mundane material processes of science in the world really structured by war, capitalist economic organization, and male-dominant social life.[73]

Haraway examined how informational models, elaborated in World War II research, gained wide embrace in postwar biology. Finding surprising origins for information theory in pre-war pragmatism, behaviorism, and semiotics, she detailed contingent political, disciplinary, and national interests that bound these into a popular and coherent postwar methodology. Rather than debunking the scientific merit of informational research, Haraway argued that its spread and embrace across the disciplines depended on the contested and uncertain labors working on science from within and without. In short, Haraway convenes a context and methodology in which "information" appears as a politically laden material practice, at once "social" and "true".

Steve J. Heims's complementary book *Constructing a Social Science for Postwar America: The Cybernetics Group (1946–1953)*[74] stands out as a sustained and widely cited treatment of informational analysis, particularly as it disseminated outside the natural sciences. Heims received advanced scientific training before abandoning science in favor of historical research into modern science's interpenetration with political and social concerns; like Haraway, ethical concerns with modern science motivated Heims to turn toward historical and social scientific research.[75] After writing a landmark biography of von Neumann and Wiener, the scientist-turned-social scientist turned his attention on how science and politics influence social science at the Macy Conferences on Cybernetics. With insightful panache, Heims traced how the styles and stakes of Cold War politics promoted a social scientific embrace of informational research. The interpenetration of funding and personnel from conference participants, Macy Foundation personnel, and classified Cold War research programs facilitated conservative formulations of informational research's bearing on society. Through the language of cybernetics, sensitive social scientific questions about politics, race, and inequality transformed quasi-scientific dilemmas of systems states, information flows, and behaviorism.

Against this national and macro backdrop, "information theory" percolated through bizarre internal regimes of disciplinary reception and re-articulation. Statistician Leonard J. Savage and anthropologist Gregory Bateson, for example, enthusiastically embrace information theory for its answers to questions Shannon neither endorsed nor imagined.[76] Donald MacKay's well-known and aberrant theory of semantic information, Heims suggests, found its origins in idiosyncratic spiritual beliefs.[77] In one striking anecdote, a conference discussion of experiments by social psychologist Alex Bavelas devolves into a feud among MacKay, Shannon, Savage, Walter Pitts, and Julian Bigelow over the respective theories of information theory's bearing on human behavior and game theory.

These two treatments offer at best a fleeting and synoptic glimpse into the broad, complex, and highly differentiated range of discourse-driven accounts driving informational historiography today. Often these studies emphasize how a language, instruments, and research communities stabilize around and through particular "discourses." Research becomes concentrated around particular kinds of questions and inquiry; the result knowledge is real, but intimately tied up with its historical and social production. Within such discursive studies, information theory appears as a social product developed at the intersections methods, questions, and preoccupations in social and natural science, politics and industry.[78]

Heims' and Haraway's systematic refusal to take science or technology as neutral rational or instrumental values, their insistence on introducing political and cultural analysis, suggests a major shift in contemporary computer historiography. Computer scientists are no longer "merely" neutral researchers or benign technocrats, but actors in historical process that weaves them deep into its fabric. The carefully demarcated laboratory spills into the social and political contexts credited with its constitution. Though research questions appear formulated by remote political and social operations, answers now hang upon the agency of socially and historically situated scientists. The dissolution of scientific neutrality informs the possibility of scientist agency and ethics. The rise of this critical, social, political historiographical mode is one of the most striking and unintended consequences of science's 20th-century politicization.

National histories

Until recently major histories of information centered on American-based research and ignored traditions abroad. This historiographic gap was partly grounded in Cold War policies that streamlined international researchers into American universities while aggressively promoting American methods, researchers, and culture globally.[79] Since the end of the Cold War and the rise of popular global digital networks, historians have begun reconsidering information in global contexts.[80]

A brief account *From Newspeak to Cyberspeak: A History of Soviet Cybernetics*[81] provides a useful and partial introduction to the new national histories of information. Author Slava Gerovitch recalls Andrei Kolmogorov, Wiener's eminent Russian rival. Approached by colleagues in 1940, Kolmogorov agreed to publicly dispute a Lysenkoite's recent challenge of Mendel's law of segregation.[82] Applying more rigorous mathematical analysis, Kolmogorov routed the challengers' critique. Yet Kolmogorov's "good science" was, in this case, bad politics. The Lysenkoites turned their attack upon Kolmogorov, reproaching him for having the audacity and indiscretion to subordinate biology to mathematics. Threatened with what Gerovitch calls "a dangerous philosophical and ideological debate,"[83] Kolmogorov judiciously backed off his earlier claims. Henceforth Kolmogorov steered clear of the life sciences and advised his students to do the same.[83] Just as American national priorities drove Wiener, Arturo Rosenblueth, Bigelow, and others headlong into math-science-biology mergers, Soviet Lysenkoism chastened similar studies. For most of the two decades, Soviet information theory progressed solidly but without the biological inflections common in America.

