Virtual Webs, Physical Technologies, and Hidden Workers: The Spaces of Labor in Information Internetworks

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The Spaces of Labor in Information Internetworks

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Barely ten years since its inception the World Wide Web has become all but impossible to ignore.[1] My undergraduate students at a large Midwestern university in the turn-of-the-millennium United States are quite comfortable with the hyperlinked front end to the Internet that they simply call "the Web." Logging in at all hours from wired dorm rooms and public computer labs, they rely on it (often to a fault) as their main resource for communication, research, and entertainment. But in my classes I confront them with a different kind of Web: the Web as a historical and geographical problem.

Dr. Downey is a Woodrow Wilson Postdoctoral Fellow in the Department of Geography at the University of Minnesota. The ideas behind this article were inspired by the 1998 SHOT conference panel "Systems, Networks and Webs: New Directions in the Historiography of Information Technology?" chaired by Paul Edwards, with comments by Thomas Parke Hughes, Geoffrey Bowker, Jon Agar, and JoAnne Yates, and by the 1999 SHOT conference paper session "Clio and the Computer: Methodological Approaches to Artifacts, Actors, Systems and Webs," chaired by Robert Seidel, with papers by James E. Tomayko and Rachel Knapp, Paul E. Ceruzzi, and the author, plus commentary by Paul Edwards. The author thanks all who participated in these sessions. He is also indebted to his dissertation advisers, David Harvey, Stuart Leslie, and Erica Schoenberger, for insisting that the historical study of internetworks be connected to present-day theory and practice, and to John Staudenmaier and the *Technology and Culture* referees for their help in turning scattered thoughts drawn from widely varying literatures into a cohesive article.

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1. The first Web server went on-line at the European Organization for Nuclear Research (CERN) in 1990; the first popular web browser, Mosaic, was released by the University of Illinois National Center for Supercomputing Applications (NCSA) in 1993. (A browser, it may not yet be needless to say, is a software application running on a client computer that allows a user to view—"browse"—documents on a Web server if it is physically accessible—over some sort of network, usually the Internet—to that client.) See George Johnson, "From Two Small Nodes, a Mighty Web Has Grown," *New York Times*, 12 October 1999; Tim Berners-Lee with Mark Fischetti, *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by Its Inventor* (San Francisco, 1999).

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My favorite trick is to juxtapose two striking images of cyberspace and ask them to consider which one better reflects the reality of the Web they know so well.[2] The first is a scene from the motion picture *The Matrix* (a favorite among my students): as the camera looks down a long, green-glowing, number-coated, virtual hallway, three villains chasing the hero are suddenly revealed to be nothing more than chaotic blobs of alphanumeric characters, computer-generated algorithms posing as humans.[3] The Web, this image seems to say, is nothing but pure data, and any illusion of humanity is merely an advertising gimmick. The second image is a similarly long-perspective photograph of a hallway stacked floor to ceiling on both sides with boxes of all shapes and sizes. In place of the computer-generated avatars of *The Matrix*, casually dressed workers walk to and fro holding small electronic devices aimed at the shelves. Another science fiction film? No: the interior of one of the eight U.S. distribution centers for electronic commerce giant Amazon.com. The point of the exercise, of course, is to question what it means to call the Web a cyberspace at all. How was this space created? Where is it located? And, especially, who makes it work?

Such questions are not limited to the classroom, but appear in the daily news as well. At one end of the wage scale, the highly skilled programmers and designers of the once booming "e-commerce" sector are starting to question their stock-option-laden compensation packages in a market where the inevitable initial public offering is no longer an automatic road to riches.[4] At the other end, many of the lower-paid workers at "e-tailers" such as Amazon.com—not only stock checkers walking the halls of warehouses, but technicians monitoring back-office "server farms" and temporary workers staffing technical-support phone lines—are demanding the right to unionize in pursuit of better wages, better hours, and more secure jobs.[5] The new virtual economy cannot escape a very old physical fact: it takes human labor to make the Web work.

This insight is crucial not only for Internet entrepreneurs but also for those who would study the Internet itself. My own interest in this topic originated in a study not of twenty-something programmers in the digital economy but of messenger boys working in the telegraph, telephone, and

2. The term "cyberspace" was coined well before the advent of the Web by William Gibson in *Neuromancer* (New York, 1984). On the Internet as cyberspace, see Rob Kitchin, *Cyberspace: The World in the Wires* (New York, 1998), and "Towards Geographies of Cyberspace," *Progress in Human Geography* 22 (1998): 385–406.

3. *The Matrix* (U.S., 1999), written and directed by Andy Wachowski and Larry Wachowski.

4. Saul Hansell and Matt Richtel, "PullingThePlug.com," *New York Times*, 6 November 2000.

5. Steven Greenhouse, "Amazon Fights Union Activity," *New York Times*, 29 November 2000.

Post Office networks of the early twentieth century.[6] In this earlier internetwork, which I call an analog information internetwork, messengers, operators, lineworkers, and the like—each occupying a key position in the internetwork—were crucial to keeping information flowing.[7] Such categories of labor—boundary workers who knit disparate communications networks together on a daily basis—are fundamental to the success of today's internetwork as well. The Internet would quickly go silent without the constant monitoring of network system operators.

Paradoxically, the more the Internet grows in scale and scope, the more its virtual attractions obscure its physical foundation. Those crucial internetworkers become visible in the historical record only when three separate processes—technological innovation, the production of space, and the daily performance of labor—are considered simultaneously. Thus, revealing such work offers a unique opportunity (and challenge) for interdisciplinary cooperation between historians of technology, human geographers, and sociologists and anthropologists of work. In this article I hope to illustrate the possibilities offered by such collaboration by again juxtaposing two apparently different but fundamentally related images: the analog internetwork of a century ago and the digital internetwork under construction today. The crucial question, though, is not whether the telegraph, telephone, and Post Office were equivalent to today's Internet, but rather whether analyzing those three networks as an internetwork—in which the whole is more than the sum of its parts—can lead to a better understanding of today's Internet.[8]

6. Greg Downey, "*Uniformed Boys for Every Occasion*"*: Telegraph Messenger Labor in the First Communications Internetwork, 1850–1950* (Ph.D. diss., Johns Hopkins University, 2000). The term "internetwork" comes from Paul N. Edwards, "Y2K: Millennial Reflections on Computers as Infrastructure," *History and Technology* 15 (1998): 7-29.

7. For general background of the components of the analog internetwork, see the following works. On the telegraph: David Hochfelder, *Taming the Lightning: American Telegraphy as a Revolutionary Technology, 1832–1860* (Ph.D. diss., Case Western Reserve University, 1998); Robert L. Thompson, *Wiring a Continent: The History of the Telegraph Industry in the United States 1832–1866* (Princeton, N.J., 1947); and Joel A. Tarr, with Thomas Finholt and David Goodman, "The City and the Telegraph: Urban Telecommunications in the Pre-Telephone Era," *Journal of Urban History* 14 (November 1987): 38–80. On the telephone: Milton L. Mueller Jr., *Universal Service: Competition, Interconnection, and Monopoly in the Making of the American Telephone System* (Cambridge, Mass., 1997); and George David Smith, *The Anatomy of a Business Strategy: Bell, Western Electric, and the Origins of the American Telephone Industry* (Baltimore, 1985). On the Post Office: Gerald Cullinan, *The United States Postal Service* (New York, 1973); Wayne E. Fuller, *The American Mail: Enlarger of the Common Life* (Chicago, 1972).

8. Note that I am not arguing here that an internetwork—or even an information internetwork—is a universal, ahistorical category; I am arguing that it might be more of a modern phenomenon than a postmodern one. As David Nye has observed, "The telephone and telegraph, the early forms of networked communication, provide an essential

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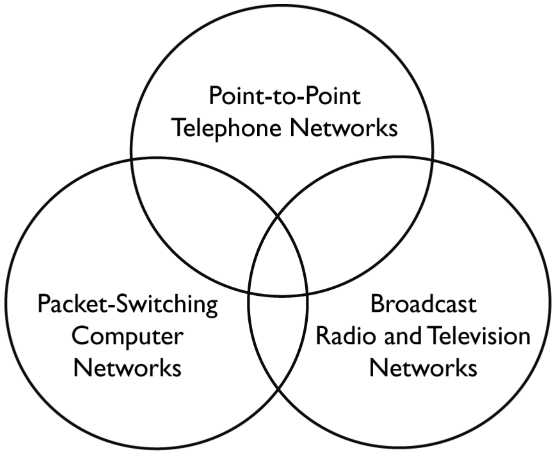

FIG. 1 The global digital information internetwork, circa 1990–2000.

Take the Internet first. Born out of the Advanced Research Projects Agency Network (ARPANET) during the cold war, the Internet-as-internetwork is today much more than a metanetwork of computer networks.[9] The Internet combines the technologies, institutions, commodities, and laborers of three preexisting networks: point-to-point telephone networks, broadcast (via cable or airwaves) radio and television networks, and packet-switching computer networks (fig. 1). I refer to this as a digital information internetwork because the key process tying its component networks together is digital convergence: the ability of nearly any kind of information—text or graphics, audio or video, even complex three-dimensional environments—to be sampled, translated, and compressed into a common mathematical language of ones and zeros.[10]

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background for understanding the computer network"; see "Shaping Communication Networks: Telegraph, Telephone, Computer," *Social Research* 64 (fall 1997): 1067–91. Similarly, Anthony Giddens proposed that new methods of "time-space distanciation," or "the conditions under which time and space are organised so as to connect presence and absence," were fundamental to modernity itself; *The Consequences of Modernity* (Stanford, Calif., 1990), 14.

9. For an excellent history of the ARPANET (which I rely upon extensively in this article), see Janet Abbate, *Inventing the Internet* (Cambridge, Mass., 1999). On the geography of the Internet, see Martin Dodge and Narushige Shiode, "Where on Earth is the Internet? An Empirical Investigation of the Geography of Internet Real Estate," in *Cities in the Telecommunications Age: The Fracturing of Geographies*, ed. James O. Wheeler, Yuko Aoyama, and Barney Warf (New York, 2000), 42–53.

10. As Paul Edwards wrote, "This process is not only technical, but also commercial, social, and political. It opens the door to integrated infrastructures of huge scale and scope." Edwards, 16.

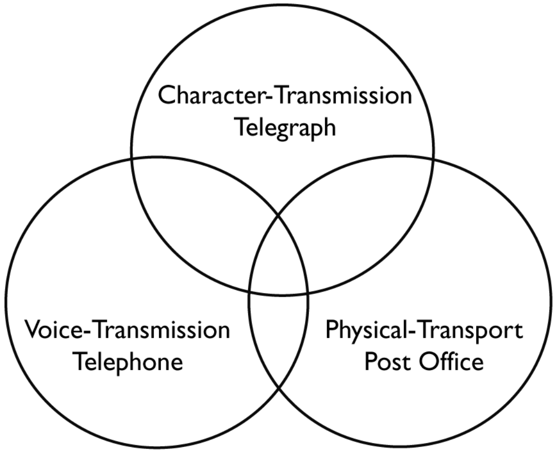

FIG. 2 The U.S. analog information internetwork, circa 1900–1940.

Now consider the analog information internetwork, a century-old combination of character-transmission telegraph, voice-transmission telephone, and physical-transport Post Office networks.[11] Although these different technological systems were each built upon specialized electromechanical devices, all three worked together in many unrecognized ways (fig. 2). The fact that a telegram sold by the telegraph network could be shepherded by messengers through the other two networks on its way to the addressee is but one example of how the telegraph, telephone, and postal system constituted a multimodal information internetwork that began and ended with messengers but encompassed a variety of technologies, commodities, and institutions in between.[12]

11. I call this an "analog" internetwork because, in contrast to the digital internetwork, information could only move over each component network in a single form, requiring repeated physical translations as it moved through the internetwork (handwriting to voice to dot-and-dash and back again). Although the telegraph itself was in some sense "digital"—based as it was on three possible states: no pulse, a short pulse (dot), and a longer pulse (dash)—those states were conveyed at varying cadences through the physical actions of rapidly pressing telegraph keys and attentively listening to telegraph sounders, and so were still analog at the core. Tom Standage, in *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers* (New York, 1998), describes a "Victorian Internet" of "A patchwork of telegraph networks, submarine cables, pneumatic tube systems, and messengers combined to deliver messages within hours over a vast area of the globe" (101). And Edward Rothstein has called the transcontinental railroad "the Internet of 1869" ("The Transcontinental Railroad as the Internet of 1869," *New York Times*, 11 December 1999). But no one has defined a turn-of-the-century internetwork using multiple communications networks as I am doing.

12. Note also that historical actors who used and studied the telegraph, telephone, and Post Office saw the three as an internetwork. Business texts from the 1910s through

A useful way to begin to think about these two internetworks is to use the technological systems framework, which treats individual technologies—whether physical devices or scripted procedures—not in isolation but together in the service of larger goals.[13] Historians using this framework have convincingly shown how the resulting large-scale arrangements of technologies emerge through a historically specific process of competition, compromise, and happenstance.[14] This process has been variously labeled the "social shaping" or "social construction" of technology, which simply means that the specific kinds of technological infrastructures that result are neither preordained by the technology itself nor free of the mate-

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the 1930s instructed students that proper business practice when sending telegrams involved all three media: even when paying for the "report delivery" and "repeat back" options to make sure telegrams were accurately transmitted and received (with those reports coming by telephone), important telegrams were to be "confirmed immediately by a properly dated and signed letter." See Frank C. McClelland, *Office Training and Standards* (New York, 1919); Lloyd L. Jones and Lloyd Bertschi, *General Business Science* (New York, 1930), 336; Clinton A. Reed and V. James Morgan, *Introduction to Business* (Boston, 1932), 72. Social scientists exploring communications practices in the 1930s also agreed that consumers used all three networks together: "[The patron] may choose freely among the various point-to-point communication agencies available, according to his needs, with the assurance that his requirements will be met no matter what patented mechanical devices are involved, or what corporate interests provide the facilities employed under any given set of circumstances." See Malcolm Willey and Stuart Rice, *Communication Agencies and Social Life* (New York, 1933), 151.

13. Thomas Hughes illustrated how the various technologies that make up the electrical power system in the United States—generators, dynamos, transformers, end-user appliances, and the like—coevolved under the conscious control of electrical power companies and appliance manufacturers. See Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore, 1983); "The Evolution of Large Technological Systems," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe Bijker, Thomas Hughes, and Trevor Pinch (Cambridge, Mass., 1987); and "Technological Momentum," in *Does Technology Drive History? The Dilemma of Technological Determinism*, ed. Merritt Roe Smith and Leo Marx (Cambridge, Mass., 1994): 101–14. Hughes considered the ARPANET in particular in his *Rescuing Prometheus* (New York, 1998). In this article I refer specifically to information internetworks, although it would be useful to consider whether the internetwork model applies to other technological arrangements—even Hughes's original example of the electrical power industry might be considered an internetwork now that global utility deregulation and new technologies such as fuel cells have complicated the picture.