Early in the history of information theory, the competition offered by Soviet information theorists was cause for alarm.[84] Unasked was the question: is this the same "information theory"? Emerging national histories of information, by contrast, foreground how national political contexts directly bore upon the funding, questions, findings, and applications of information theory and related sciences. Not simply using national context to explain a theory, these accounts also suggest that "science" can be interrogated for traces of national identity.

Material histories

Recent "material histories" of feedback, operations research, and Cold War technologies have suggested an alternate fulcrum in the story of information: material artifacts and the complex practices, beliefs, and institutions conjoined with them. These histories attend to the massive technological infrastructures located in major university and industrial research labs.[85] Though these histories bear some resemblance to institutional histories, they offer no quasi-transcendental institutional identity to confer global continuity on these stories. Assemblages of humans, machines, and laboratories come to the fore. "Knowledge" transmits itself not only through the great papers of famous researchers, but also through the machinic environs sustaining research cultures.

David Mindell's *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics*[86] offers the most recent and decidedly techno-materialist history of information's origins. Eschewing a discourse-centric study of information, Mindell conjures an eccentric genealogy narrated by feedback-driven machines, diagrams, and forgotten applications. Within Bell Labs research cultures, Shannon's research findings are displaced into institutional forebears; institutional forebears are displaced onto technological milieus. Nyquist and Hartley appear within vast technocultural environs, shaped by trends in industry, commerce, and physics. Theories of machinery and research papers offer decisive but minute—and sometimes late-arriving—records of these environs. Nyquist and Hartley, Mindell argues,

> epitomized the engineering culture of the telephone company in the 1920's and '30s, as it began to conceptualize the telephone network as a transmitter of generalized signals, not simply of telephone conversations.[87]

This culture—rather than Cold War politics, national culture, or even the foresight of institutional overseers—lays the fortuitous and happenstance framework for Shannon's generally forgotten 1940s artillery control research. Shannon, Richard Blackman, and Hendrik Bode, Mindell explains, "broadened the relevance of their study beyond fire control, treating it as [in their own words] 'a special case of the transmission, manipulation, and utilization of intelligence.'"[88] Shannon's subsequent information theory "carried traces of fire control." Contrary to accounts that treat Shannon or Wiener as an initiator of a new discourse, Mindell argues that continuity and coherence across these "feedback cultures" made Shannon's and Wiener's novel findings possible and intelligible.

These material histories corroborate an older cybernetics premise; that machines are active agents in their world, whose behavior provides insight into the structures, constraints, and laws of human society.[89] These histories introduce reciprocity between science, institutions, society, and machines: each appears obdurate, active, amenable appropriation but resistant to full subordination. They embody an epistemic shift from the classical sciences—focused on discovering the laws always already there—to contemporary technoscience confronting experiments and realities unimaginable without massive technical infrastructures.[90] Without naturalizing information processing, these histories grant it the authority of an obdurate existence in the world not entirely subsumed to human machinations, constructions, or intentions. Computers become agents.

Grandfathering history

It is true that each of these histories "represents" computers in history; it is more important that they are also coextensive with computer history. This was clearest in the early historiography. Though rarely recognized as historians, Shannon and Wiener relied on carefully tailored historiographical perspectives to conceive, disseminate, and promote their research. For patrons MIT and AT&T, likewise, history was an extension of established institutional responsibilities to promote researchers and curry popular support. The same institutional and political promotion supporting informational research also installed computational models deep within mid-century American and academic culture; this encounter seeded the prolific, professional discursive histories written by social scientists today. New national histories closely coincided with the post–Cold War revaluation of computing outside narrow American hegemonies. Writing amidst a proliferation of global information systems and human–computer couplings in Western white-collar life, material historians not only remember the information machines but also embody a revival of cybernetic epistemologies.

This historiographic proliferation defers our discovery of information's origins. The flat, two-dimensional information "birthed" in 1948 becomes promiscuous, lively—even schizophrenic. No longer a property quietly awaiting discovery, it becomes a changing, active, unpredictable agent fraternizing and transforming through changing social and historical opportunities. Even Shannon seems enlivened: knocked from the staid pedestal of discovery and fatherhood, he becomes a challenging, dramatic actor tracing in equations, signals, and machinery in an ever-widening gyre of social and historical forces.

This reinvigorated "information" and more animated "Shannon" have little to do with writing definitive, or even better, histories. Rather, they stem from concerted efforts to write relevant histories tailored to the present. Technological "fathering" gives way to technological "grandfathering," the retroactive application of present priorities to past events. Unlike "grandfather clauses" exempting the past from meddling in the present, technological grandfathering recognizes an ethical imperative in presently "re-producing" the past. From the strife of emerging events, the technological father is reevaluated, reformulated, rediscovered. Transformative upon past and present alike, technological grandfathering enables the myriad users of today—from institutions to governments to users to machines themselves—to find themselves within computer history. Through this will to grandfather their forebears, computer historians assume their proper place producing and participating in the world of computing today.