14. In terms of the digital internetwork, Janet Abbate has shown that the shape of the ARPANET was determined largely by its enthusiastic (and technically savvy) user base. As for the analog internetwork, studies by Paul Israel, Claude Fischer, and Richard John have shown how operators, consumers, and legislators helped to shape the telegraph, telephone, and Post Office networks: see Paul Israel, *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830–1920* (Baltimore, 1992); Claude S. Fischer, *America Calling: A Social History of the Telephone to 1940* (Berkeley, Calif., 1992); and Richard R. John, *Spreading the News: The American Postal System from Franklin to Morse* (Cambridge, Mass., 1995).

rial constraints of the physical and chemical properties of matter, but are instead a compromise between technological possibility and societal action—even if in many cases those actions are carried out by a relatively small and elite segment of society.[15] These may seem like obvious points, but they still drop out of many analyses of the so-called network society. For example, Manuel Castells, who theorized a new "informational mode of development" operating through what he called the "spaces of flows," wrote that the information technology underlying those spaces emerged through "autonomous dynamics of technological discovery and diffusion."[16] But technology neither emerges nor diffuses autonomously. Just as earlier societies created particular kinds of agrarian and industrial modes of development, today a particular kind of informational mode of development is being created, negotiated through contemporary societal choices and built upon historical precedents set by the telegraph, telephone, and Post Office decades earlier.

Still, there are technological patterns to this evolving informational mode of development. Both the analog and the digital internetworks are, at their core, networks. In other words, these aggregations of technology are constructed with two particular geographic goals in mind: first, to overcome the material constraints of time and distance in the transmission of information, and second to leverage the economies of scale of aggregate activity among many simultaneous users. A network arrangement involves both the regular interconnection over space of homogeneous systems into some organized pattern (daisy chain ring, hierarchical tree, star and hub) and some sort of scaled-up functionality over time that emerges only as the number of interconnections increases (greater processing or storage power, more flexible user access, larger numbers of simultaneous users). In fact, such benefits are themselves known as "network effects."[17]

Consider the history of the Internet, a digital internetwork that evolved out of a carefully planned digital network, the ARPANET. The original pur-

15. For other views on more specific meanings of social shaping and social construction, see Trevor Pinch and Wiebe Bijker, "The Social Construction of Facts and Artifacts," in Bijker, Hughes and Pinch; Donald MacKenzie and Judy Wajcman, eds., *The Social Shaping of Technology* (Philadelphia, 1999).

16. Manuel Castells, *The Informational City: Information Technology, Economic Restructuring, and the Urban-Regional Process* (New York, 1989); *The Rise of the Network Society*, vol. 1 of *The Information Age: Economy, Society and Culture* (New York, 1996); and "Grassrooting the Space of Flows," in Wheeler, Aoyama, and Warf (n. 9 above), 18–30. For a critique of the Castells thesis, see Neil Smith, "Spaces of Vulnerability: The Space of Flows and the Politics of Scale," *Critique of Anthropology* 16 (1996): 63–77. On autonomous technology, see Smith and Marx; see also Langdon Winner, *Autonomous Technology* (Cambridge, Mass., 1977).

17. This phenomenon is sometimes described as "Metcalfe's Law," after a statement made by John Metcalfe, codesigner of the Ethernet protocol: "the usefulness, or utility, of a network equals the square of the number of users." John Markoff, "New Economy: Airborne and Grass Roots," *New York Times*, 30 October 2000.

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pose of the ARPANET was to connect many different institutions (universities and defense contractors) across the space and time of North America so that they could share each other's unique or expensive resources (new mainframe computers). Even though these shared resources were heterogeneous in a narrow sense—computers made by different manufacturers for different uses—they were also homogeneous as electronic, digital, programmable computing devices.[18] Given this desired network effect, the problem became a geographical one: how to create a pattern of interconnections that met Cold War requirements for resiliency and redundancy. Distributed packet-switching was the novel solution.[19]

A similar geographical question drove the creation of the earlier analog internetwork: how to allow people to exchange information across the vast space of a continent in the shortest possible time. The Post Office, telegraph, and telephone emerged in sequence as solutions to this problem, but instead of replacing each other these networks ended up connecting together and assisting each other in serving that overarching goal.[20] The more people who could be reached by each information network, the more valuable all three networks became, because whenever one network couldn't reach the addressee itself it could hand the message over to one of the other two networks.

Such cooperation continued even though each individual network exhibited changing spatial and temporal extent over its own history. Spatially, the Post Office closed branch offices but moved to free urban and rural door-to-door delivery, the telephone entered more and more homes and businesses, and the telegraph struck deals with railway stations, drugstores, and hotels to act as subcontracted offices. Temporally, the Post Office augmented its daily routes with special messengers when immediate delivery was necessary, the telephone staffed its exchanges with messenger boys in the late hours when female operators were not available, and the

18. Note that this description differs from Edwards's conceptualization (n. 6 above) of networks as arrangements linking *heterogeneous* technological systems.

19. Abbate (n. 9 above), ch. 2. Furthermore, the network links were made not only through the design of a shared protocol to be used by the heterogeneous hosts—the "Network Control Program" (NCP)—but also through the construction of a homogeneous set of hardware additions—an "Interface Message Processor" (IMP) for each heterogeneous host.

20. Here I am challenging the model of technological succession that is so often repeated in the history of communications. That model argues that the method, speed, and form of message delivery all gradually advanced starting from the early 1800s. First came the Post Office, sending print messages at railroad speeds; then came the telegraph, sending text messages at electric speeds; finally came the telephone, sending voice messages at electric speeds. But the technological succession argument is nothing more than a technological determinism argument in disguise. Rather than a story of succession, mine is a story of blurring, in which disparate networks coexist uneasily for extended periods of time.

telegraph ran messages on Sundays and holidays when the Post Office was closed. Attention to network geography reveals such shifts.

In both of these eras, the construction of the communications internetwork represents what geographers have called the production of space and time.[21] Briefly stated, this means that both space and time can be thought of as produced commodities, since the means to overcome temporal and spatial barriers must first be produced through capital and labor (and since such means are subsequently used in the further accumulation of capital through labor). For example, adding floors to a building creates more office or factory space, allowing for the mustering of more workers for a single task; similarly, speeding up a machine that controls a labor process produces more time for commodity production or service delivery. In fact, almost any change in the social process of production and reproduction requires a change in the organization of space and time as well. Especially in moments of crisis brought on by economic overproduction, when existing fixed assets are suddenly devalued just as investment in new fixed assets is most urgently needed, new capital accumulation often hinges on how quickly new space and time can be produced (or old spatial and temporal arrangements destroyed).[22]

Considering both the analog and the digital internetworks as produced spaces highlights a key similarity between the two: both used new socially constructed technologies to create new socially constructed spatialities. Though all social processes are inevitably temporal and spatial in nature (in that time and space are universal, fundamental categories), every society's conception of those categories is nevertheless historically unique. Whether time is thought of as linear or cyclical, or whether points in space are thought of as distant or connected, the work we do in molding our environments in order to live our lives affects how we think about the spatiotemporality of those same environments.[23]

Time and space, however, are no less real because they are socially constructed.[24] Advertisements in *Wired* magazine that show the digital internetwork "shrinking the globe" represent the reworking of a metaphor previously applied to the analog internetwork, which was supposed to

21. Henri Lefebvre, *The Production of Space*, trans. Donald Nicholson-Smith (Cambridge, Mass., 1991).

22. David Harvey, *The Limits to Capital* (Cambridge, Mass., 1982), and "Between Space and Time: Reflections on the Geographical Imagination," *Annals of the Association of American Geographers* 80 (1990): 418–34.

23. On social and cultural theories of space and time, see Edward T. Hall, *The Hidden Dimension* (Garden City, N.Y., 1966) and *The Dance of Life: The Other Dimension of Time* (Garden City, N.Y., 1983); Stephen Kern, *The Culture of Time and Space: 1880–1918* (Cambridge, Mass., 1983).

24. As David Harvey noted, "Social constructions of space and time operate with the full force of objective facts to which all individuals and institutions necessarily respond"; *Justice, Nature, and the Geography of Difference* (Cambridge, Mass., 1996), 211.

annihilate space and time.[25] In both cases, internetwork-enabled processes compressing time and space involved the coordination of human activity, flows of cultural information, and the turnaround time of money capital, all very real elements of the global capitalist production process.[26] And just as space and time are both physical and social phenomena, the production of space and time may have both physical and social implications as well, with space arranged specifically to exclude certain disempowered persons, or time arranged specifically to accommodate certain powerful persons. Tracing such "uneven development" is the key advantage of geographic analysis in the first place.[27]

But socially constructed virtual spaces must still be grounded in the socially constructed physical world.[28] The Web may be creating virtual meeting rooms to which highly paid knowledge workers can "transport" themselves for corporate brainstorming sessions while physically remaining at home, but those electronic spaces depend on underground fiber optic cables, rooftop microwave transceivers, and suburban offices where network administrators keep backup power supplies on call. Similarly, the telegraph changed the temporality of market investment and news dissemination, virtually "moving" all large urban centers closer to New York City. Yet that telegraph operated within the physical world of railroad rights-of-

25. Although Karl Marx used the phrase "annihilation of space by time" in the *Grundrisse* during the 1850s, the first example of this in reference to communications technology may have been in Western Union's annual report of 1869: "The value of the telegraph does not consist in the amount of time which can be saved by it over the mail or other means of communication, but in its practical annihilation of time"; Western Union Telegraph Company, *Annual Report of the President of the Western Union Telegraph Company to the Stockholders* (New York, 1869), 39.

26. David Harvey, *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change* (Cambridge, Mass., 1989), 240. See also Scott Kirsch, "The Incredible Shrinking World? Technology and the Production of Space," *Environment and Planning D: Society and Space* 13 (1995): 529–55.

27. Neil Smith, *Uneven Development: Nature, Capital, and the Production of Space* (New York, 1984). The discipline of geography has been contested terrain for much of this century, and my interpretation of the field is only one view among many. See Derek Gregory, *Geographical Imaginations* (Oxford, 1994); John Agnew, David N. Livingstone, and Alisdair Rogers, eds., *Human Geography: An Essential Anthology* (Cambridge, Mass., 1996); Richard Peet, *Modern Geographic Thought* (Malden, Mass., 1998); and Tim Unwin, *The Place of Geography* (New York, 1992). Interestingly, geographers have historically paid less attention to communications than to transportation and location theory. For a discussion of this bias, see Ronald F. Abler, *The Geography of Intercommunications Systems: The Postal and Telephone Systems in the United States* (Ph.D. diss., University of Minnesota, 1968); Aharon Kellerman, *Telecommunications and Geography* (London, 1993).

28. As Neil Smith argued in his critique of Manuel Castells, "capital and information are never entirely free of place, and spatial fluidity is only ever achieved via a parallel and deepening spatial fixity which at crucial moments reasserts itself, often violently"; "Spaces of Vulnerability" (n. 16 above), 69.

way, wooden poles, and high-rent urban offices where messengers waited on benches, sheltered from the cold.

Paying closer attention to the boundary between the virtual and the physical reveals how the "ARPA Internet" project, which followed the ARPANET but preceded today's Internet, was still a network at its heart. After launching the ARPANET, ARPA set up two similar packet-switching networks, PRNET (using ground-based radio transmission) and SATNET (using satellite radio transmission). Each of these new networks was optimized for a different kind of physical environment than the telephone-wired ARPANET. In connecting PRNET and SATNET to the ARPANET, ARPA's desired network effect was no longer the remote sharing of expensive computing resources (made moot by smaller and cheaper minicomputers) but instead electronic mail (e-mail) communication (the most popular activity on the ARPANET) among an ever growing population of users. Yet the problem was still a geographical one: how to build a more reliable network using different technologies for different environmental conditions.[29]

The connection between the virtual and the physical also solves a major difficulty with treating the telegraph, telephone, and Post Office as an internetwork. Paul Edwards, using the technological systems framework, has argued that any internetwork would have two main qualities. First, technical control that was previously centralized in a single system would be decentralized in an internetwork. For example, designers built resiliency and redundancy into the ARPANET by having each individual host computer be responsible for routing incoming packets of data around the network, rather than designating a centralized routing machine that would be prone to physical or electronic attack.[30] Second, internetworks would operate through shared protocols carefully designed by innovative "protocol builders."[31] For example, the fact that today a single "IP address" uniquely identifies any Internet-accessible computer on the globe is the result of a long history of ARPA protocol building.[32]

These criteria can be applied to the historical combination of telephone, telegraph and Post Office as well, even though there is a fundamen-

29. Abbate (n. 9 above), ch. 4. The three ARPA networks may have been heterogeneous in their physical method of operation, but they were homogeneous in their packet-switching basis, in their shared goals, and in their institutional management. And since the new Internet protocols were written to entirely replace the old ARPANET protocol, it is unclear whether this was actually an internetwork project or just a newer, more versatile network that was being created using reprogrammable components of an older network.

30. Edwards (n. 6 above); Abbate, ch. 1.

31. This is analogous to Hughes's "system builders," those innovators and entrepreneurs who combine not only material technologies but also sources of capital and management expertise into cohesive institutions with specific business agendas.

32. Edwards; Abbate, ch. 4.

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tal difference between the electrical communication occurring in the telegraph or the telephone and the physical process of moving letters through the Post Office. Rather than a combination of two virtual communication networks and one physical transportation network, the analog internetwork was a combination of three comparable networks, each having both virtual and physical aspects. The very point of the internetwork in this case was not that a particular piece of technology would be replicated over space, but that a virtual commodity, a single message of information, could be rendered in many different physical forms—a phone call, a printed telegram, or a mailed letter (not to mention the neural pathways of a messenger boy). No matter how that message traveled, it moved through physical offices, streets, machines, hands, and brains. In transporting a message to its final destination, then, all three networks shared a common protocol, inherited instead of innovated: the protocol of the physical street address. Each network depended so heavily on this information that it kept its own address list, trading with the others whenever incomplete or incorrect addresses were uncovered (often required by law to do so).[33]

Moving information back and forth between such realms—from the virtual to the physical, the verbal to the written, the personal to the mechanical—requires more than just technological protocols, especially when technological capabilities, message types, and even the very norms of communication are themselves constantly changing. Vast numbers of individual workers, situated within simultaneously competing and cooperating institutions, are crucial to both the daily maintenance and the gradual evolution of technological internetworks. Social theorists have been predicting that information technology would radically transform work ever since Daniel Bell theorized a postindustrial society in the early 1970s.[34] But specifying and understanding these changes requires an appeal to ethnographic studies of labor within networked institutions—labor which is, much like the technology surrounding it, hidden somewhere behind the virtual space inhabited by users of the information internetwork.[35]

33. The competitive advantage of each network was tied to its spatial and temporal relationship to this physical street address: a telephone might exist at the address, ready for use twenty-four hours a day, a letter carrier might visit the address once a day at a set time, and a telegraph messenger could visit the address twenty-four hours a day, with the added bonus of tracking down the addressee if he or she wasn't at the expected location. Interestingly, street addresses are still important, converging today not only with telephone numbers but with e-mail addresses (for an extra fee of thirty-six dollars a year) in the humble printed telephone directory; Joyce Cohen, "New Media Meets an Old Medium in the Phone Book," *New York Times*, 19 October 2000.