Acknowledgments

I thank Ken Alder, William Aspray, Bridget Hanna, Ronald Kline, Andrew Pickering, and the reviewers for commenting on drafts of this article. This article also benefited immensely coursework and conversations on historiography with Jamie Cohen-Cole, Scott Curtis, Mats Fridlund, and Lynn Spigel. The helpful staff at the British Library, MIT's archives and libraries, and Northwestern University's interlibrary loan department provided access to unpublished materials. This article is dedicated to my father, information processing consultant Patrick Geoghegan.

References and notes

1. G. Johnson, ''Claude Shannon, Mathematician, Dies at 84,'' *New York Times*, 27 Feb. 2001, p. B7.
2. M.M. Waldrop, ''Claude Shannon: Reluctant Father of the Digital Age,'' *MIT's Technology Rev.*, vol. 104, no. 6, 2001, pp. 64-71.
3. J. Gleick, ''The Lives They Lived: Claude Shannon, b. 1916; Bit Player,'' *The Sunday Times Magazine*, 30 Dec. 2001, p. 48.
4. Lucent Technologies, ''Claude Shannon, Father of Information Theory, Dies at 84,'' press release, 26 Feb. 2001, http://www.bell-labs.com/news/2001/february/26/1.html.
5. MIT Press Office, ''MIT Professor Claude Shannon Dies; Was Founder of Digital Communications,'' press release, 27 Feb. 2001, http://web.mit.edu/newsoffice/2001/shannon.html.
6. The redistribution of scientific labor across humans, machines, and institutes has been said to introduce ''posthuman'' paradigms at variance with traditional narratives of science and humanism. See N.K. Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*, Univ. of Chicago Press, 1999; A. Pickering, ''Cyborg History and the World War II Regime,'' *Perspectives on Science*, vol. 3, no. 1, Spring 1995, pp. 1-48.
7. On heroic, humanist narratives of science, see M. Terrall, ''Heroic Narratives of Quest and Discovery,'' *Configurations*, vol. 6, no. 2, Spring 1998, pp. 223-242.
8. For more on anxiety over the proliferation of information and communications and technologies during this period, see: W. Hui-Kyong Chun, *Control and Freedom: Power and Paranoia in the Age of Fiber Optics*, MIT Press, 2006, esp. pp. 77-128.
9. J. Gleick, *Chaos: Making a New Science*, Penguin, 1988; M.M. Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos*, Simon & Schuster, 1992; G. Johnson, *Fire in the Mind: Science, Faith, and the Search for Order*, Knopf, 1995.
10. Throughout this article I try to illustrate historiographic approaches toward computers through instances of exemplary, already written, histories. In the case of information theory, there is a dearth of ''cultural history'' (though numerous historians discussed later incorporate elements of cultural history, especially Paul Edwards). Cultural histories frequently situate historical events within popular culture, and are often concerned with popular consumption and popular meaning. For an exemplary cultural history of a technological artifact, see L. Spigel, *Make Room for TV: Television and the Family Ideal in Postwar America*, Univ. of Chicago Press, 1992.
11. Media historian James Schwoch wrote that ''the idea of global TV networks was spurred in large part by the global postwar interest in television … and most of all, by visions of military security, psychological warfare, and concerns about the global image of America.'' J. Schwoch, ''Crypto-Convergence, Media, and the Cold War: the Early Globalization of Television Networks in the 1950s,'' *Media in Transitions Conference 2*, MIT, 2002; http://web.mit.edu/cms/Events/mit2/Abstracts/MITSchwochTV.pdf, p. 3, para. 1.
12. On the postwar centrality of importance and centrality of communications paradigms, see P.N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*, MIT Press, 1996; C. Simpson, *Science of Coercion: Communication Research and Psychological Warfare, 1945–1960*, Oxford Univ. Press, 1994; A.A. Needell, ''Project Troy and the Cold War Annexation of the Social Sciences,'' *Universities and Empire: Money and Politics in the Social Sciences During the Cold War*, C. Simpson, ed., The New Press 1998. For communications' application to managing industrial military systems, see Pickering, 1995, and T. Parke Hughes, *Rescuing Prometheus*, Pantheon Books, 1998, esp. pp. 15-68.
13. In popular representations and the practical implementation, American multimedia technologies, domestic consumer goods, and new computational technologies were closely intertwined. For more, see B. Colomina,

''Enclosed by Images: The Eameses' Multimedia Architecture,'' *Grey Room*, vol. 1, no. 2, pp. 6-29, noting in particular the treatment of information theory and communications flows on pp. 16-18.