34. Daniel Bell, *The Coming of the Post-Industrial Society: A Venture in Social Forecasting* (New York, 1973).

35. For an introduction to the sociology and anthropology of work, see Michael Burawoy, "The Anthropology of Industrial Work," *Annual Review of Anthropology* 8 (1979): 231–66, and Aihwa Ong, "Gender and Labor Politics of Postmodernity," *Annual*

In the history of information internetworks in the United States, mediated by a capitalist political economy, human actors have labored in three conceptually separate and unequal roles: as managers of state and corporate institutions owning parts of the internetwork, as consumers of internetwork services and commodities (who must themselves labor to understand these new and complex technologies even as they consume internetwork services), and as workers paid to help produce and reproduce the internetwork on a daily basis.[36] Considering the spatial dynamics of each of these groups can help clarify how internetworks arise and function.

Institutional managers, for example, exert a form of distributed control in any multi-institution internetwork. Every decision an institution makes concerning its own operations can have a direct effect on how that institution creates, uses, and manages its own spatial and temporal networks—that is, on how it produces space in the internetwork.[37] Attention to this kind of distributed institutional control is key to understanding how the ARPA Internet (ARPANET, PRNET, and SATNET) became a true internetwork. In the 1980s, ARPA pushed its "transmission control protocol/internet protocol" (TCP/IP) as an international networking standard, with limited success. But at the same time, ARPA continually modified TCP/IP to allow interconnection to a wider array of networks, each managed by different institutions promoting their own protocols as standards. Through this process, TCP/IP eventually did become the de facto Internet standard.[38]

Review of Anthropology 20 (1991): 279–309. Key to the best work in this field is the recognition that the idea of "work" itself is socially constructed, not a problem-free universal economic category; work produces values and social relations, not just commodities. See Sandra Wallman, ed., *Social Anthropology of Work* (London, 1979). Note that this genre of the ethnography of work is quite distinct from the ethnography of laboratory practice in recent science and technology studies (STS) literature, though there are important connections to be made between them. On the STS ethnographies, see David J. Hess, "The New Ethnography and the Anthropology of Science and Technology," in *Knowledge and Society: The Anthropology of Science and Technology*, ed. David J. Hess and Linda L. Layne (Greenwich, Conn., 1992), 1–28; Gary Lee Downey and Joseph Dumit, eds., *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies* (Seattle, 1997).

36. This is a Marxian framework, modified by the recognition that individual persons may in practice play more than one role simultaneously. Note as well that there is a sort of American exceptionalism here, since most other industrialized countries nationalized their telegraph and telephone networks together with their postal networks (England as early as 1868). See Jeffrey Kieve, *The Electric Telegraph: A Social and Economic History* (London, 1973).

37. Erica Schoenberger has argued that the strategic challenges of firms can be defined in terms of time and space since "the compulsion to eradicate spatial barriers to the free circulation of capital unavoidably produces spatial fixity and new spatial barriers which immobilize and/or channel capital geographically for considerable periods"; *The Cultural Crisis of the Firm* (Cambridge, Mass., 1997), 21–22.

38. For example, ARPA revised the IP address system to allow for more hosts, and

From the point of view of institutions managing non-ARPA networks, the beneficial network effects of connecting to the ARPA Internet soon outweighed any benefits of pursuing their own proprietary protocols. Interactions among institutions, rather than government initiatives alone, enabled the connection of the ARPA network to enough other networks to transform them all into today's internetwork.

Similar institutional control issues molded the earlier analog internetwork. Even though the telegraph, telephone, and Post Office were each controlled by different institutions in the United States, at key moments the telegraph ventured into the telephone arena (in the late 1870s patent war over Bell's invention), the telephone controlled the telegraph (AT&T's stock purchase of Western Union in the 1910s), and the Post Office controlled both the telegraph and the telephone (during World War I). Each of these episodes had consequences for the development of the internetwork, spawning either new market-sharing agreements, new hybrid technologies, or new labor practices. And all three of these network institutions relied on each other for their day-to-day functioning under regular operating circumstances as well, whether coordinating personnel movements by phone or handling billing through the mail. Cooperation took place simultaneously with competition.

What about internetwork consumers in this competitive/cooperative environment?[39] End users of the ARPANET influenced the evolution of today's Internet, especially through their enthusiasm for e-mail.[40] Geography can help in the analysis of the time and space characteristics of such "emergent commodities." For example, formerly discrete media types blur together on today's Web. Publishing and broadcasting networks are forging intimate connections with computer and communications networks, as the unprecedented attempted buyout of Time Warner by America Online in early 2000 illustrated so well.[41] Radio shows, video advertisements, text references, and photographic images all coexist on the Internet, whether users see them as being broadcast to individuals or transported between computers.

The analog internetwork also generated emergent commodities. The singing telegram began as a commodity delivered through the telegraph network without even using that network itself: first, a female telephone operator employed by the telegraph network would sing the message over

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they altered the function of their gateway machines from simply routing packets between networks to doing more translation of different protocols between networks. Abbate (n. 9 above), ch. 5.

39. Ruth Schwartz Cowan has urged historians using the technological systems approach to consider consumers at what she called the "consumption junction"; "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology" in Bijker, Hughes, and Pinch (n. 13 above).

40. Abbate, ch. 3.

41. "The Net Gets Real," *Economist*, 15 January 2000.

the phone to the recipient, then a print version of the message would be sent through the Post Office. But eventually singing telegrams became so popular that the telegraph network's own delivery force, the messenger boys, were told to deliver the festive messages in person. Thus a new commodity emerged through the cooperation of all three networks.[42]

As this example shows, fundamental both to the managers who forge internetwork relationships and to the consumers who purchase emergent internetwork commodities are the laborers who not only produce those internetworks in the first place but also reproduce them on a daily basis. Under the technological systems paradigm, only one aspect of this labor is visible: the initial construction of shared protocols by a few protocol builders.[43] But a more complete study of internetworks must incorporate an understanding of protocol building that also involves creating and managing new categories of what might be called "protocol labor."

Protocols are neither simple to create nor eternal once created. Especially in an internetwork, where decisions are being made simultaneously by the managers of many different competing and cooperating institutions, one protocol is never enough; new protocols are continually being developed, old protocols are periodically revised, and all protocols are carefully layered in an ongoing process. When individual system managers did not want to spare their own personnel to support the construction of the ARPANET in 1969, the network protocols were modified almost immediately, split into two separate layers that allowed for a programming division of labor. Local protocol builders still had much to do, as Janet Abbate has observed: "Operators of a host system had to build a special-purpose hardware interface between their computer and its IMP, which could take from 6 to 12 months. They also needed to implement the host and network protocols, a job that required up to 12 man-months of programming, and they had to make these protocols work with the rest of the computer's operating system." Nevertheless, this split allowed most of the network programming to be subcontracted to an outside firm.[44]

42. For conflicting stories on the origin of the singing telegram (from two former Western Union employees), see Mike J. Rivise, *Inside Western Union* (New York, 1950), and George P. Oslin, *One Man's Century: From the Deep South to the Top of the Big Apple* (Macon, Ga., 1998). Note that the private teletype system crossed internetwork institutions in a similar way, pioneered by Western Union as the ultimate replacement for telegraph operators and messenger boys but proven in the marketplace by AT&T, which sent multiplexed telegraphic information over its telephone lines.