14. C.E. Shannon, ''A Mathematical Theory of Communication,'' *Bell System Technical J.*, vol. 27, July and Oct. 1948, pp. 379-423 and 623-656, respectively.
15. C.E. Shannon and W. Weaver, *The Mathematical Theory of Communication*, Univ. of Illinois Press, (orig. pub. 1949), 1964.
16. W. Weaver, ''The Mathematics of Communication,'' *Scientific Am.*, vol. 181, no. 1, 1949, pp. 11-15. Weaver and Shannon worked together through the National Defense Research Council during the war, and Weaver was an optimistic advocate for adopting military research to a progressive and enlightened postwar way of life in fields ranging from industrial management to literary criticism.
17. The quote comes from an advertisement for *The Scientific American Reader* identified in ProQuest as ''Display Ad 44—No Title,'' *New York Times*, 2 Feb. 1954, p. 48. Popular press readers synopsizing or featuring work by Shannon during this period include *The Scientific American Reader*, Simon & Schuster, 1953; *The World of Mathematics: A Small Library of the Literature of Mathematics from A'h-mosé the Scribe to Albert Einstein*, R. Newman, ed., Simon & Schuster, 1956; J. Bronowski, ''Science as Foresight,'' *What Is Science*, J.R. Newman, ed., Simon & Schuster, 1955, pp. 385-436. I thank Jamie Cohen-Cole for bringing this last article (among others) to my attention.
18. C. Eames and R. Eames, *A Communication Primer*, 16 mm, 1953. This delightful film is available online at http://www.archive.org/details/communications_primer.
19. Entitled ''The Search,'' this 1954 documentary featured Shannon and fellow military-communication researchers Jay Forrester and Norbert Wiener. The full script can be found in the Papers of Norbert Wiener at the MIT Archives, box 31A, folder 759.
20. Shannon spoke at the Case Institute of Technology in April 1953 on a panel including his former National Defense Resource Committee director Vannevar Bush and military communications engineer Louis Ridenour. It is briefly documented in ''News and Notes,'' *Science*, vol. 117, no. 3038, 20 Mar. 1953, p. 294.
21. Held at the Hayden Planetarium, among the more interesting ideas was a proposal to refit the Viking Rocket for space flight. For a brief account, see W. Kaempfert, ''Astronauts Get Down to Cases in Discussion of the Possibilities of Travel in Space,'' *New York Times*, 9 May 1954, p. E11.
22. These ellipses are found in the original advertisement, identified in ProQuest as ''Display Ad 332—No Title,'' *New York Times*, 3 Dec. 1961, p. SM106.
23. Interestingly, Shannon's early fame in information theory emerged some 20 years prior to information theory's effective implementation. Indeed, by the late 1960s and 1970s when government funding permitted implementation of Shannon's theorems, Shannon had faded from popular culture. This dissonance further documents the divorce between the scientific/laboratory status of information theory and its popular acclaim. For a particularly useful history of information theory and its applications, see O. Aftab et al., ''Information Theory: Information Theory and the Digital Age,'' MIT, pp. 1-27; http://mit.edu/6.933/www/Fall2001/Shannon2.pdf. Its discussion of information theory's early identity crises and ultimate professionalization around Shannon's methods (themes I develop later) is also instructive.
24. W. Aspray, ''The Scientific Conceptualization of Information,'' *Annals of the History of Computing*, vol. 7, no. 2, 1985, pp. 117-140.
25. Ibid., p. 138.
26. Ibid., p. 119.
27. By ''historicized'' I mean rendered intelligible and meaningful according to a given narrative of historical events. Every history I treat puts information research within a different milieu of researchers and practices, suggesting readers understand its importance in a different way. By writing information into new historical contexts and reconsidering earlier histories, every history of information both historicizes and re-historicizes information.
28. A few provisional and contingent choices are particularly pertinent. These overarching categories are tailored to historical accounts of information theory (though I hope they have larger purchase for thinking about histories of computing and the 20th-century history of science) and my own effort to offer a manageable survey of that field. I also favor texts that treat Shannon directly but put his work in the context of competing approaches and interpretations. In some cases, this focus has led to some very interesting texts on the broader milieu of information theories and sciences; in other cases it has played a part in my decision to extract one strand of authors' otherwise multifaceted arguments. Appropriately, such choices and extractions made here are themselves the subject matter of historiography. I hope my article encourages a reading and rereading of these texts, rather than acting as a substitute for that work.

29. My reflections on computer history and historiography have been greatly enriched by the pithy article by P. Edwards, ''Think Piece: Making History—New Directions in Computer Historiography,'' *IEEE Annals of the History of Computing*, vol. 23, no. 1, 2001, pp. 86-88.
30. I comment on historiography in the work of Norbert Wiener below; on how the repression of women's role in the history of computing promoted computing as a ''masculine'' profession, see J.S. Light, ''When Computers Were Women,'' *Technology & Culture*, vol. 40, no. 3, 1999, pp. 43-73; on the historical origins and mutations of the ''paperless office myth'' (which Gates adapts from Xerox), see A.J. Sellen and R. Harper, *The Myth of the Paperless Office*, MIT Press, 2002, p. 231; for comments on the re-narrating and re-representing of computers to develop new markets for their application, see D. Haraway, ''The Promises of Monsters: A Regenerative Politics for Inappropriate/d Others,'' *The Donna Haraway Reader*, Routledge, 2004, pp. 63-124.
31. C.E. Shannon, ''A Mathematical Theory of Cryptography,'' Memorandum MM 45-110-02, 1 Sept. 1945, Bell Laboratories. Archival access courtesy the British Library.
32. Shannon also worked on a theory of information in his spare time from the late 1930s onward, but he seemed to identify the cryptography report as a place where he put many of these long-simmering ideas together in a written report. See R. Price, ''A Conversation with Claude Shannon: One Man's Approach to Problem Solving,'' *IEEE Comm. Magazine*, vol. 23, sno. 5, 1984, especially pp. 123-124.
33. C.E. Shannon, ''Communication Theory of Secrecy Systems,'' *Bell System Technical J.*, vol. 28, 1949, pp. 656-715.
34. For comments on the distinction between cryptographic and philosophical definitions of truth, see C.E. Shannon, ''Mathematical Theory of Cryptography,'' note on p. 3. See also p. 49 where Shannon also explains that one of his figures was drawn from work by Harvard philosopher and mathematician W.V. Quine. By the time this same figure appeared in ''Communication Theory of Secrecy Systems,'' the reference to Quine was gone. In these small differences I believe we can begin to delineate the different historiographical and conceptual horizon that emerged as research moved from often less regulated environs within Bell Labs to the public scrutiny characteristic of a broadly distributed, often utilitarian, professional journal. For another example of Shannon's much freer, speculative mode in private presentations, see C.E. Shannon, ''Creative Thinking,'' typescript, 20 Mar. 1952, Bell Laboratories, 10 pp., unpublished. Archival access courtesy the British Library.
35. ''Ahistorical'' in the sense that Shannon's work seemed as if it stood outside history. Much has been written in recent years on how scientific writing suppresses the representation of historical and cultural contingency. See S. Shapin and S. Shaffer, *Leviathan and the Air-pump: Hobbes, Boyle, and the Experimental Life*, Princeton Univ. Press, 1989; L. Daston, ''Objectivity and the Escape from Perspective,'' *The Science Studies Reader*, M. Biagioli, ed., Routledge, 1999, pp. 110-123. On the vexed relation between science and historical exposition, see K. Alder, ''The History of Science, Or, an Oxymoronic Theory of Relatavistic Objectivity,'' *A Companion to Western Historical Thought*, L. Kramer and S. Maza, eds., Blackwell, 2002, pp. 297-318.
36. A reference which itself literally united Shannon's undergraduate training at Michigan, his graduate research at MIT and AT&T, and his postgraduate employment at Bell Labs. For his early reading and longstanding concern with the Hartley work, see R. Price, ''A Conversation with Claude Shannon: One Man's Approach to Problem Solving,'' *IEEE Comm. Magazine*, vol. 22, no. 5, 1984, especially pp. 123-124; for his graduate interest in the Hartley and Nyquist work, see C.E. Shannon, ''Letter to Vannevar Bush [16 February 1939],'' *Collected Papers*, N.J.A. Sloane and A.D. Wyner, eds., IEEE Press, 1999, pp. 455-456.
37. C.E. Shannon, ''The Mathematical Theory of Communication,'' p. 85.
38. Ibid. Here Shannon cites the postwar declassified version, not the classified draft he likely read during the war.
39. F. Conway and J. Siegelman, *Dark Hero of the Information Age: In search of Norbert Wiener, The Father of Cybernetics*, Basic Books, 2004, p. 126.
40. N. Wiener, *Cybernetics; or, Control and Communication in the Animal and the Machine*, MIT Press and John Wiley & Sons, (orig. pub. 1949), 1965.
41. Ibid., p. 38.
42. Ibid., p. 39.
43. Ibid., p. 12.
44. C.E. Shannon, ''The Bandwagon (editorial),'' *IRE Transactions on Information Theory*, vol. 2, no. 1, p. 3; N. Wiener, *Cybernetics; or, Control and Communication in the Animal and the Machine*, pp. 24-25.
45. Of course, it wasn't always ''alternative.'' Cherry worked for a time at MIT's Research Laboratory of Electronics, arguably the center producing a rigorous, academic, and scientific cadre of students, researchers, and methods in communication science and information theory during the 1950s and 1960s. During this period Cherry was but one of the many different kinds of researchers exploring this field's promise. Even