43. These innovators are important but, just as with Hughes's system builders, they are usually the same inventor-entrepreneurs of Alfred Chandler's "visible hand" of institutional management. David A. Hounshell, "Hughesian History of Technology and Chandlerian Business History: Parallels, Departures, and Critics," *History and Technology* 12 (1995): 205–24; Alfred D. Chandler Jr., *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass., 1977).

44. Abbate (n. 9 above), ch. 2.

This was only the first change to the slew of protocols that the Internet would eventually inherit. Such creative destruction of shared protocols reflects a basic tension in any network: as ARPA's Lawrence Roberts noted as early as 1966, the network must "overcome the problems of computer incompatibility without enforcing standardization."[45] In today's Internet, just as in yesterday's ARPANET, a certain degree of computer heterogeneity has its advantages (even though it makes maintaining the internetwork more difficult), as different sites can arrange different hardware and software combinations that best fit their local needs. Through this self-interest, a diverse array of resources is made available to all internetwork users—a valuable network effect. But to be available on the internetwork, compatibility compromises must be made. Because protocols are constantly shifting as new institutions attempt to enter the internetwork, labor is crucial not just in setting up internetworks but in operating them as well.[46]

This kind of ongoing, flexible labor is hard to see. Indeed, the very advantage of constructing an information network can be that the commodification of the virtual serves to mystify the material, an example of what Karl Marx originally termed "the fetishism of commodities."[47] The Web works even though users need have no idea how (or where) it works—whether over telephone lines, coaxial cables, or cell phone relays, whether in North America or Southeast Asia, and whether on an expensive IBM-owned server array or a teenager's secondhand personal computer.

The same was true for the telegraph, a single network from the user's point of view but part of an internetwork behind the scenes. Yet instead of being an "invisible" infrastructure, as some have argued, the telegraph, like the rest of its internetwork, was made visible through the people who worked on it.[48] Every user of the telegraph interacted with particular

45. Abbate, p. 66. The phrase "creative destruction" comes from Joseph Schumpeter, *Capitalism, Socialism, Democracy* (New York, 1947).

46. Larry Hirschhorn made a similar point about labor in postindustrial, cybernetically automated, continuous-process industries, arguing that as the complexity of the production process increased, so did the risks of downtime and failure due to unforeseen conditions—risks that no amount of preventative programming could eliminate. He advocated organizing firms into "learning organizations" that would educate, rather than de-skill, laborers. See Larry Hirschhorn, *Beyond Mechanization: Work and Technology in a Postindustrial Age* (Cambridge, Mass., 1984); also Shoshanna Zuboff, *In the Age of the Smart Machine: The Future of Work and Power* (New York, 1988).

47. Karl Marx, *Capital: A Critique of Political Economy*, vol. 1, trans. Ben Fowkes (New York, 1990). As David Harvey noted, "[T]hrough the experience of everything from food, to culinary habits, music, television, entertainment, and cinema, it is now possible to experience the world's geography vicariously, as a simulacrum. The interweaving of simulacra in daily life brings together different worlds (of commodities) in the same space and time. But it does so in such a way as to conceal almost perfectly any trace of origin, of the labour processes that produced them, or of the social relations implicated in their production"; *Condition of Postmodernity* (n. 26 above), 300.

48. Ken Hillis, for example, argued that "[t]he *activity* performed by the telegraph—

humans, such as clerks or messengers, in particular material spaces—telegraph offices, telephone booths, or hotel desks. And the telegraph companies knew this, concentrating resources on making offices appealing places to enter and on making messengers into crisply uniformed, walking embodiments of their invisible service.[49]

Because of both the special nature of this internetwork protocol labor and the importance of where it occurs, I conceptualize such labor as "boundary work." No matter what automated protocols are in place at any given moment, they will be imperfect and incomplete; disparate information networks can only work together through the efforts of specific workers who maintain the links, transform the content, and police the boundaries between those networks. The telephone, telegraph, and Post Office networks were interconnected only through the constant labor of workers who used all three in their daily tasks—telephone operators accepting phoned-in telegrams for the telegraph company, Post Office letter carriers delivering duplicate telegrams through the mail, or telegraph messengers running urgent letters to and from the Post Office. Internetwork studies must consider how individual occupations become involved in smoothing the transition from one network to another, and how changes in those occupations help define the spaces of the networks themselves—especially those spaces where the networks present themselves to their users.

The history of the telegraph messengers provides a striking example of this boundary work. Messengers were among the first switchboard operators in the initial competition between telegraph and telephone exchanges, messenger turnover was a key reason Western Union partnered with AT&T to collect and deliver telegrams by phone instead of in person, and poor messenger conditions and wages were among the reasons always cited in favor of Post Office control of the telegraphs. But more than this, messengers enabled the internetworking function of multimodal message delivery, dealing with all the problems that thwarted that delivery—incorrect addresses, lack of a telephone, recipient at work when expected at home—whether they themselves were paid by the local telegraph, telephone, or Post Office branch. The messengers worked in a service role literally outside the office-bound technological production and transmission of information, at the boundaries between all three networks, in full view of the consumer.[50]

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the transmission of information separated from an embodied messenger—though apparent to all users, was and remains *invisible*"; "On the Margins: The Invisibility of Communications in Geography," *Progress in Human Geography* 22 (1998): 543–66, emphasis in original.

49. Similarly, letter carriers wore military-style uniforms themselves, and telephone operators, or "hello girls," were trained in proper patterns of middle-class pronunciation.

50. With an eye to the spaces between networks, we can see how other groups of workers served boundary functions as well. Female telephone operators in the telegraph network worked with two supposedly competing technologies every day. Male linework-

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To properly understand either the analog or the digital internetwork requires not just finding such spaces of labor, but entering those spaces to recover the work that occurs there—including who performs it and how it has changed over time. In the days of the telegraph, boundary tasks of maintenance, translation, and error correction fell to the lowest-status employees in the internetworked institutions: telephone operators and telegraph messengers. But today almost all Internet workers need some sort of technical training in order to do their jobs, training that would mark them as at least semiskilled. Has the complexity of boundary work increased along with the complexity of the material technology, or is this a warning that the turn-of-the-century tasks of telephoning and bicycling were not as unskilled as was once thought?

To answer such a question requires more than just a passing reference to labor history.[51] Instead, it requires careful study of the labor process itself, both what boundary workers do and where they do it, because these workers are, dialectically, both technologies themselves and molders of technology. This is not to say that boundary workers in these networks are equivalent to mass-produced components, on one hand, or that they have the power of entrepreneurial system builders on the other. But only by realizing how such workers simultaneously are constructed and exert agency—and within what limits—can analysts capture the complexity of the value they add in the spaces between interconnecting information networks.[52] Of course, many social and labor historians have viewed workers as important actors when writing about individual information networks, and have often incorporated a spatial awareness as well.[53] But too many studies of the

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ers stringing telephone wires may not have realized what a large number of those wires were actually leased out to carry telegraph traffic. And even the same inventors and businessmen who built the networks in the first place rarely confined their efforts, their vision, or their stock portfolios to one network technology exclusively.

51. Though, as Philip Scranton argued over a decade ago, coherently drawing together labor history and the history of technology is in itself a worthy goal; "None-Too-Porous Boundaries: Labor History and the History of Technology," *Technology and Culture* 29 (1988): 722–43.