the hardcore Shannon-partisan John Pierce complemented Cherry's work in J. Pierce, ''The Early Days of Information Theory,'' *IEEE Trans. Information Theory*, vol. IT-19, no. 1, 1973, p. 3.
46. Cherry republished this primer on information and communication over a series of years and journals. This seems to be the earliest print version. C. Cherry, ''A History of the Theory of Information,'' *IRE Trans. on Information Theory*, vol. 1, no. 1, 1953, pp. 22-43.
47. For more, see Bar-Hillel's note on the difference between American and British information theory, Y. Bar-Hillel, ''An Examination of Information Theory,'' *Philosophy of Science*, vol. 22, no. 2, 1955, p. 97. Also see the important attempts to reconsider the cultural import of the Shannon/MacKay distinctions in N.K. Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*''; M.B.N. Hansen, *New Philosophy for New Media*, MIT Press, 2006.
48. Pierce, ''The Early Days of Information Theory,'' pp. 3-8.
49. For an important predecessor text, see P. Elias et al., ''Progress in Information Theory in the U.S.A., 1957–1960,'' *IRE Trans. on Information Theory*, July 1961, pp. 128-144.
50. Pierce, ''The Early Days of Information Theory,'' p. 3 (italics added).
51. Ibid., p. 5.
52. Pierce was a member of Project Troy. For an account of Project Troy, see Needell, ''Project Troy and the Cold War Annexation of the Social Sciences.''
53. For a discussion of the government and commercial programs funding information theory from the 1960s onward, see Aftab et al., ''Information Theory: Information Theory and the Digital Age,'' pp. 16-22.
54. S. Verdú, ''Fifty Years of Shannon Theory,'' *IEEE Trans. on Information Theory*, vol. 44, no. 6, 1998, pp. 2057-2078.
55. Ibid., p. 2057.
56. The ''social construction'' of science and technology has been a robust research area for over a decade. Its progressive or postmodernist perspective often argues that social and cultural factors shape and constrain research, knowledge, and technology. At first glance conservative, even hidebound, ''institutional histories'' appear to be at odds with the more theoretical or revisionist methods of social constructionists. Yet institutional histories' concern for how communities, structural-institutional arrangements, and institutional-social interaction shape research have much similarity to some social constructionist perspectives.
57. R. Lucky, electrical engineer, an oral history conducted by D.P. Hochfelder, 1999, IEEE History Center, Rutgers Univ., New Brunswick, New Jersey, p. 6; online at http://www.ieee.org/portal/cms_docs_iportals/iportals/aboutus/history_center/oral_history/pdfs/Lucky361.pdf.
58. AT&T's monopoly, peculiar relation with the government, its ''R&D tax,'' and the lawsuit that lead to its breakup are outlined in M. Riordan, ''The End of AT&T,'' *IEEE Spectrum*, July 2005, pp. 446-448.
59. The lawsuits were filed in 1974, and the histories commenced in 1976. In 1984 the lawsuits lead to AT&T's breakup.
60. A. Joel, electrical engineer, an oral history conducted by W. Aspray, 1992, IEEE History Center, Rutgers Univ., New Brunswick, New Jersey, p. 147.
61. Possibly self-serving concerns hardly undermine the text's historiographic validity or interest; my point here, as elsewhere, is that disciplinary, intellectual, commercial, scholarly, commercial, and political conflict have consistently made the writing of information theory's history possible. Through these historical, contingent, and controversial encounters history, science, and technology become vibrant, lively, rich, and informative.
62. S. Millman, ed., *A History of Engineering and Science in the Bell System: Communications Sciences (1925–1980)*, vol. 5, Bell Laboratories, 1984.
63. M.D. Fagen, ed., *A History of Engineering and Science in the Bell System: National Service in War and Peace (1925–1975)*, Bell Laboratories, 1978.
64. K. Wildes and N. Lindgren, *A Century of Electrical Engineering and Computer Science at MIT, 1882–1982*, MIT Press, 1985, p. 423.
65. Ibid., p. 243.
66. Ibid., pp. 256-266.
67. According to economist Paul A. David, the modern research university found important origins in Renaissance European courts, which competed among one another by cultivating the reputation of their natural philosophers (proto-scientists). David contrasts this with more secretive traditions of mercantilist, commercially driven research and technology. Accordingly, I offer the provisional hypothesis that *institutional origins* may explain the MIT history's unusual emphasis on personality. See P.A. David, ''Understanding the Emergence of 'Open Science' Institutions: Functionalist Economics in Historical Context,'' *Industrial and Corporate Change*, vol. 13, no. 4, 2004, pp. 571-589.
68. These historians do not argue for a pure science, unpolluted by political interest. Rather, they regard a more realistic recognition of how politics

and culture are always integral to scientific practice.

69. This is the largest area of ongoing informational historiography, and could arguably subsume other historiographic genres I discuss. It could also be argued that a number of the texts I call ''discourse analysis'' are more concerned with material history of some other historical genre of analysis. The most exhaustive text in this area is P. Edwards's *The Closed World* although I focus my exposition on two key texts that preceded Edwards's account. A partial list of studies particularly concerned with information theory includes these: in embryology, E.F. Keller, *Refiguring Life: Metaphors of Twentieth-Century Biology*, Columbia Univ. Press, 1995, pp. 81-118; in genetics, L.E. Kay, ''Cybernetics, Information, Life: The Emergence of Scriptural Representations of Heredity,'' *Configurations*, vol. 5, no. 1, Winter 1997, pp. 23-91; in neuroscience, see L. Kay, ''From Logical Neurons to Poetic Embodiments of Mind: Warren S. McCulloch's Project in Neuroscience,'' *Science in Context*, vol. 14, no. 15, 2001, pp. 591-614; in economics, P. Mirowski, ''Cyborg Agonistes: Economics Meets Operations Research in Mid-Century,'' *Social Studies of Science*, vol. 29, no. 5, 1999, pp. 685-718; P. Mirowski, ''What Were von Neumann and Morgenstern Trying to Accomplish? '' *Toward a History of Game Theory*, E.R. Weintraub, ed. Duke Univ. Press, 1992, pp. 113-147; in mathematics, see L. Varshney, ''Engineering Theory and Mathematics in the Early Development of Information Theory,'' *IEEE Conf. History of Electronics*, 2004, pp. 1-6, http://www.ieee.org/portal/cms_docs_iportals/iportals/aboutus/history_center/conferences/che2004/Varshney.pdf; in interdisciplinary discourse, see G. Bowker, ''How to be Universal: Some Cybernetic Strategies, 1943–1970,'' *Social Studies of Science*, vol. 23, no. 1, 1993, pp. 107-127; in postwar French philosophy, C. Lafontaine, *L'Empire Cybernétique: Des Machines à Penser à La Pensée Machine* [The Cybernetic Empire: From Machines for Thinking to the Thinking Machine], Seuil Essai, 2004 (in French); in urban planning, see J.S. Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War*, Johns Hopkins Univ. Press, 2003; for a short discussion in the context of semiotics, see L. Manovich, ''Chapter 4: The Engineering of Vision from Constructivism to MIT,'' doctoral dissertation, Univ. of Rochester, New York, 1993; for an account of cybernetics concretizing contingent historical contexts within discursive paradigms, see P. Galison, ''The Ontology of the Enemy,'' *Critical Inquiry*, vol. 21, Autumn 1994, pp. 228-268.
Other important examples are discussed later, as well.
70. See, in particular, D. Haraway, ''Signs of Dominance: From a Physiology to a Cybernetics of Primate Society, C.R. Carpenter, 1930–1970,'' *Studies in History of Biology*, W.R. Coleman, and C. Limoges, eds., Johns Hopkins Univ. Press, 1977; D. Haraway, ''The High Cost of Information in Post World War II Evolutionary Biology: Ergonomics, Semiotics, and the Sociobiology of Communications Systems,'' *Philosophical Forum*, vol. 13, no. 2-3, 1981–1982, pp. 244-278; D. Haraway, ''A Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s,'' *The Haraway Reader* (orig. pub. 1985), 1991, pp. 7-46.
71. Haraway, ''A Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s,'' 1991, p. 31.
72. Haraway, ''The High Cost of Information in Post World War II Evolutionary Biology.''
73. Ibid., p. 271.
74. S.J. Heims, *Constructing a Social Science for Postwar America: The Cybernetics Group (1946–1953)*, MIT Press, 1993.
75. J.P. Dupuy, *The Mechanization of the Mind: On the Origins of Cognitive Science*, Princeton Univ. Press, 2000, p. 23.
76. Heims, *Constructing a Social Science for Postwar America*, pp. 96-98.
77. Ibid., pp. 111-112.
78. This claim may be more radical than it appears. Even Shannon was at pains to indicate that information theory was first and foremost a process and method of inquiry that bound up the activities, cooperation, and writing styles of its participants. He insisted that findings' validity found their basis there. See C.E. Shannon, ''The Bandwagon (Editorial).'' Also note that even Shannon's careful definition of information and communication rigidly restricted itself to what he called ''the engineering problem,'' developing its observations, assertions, and research questions out of existing engineering practice and theory. See C.E. Shannon, ''The Mathematical Theory of Communication,'' 1964, p. 31.
79. The effects of this may be most clear in J. Wiesner's account of the Research Laboratory of Electronics, which paints it as a clearinghouse for global information theorists. See the RLE-produced article privately distributed by MIT by J.B. Wiesner, ''The Communication Sciences—Those Early Days,'' *R.L E.: 1946+20*, The Research Laboratory of Electronics, 1966 (available at the MIT Libraries). For more on the use of educational exchange to promote American Cold War interests, and particularly to secure the predominance of American culture, see L. Bu, ''Educational Exchange and Cultural Diplomacy in the Cold War,'' *J. Am. Studies*, Dec. 1999 vol. 3, pp. 393-415.