52. A good example is Kevin Borg's recent article exploring the history of automotive service work using Anthony Giddens's "structuration theory," arguing that "chauffeurs used new automotive technology to enhance their social power," if only for a short period; "The 'Chauffeur Problem' in the Early Auto Era: Structuration Theory and the Users of Technology," *Technology and Culture* 40 (October 1999): 797–832. For a discussion of the structure/agency issue within the sociology of work, see Randy Hodson, "The Worker as Active Subject: Enlivening the 'New Sociology of Work,'" in *The New Modern Times: Factors Reshaping the World of Work*, ed. David B. Bills (Albany, N.Y., 1995), 253–80.

53. For example, Edwin Gabler showed how the very mobility of post–Civil War telegraph operators in the United States militated against their waging a successful strike against Western Union; *The American Telegrapher: A Social History, 1860–1900* (New Brunswick, N.J., 1988).

Internet fail to include most workers in the mix at all, focusing only on a few millionaires.[54]

Here the ethnography of work can help. This approach, whether rooted theoretically in anthropology, sociology, or geography, was closely related to labor history and Marxian political-economic analysis in its early years, with participant-observation studies focused on exploring the question of whether technology degraded worker skills and workplace experiences.[55] Much of this work was a reaction against the field of industrial sociology, then caught in the dualism that workers must either be "somehow irrational in their responses to work" or "lean toward economic rationality."[56] Today, with the restructuring of the global economy, the ethnography of work has shifted away from the old masculine factory floor to focus on new kinds of work performed by new groups of workers in new spaces.[57] Braverman himself called for more study of services, that "ghostly form" of production: "Here the productive processes of society disappear into a stream of paper—a stream of paper, moreover, which is processed in a continuous flow like that of a cannery, the meatpacking line, the car assembly conveyor, by workers organized in much the same way."[58] Today such streams of paper are more likely to be backed by streams of electronic bits, enabling them to reach new places and new workers, as in the case of the low-wage, part-time, computer-mediated homework so often designed for women rearing children, a ghostly form of production finally coming under study itself.[59]

With many of today's newest service jobs dependent on internetworked information technology, new ethnographic studies of technical work have

54. Such as Robert X. Cringely, *Accidental Empires: How the Boys of Silicon Valley Make Their Millions, Battle Foreign Competition, and Still Can't Get a Date* (New York, 1996); Randall E. Stross, *Eboys: The First Inside Account of Venture Capitalists at Work* (New York, 2000); Michael Lewis, *The New New Thing: A Silicon Valley Story* (New York, 2000).

55. Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century* (New York, 1974).

56. Michael Burawoy, *Manufacturing Consent: Changes in the Labor Process under Monopoly Capitalism* (Chicago, 1979).

57. For example, María Patricia Fernández-Kelly has explored the conditions of work and home life for women in the textile and electronics *maquiladoras* along the U.S.–Mexico border, and Robin Leidner has brilliantly compared the gendering of work in two types of service jobs. See María Patricia Fernández-Kelly, *For We Are Sold, I and My People: Women and Industry in Mexico's Frontier* (Albany, 1983); Robin Leidner, "Selling Hamburgers and Selling Insurance: Gender, Work and Identity in Interactive Service Jobs," *Gender and Society* 5 (1991): 154–77.

58. Braverman, 301.

59. Eileen Boris and Cynthia R. Daniels, eds., *Homework: Historical and Contemporary Perspectives on Paid Labor at Home* (Urbana, Ill., 1989); Eileen Boris, *Home to Work: Motherhood and the Politics of Industrial Homework in the United States* (Cambridge, 1994); Eileen Boris and Elisabeth Prügl, eds., *Homeworkers in Global Perspective: Invisible No More* (New York, 1996).

begun to emerge. Stephen Barley and Julian Orr have argued that this kind of labor has four main characteristics: (1) complex technology is central to the work; (2) contextual knowledge and skill are both necessary; (3) theoretical and abstract knowledge are also necessary; and (4) a "community of practice" exists, serving as a repository for all this knowledge and skill.[60] But such definitions are hard to pin down to actual occupations, which carry a wide range of social meanings in addition to their functional requirements. Most people today would probably consider the job of computer programmer to be a professional position instead of a technical one; however, recent data from *Current Population Survey* categorizes computer programmers as "technicians."[61]

Historical awareness is needed here. As Jennifer Light has demonstrated, "the job of programmer, perceived in recent years as masculine work, originated as feminized clerical labor." Light retold the story of automated ballistics computation during World War II, pointing out that "Nearly two hundred young women, both civilian and military, worked on the project as human 'computers,' performing ballistics computations during the war. Six of them were selected to program a machine that, ironically, would take their name and replace them, a machine whose technical expertise would become vastly more celebrated than their own." Though she didn't cite the literature on technical work, Light's story fit into that framework: "Ballistics computation and programming lay at the intersection of scientific and clerical labor. Each required advanced mathematical training, yet each was categorized as clerical work."[62]

These attempts at defining technical work echo my notion of boundary work. Barley and Orr described technical work metaphorically as sitting between different realms in four ways: (1) "at the intersection of craft and science," invoking both theoretical and practical knowledge; (2) where "mental and manual skills coexist inseparably," combining aspects of work commonly constructed as "white collar" and "blue collar"; (3) "culturally situated between technology and . . . a society not quite ready to leave behind the categories of industrialism, its distribution of power, and its presumed distribution of knowledge"; and (4) "between technology and society in a structural sense" because "they link us to technologies that are nearly transparent when they work and troublesomely opaque when they do not."[63] In

60. Stephen R. Barley and Julian E. Orr, eds., *Between Craft and Science: Technical Work in U.S. Settings* (Ithaca, N.Y., 1997), 12.

61. Jeffrey Keefe and Denise Potosky, "Technical Dissonance: Conflicting Portraits of Technicians," in Barley and Orr, 53–81. (This may simply be my own bias as well, since I was trained in a university computer science department and worked as a computer programmer for about eight years.)

62. Jennifer S. Light, "When Computers Were Women," *Technology and Culture* 40 (1999): 455–83.

63. Barley and Orr, 12–14.

a subsequent article, Barley and Peter Whalley argued that technical workers negotiated a boundary between the virtual and the physical: "[U]nlike the popular image of a knowledge worker whose work is entirely symbolic, technicians also remain intimately involved with the material world. Technicians work routinely with machines, human bodies, and a host of other physical systems." Thus technicians work at the "empirical interface" between the material world and machine-generated representations of that world.[64] Jeffrey Keefe and Denise Potosky, drawing from the example of "invisible" laboratory technicians, as described by Steven Shapin, speculated that this kind of boundary work meant technicians would become visible within the organization "only when they made mistakes, departed from their assigned routines, or demonstrated incompetence."[65]

Such studies can also reveal the wider implications of space in such labor. In his research on photocopier technicians, Orr showed that Xerox, "the document company," straddled a fine line between the dream of the virtual paperless office and the reality of selling profoundly physical products that encouraged the increasing consumption of paper. A fundamental element of that paper consumption system was the regular maintenance performed by firmly place-bound repair workers, limited not only by the distance they could drive in a single day but by the physical space available in the trunks of their cars for supplies and spare parts.[66] Such spatial insights take on even more importance when one examines Xerox's current fortunes, since its single biggest nongovernment customer is itself a decentralized reseller of "flexible officing" solutions: Kinko's copy centers.[67]

Are there similar studies to be made of the labor that keeps the Internet's "spaces of flows" flowing? Thankfully, there is no messenger-boy job category within the Internet (though urban bicycle courier services increasingly cater to e-businesses).[68] But there are plenty of other new jobs—from network system operators to "help desk" technicians—that are just as essential, and often similarly underappreciated.[69] A historical study

64. Peter Whalley and Stephen R. Barley, "Technical Work in the Division of Labor: Stalking the Wily Anomaly," in Barley and Orr, 23–52.