80. For comparative study of information theory in France, Germany, England, and the US, see J. Segal, *Le Zéro Et Le Un: Histoire De La Notion Scientifique d'Information Au 20e Siècle* [The Zero and the One: The History of the Scientific Conception of Information in the 20th Century], Editions Syllepse, 2003 (in French). Eden Medina recently completed a doctoral dissertation at MIT on Chilean cybernetics. Her published, related research includes ''Designing Freedom, Regulating a Nation: Socialist Cybernetics in Allende's Chile,'' *J. Latin American Studies*, vol. 38, 2006, pp. 571-606; ''Democratic Socialism, Cybernetic Socialism: Making the Chilean Economy Public,'' *Making Things Public*, B. Latour and P. Weibel, eds., MIT Press, 2005. On Chinese cybernetics, see Y. Peng, ''The Early Diffusion of Cybernetics in China (1929–1960),'' *Studies in the History of the Natural Sciences*, vol. 23, 2004, pp. 299-318 (in Chinese). This text came to my attention through the *Isis* ''Current Bibliography.'' G. Moynahan and A. Pickering are preparing book-length studies on cybernetics in Germany and the UK respectively.
81. S. Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics*, MIT Press, 2002.
82. Mendel's law of segregation offered a seminal account of transmission of genetic traits. Lysenkoism, a major movement in Soviet Russia, was based on a politically expeditious but poorly reasoned attack on genetics and geneticists.
83. Gerovitch, *From Newspeak to Cyberspeak*, p. 60.
84. R.K. Plumb, ''Computer Study in Soviet Union Grows,'' *New York Times*, 27 Mar. 1959, p. 9.
85. Although few histories discussed in my survey are devoid of ''material history,'' a number of recent studies have prominently exploited a mixture of material history and discursive analysis. Edwards 1996 (Ref. 12) and Galison 1994 (Ref. 69) works contain major aspects of material history. Andrew Pickering's current and forthcoming studies on British cybernetics complicate my definition of the material history, and perhaps my genres as a whole. He pursues a materialist history of cybernetics operating outside established, stable institutions. Also, his forthcoming book attempts to document an alternative future that never emerged (the other histories and genres I document tend to more squarely resolve an existing, present-day practice). See A. Pickering, *Sketches of Another Future: Cybernetics in Britain, 1940–2000*, forthcoming; A. Pickering, ''Cybernetics and the Mangle: Ashby, Beer and Pask,'' *Social Studies of Science*, vol. 32, no. 3, June 2002, pp. 413-437; A. Pickering, ''The Tortoise Against Modernity: Cybernetics as Science and Technology, Art and Entertainment,'' paper, Experimental Cultures: Configurations of Life Sciences, Art, and Technology (1830–1950) conference, Max Planck Inst. for the History of Science, 2001. See also Ref. 90. For another materialist-concerned historical account of British cybernetics, see R. Hayward, ''The Tortoise and the Love-Machine: Grey Walter and the Politics of Electroencephalography,'' *Science in Context*, vol. 14, no. 4, 2001, pp. 615-41.
86. D.A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*, Johns Hopkins Univ. Press, 2002.
87. Ibid., p. 135.
88. Ibid., p. 320.
89. See in particular Pickering, ''Cybernetics and the Mangle: Ashby, Beer and Pask,'' and also *The Search* television special (Ref. 19) featuring Forrester, Wiener, and Shannon explaining how machines provide models for understanding humans, nature, and society.
90. In the introduction to Mindell, *Between Human and Machine*, the author discusses his interest in Latourian models of machine agency. Differences between cybernetics and the classic sciences are a particular focus of Pickering's forthcoming book. In a recent email to me, Pickering also qualified my comments in the conclusion of this article by writing ''my history of cybernetics is 'tailored to the present' only inasmuch as I think the present is a bit of a disaster,'' hence his book's title *Sketches of Another Future.*

Bernard Geoghegan is a doctoral candidate in screen cultures at Northwestern University and an Institute Visitor at the Massachusetts Institute of Technology. His current research focuses on the cultural history of information theories. He is a former research fellow at Harvard University's Institute for the Study of Money and Culture and at l'Institut de Recherché et d'Innovation at the Centre Pompidou in Paris. Geoghegan received an MS in media, technology, and society from Northwestern University. In 2005 the US Department of Education granted him a four-year appointment as a Jacob K. Javits Fellow in Communication Studies.

Readers may contact Geoghegan about this article at b-geoghegan@northwestern.edu.