65. Keefe and Potosky; Steven Shapin, "The Invisible Technician," *American Scientist* 7 (1989): 554–63.

66. Julian E. Orr, *Talking about Machines: An Ethnography of a Modern Job* (Ithaca, N.Y., 1996).

67. Claudia H. Deutsch, "Xerox, Fading Copier King, Hasn't Used Its Innovations Well," *New York Times*, 19 October 2000.

68. Glenn Collins, "Selling Online, Delivering on Bikes: Low-Tech Couriers Thriving," *New York Times*, 24 December 1999.

69. See, for example, Dennis Hayes, *Behind the Silicon Curtain: The Seductions of Work in a Lonely Era* (Boston, 1989); Barbara Garson, *The Electronic Sweatshop: How Computers Are Transforming the Office of the Future into the Factory of the Past* (New York, 1989); and especially the on-line newsletter *CPU: Working in the Computer Industry* (http://www.gocatgo.com/cpu/cpu.html). Interesting (though overly sensation-

of either of these groups would shed new light on the production and reproduction of the Internet.[70]

Take help desk workers first. Using the historical example of the WordPerfect Corporation, one Silicon Valley columnist estimated that "when the founders of a five-person software start-up dream about selling 100,000 copies of their new application, they are also dreaming about (though usually they don't know it) spending at least 8.3 man-years on the telephone answering the same questions over and over and over again."[71] Yet even though some of today's estimated two hundred and fifty thousand to three hundred thousand help desk workers earn between twenty-five thousand and fifty thousand dollars per year, others are low-paid, subcontracted, contingent workers.[72] They must work long shifts when consumers are likely to be using their company's software or hardware, whether during the business day or deep into the night.[73] And though their jobs are often advertised as "foot in the door" positions with up-and-coming technology companies (like those of the telegraph messengers before them), such jobs are meant to be unskilled ones, with carefully programmed expert-system decision trees anticipating every possible caller anxiety, ideally providing the appropriate answer (and phrasing) to help-line personnel at the appropriate moment.

But as technologies are combined, new situations arise. Help desk workers employed by an operating systems company may find themselves

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alist and often dubious) firsthand anecdotal accounts of various forms of hidden information-technology work can be found in Chris Carlsson, ed., *Bad Attitude: The Processed World Anthology* (New York, 1990); Jeff Kelly, *Best of Temp Slave!* (Madison, Wisc., 1997); and Bill Lessard and Steve Baldwin, *Netslaves: True Tales of Working the Web* (New York, 2000).

70. Research on these two job categories is sparse (and that is one of the reasons I consider them here). Many of my observations in this section come from my own university training and personal work experience in the computer industry through the mid-1990s.

71. Cringely (n. 54 above), 241–42. Note that this is the only time such workers are mentioned in his popular account of the birth of the microcomputer industry.

72. Joel Kotkin, "Unions See a Fertile Field at Lower End of High Tech," *New York Times*, 26 September 1999; David Leonhardt, "Computer Technicians Learn They Are Indispensable Parts," *New York Times*, 5 January 2000. Even a salary of twenty-five thousand dollars per year might be difficult to live on in some of the hyperinflated residential housing markets surrounding high-tech corridors; see Evelyn Nieves, "Homeless on $50,000 a Year in Luxuriant Silicon Valley," *New York Times*, 20 February 2000. On contingent work, see Kathleen Barker and Kathleen Christensen, eds., *Contingent Work: American Employment Relations in Transition* (Ithaca, N.Y., 1998).

73. The temporal variability and urgency of help-line requests has even spawned a sort of on-line auction for technical assistance: "Once a user types in a question, Expertcity gives its online experts two minutes to respond. Almost immediately, someone . . . responded and said he could solve my problem in a session that he estimated would take no more than 20 minutes and cost me $20." Michel Marriott, "Fast PC Help for a Fee," *New York Times*, 2 November 2000.

fielding questions concerning computer hardware, applications software, peripherals such as printers or monitors, and even telecommunications glitches. From the point of view of the consumer these are not discrete systems with individual license agreements and individual service procedures—they are simply "the computer" or even "the Internet," and a problem with one is a problem with all. Help desk workers must somehow negotiate these boundaries, either by analyzing such problems themselves or by forwarding callers to appropriate experts. And through it all, like the telegraph messengers, they must maintain their polite composure, appearing before the consumer as the public faces (or voices) of the employer.

A historical study of help desk workers would also offer an opportunity to explore the relationship between physical location and virtual location in boundary work. Support workers are simultaneously hidden and revealed, often physically located in a remote site—perhaps one with lower office rents, or closer to particular labor markets (even overseas)—yet virtually the first point of contact between company and consumer. Support workers are housed together in carefully crafted work environments, surrounded by sophisticated technology, and expected to work at a rapid pace to process calls, in an industrial factory-floor environment, yet they remain service workers. And the entire purpose of employing legions of support workers, immediately accessible to customers either by phone or by e-mail, is to use a sort of virtual transport to substitute for expensive on-site service calls. Brian Pentland even used spatial metaphors to describe the "hotline" workers he studied firsthand: "[S]upport people occupy the boundary between the known and the unknown, between software that works and software that does not."[74]

As another example of a contemporary boundary work study, consider the computer network system operator (or "sysop"). Here is an occupation that emerged with the networking of computers and has evolved in skills and responsibility with every change in the scale and scope of those networks. But the forging of new links between information networks on the Internet fundamentally changed the sysop's daily routine. Questions of data security arose when financial networks and home PCs became connected through phone lines; questions of limited bandwidth followed from the advertising demands of audio and video content, drawn from the broadcast radio and television networks; and even problems of indexing

74. Brian T. Pentland, "Bleeding Edge Epistemology: Practical Problem Solving in Software Support Help Lines," in Barley and Orr (n. 60 above), 113–28. See also Brian T. Pentland, "Organizing Moves in Software Support Hot Lines," *Administrative Science Quarterly* 37 (1992): 527–48, in which Pentland analyzes the "moves" that support workers used to either ask for help on a call from another member in the organization or transfer responsibility for the call to another member. Pentland effectively illustrates the "ritual structure" of asking for and giving help, and how this depends on and further affects one's perceived status within the organization.

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data fell to sysops, as their former user populations suddenly became producers of decentralized information on the Web.

Certainly, many of these functions were taken out of the realm of the sysop's power as the Internet grew—but this is only apparent through historical study of the sysop. Then again, through all these changes the sysop's job has remained fundamentally the same: to smooth the connections between disparate networks, to enable the transfer of disparate data, and to act as a gatekeeper for more and more users who suddenly want to (or don't want to) interact. How do sysops negotiate the boundaries of taste and community standards that stand between free access to information and censorship? And how is the persona of the sysop bound up with the value of the very service that a given computer network is selling—reliable, discreet, and/or carefully moderated communications? The sysop represents the spatial grounding of the virtual Internet: wiring boards and web servers have to be stored somewhere, as do the people who are paid to understand, connect, and maintain them. But how does the sysop move from being just another component in the computer network to being an active participant in, and molder of, that network?

Stacia Zabusky's ethnographic study of university microcomputer technicians suggested some answers to these questions. Zabusky argued that in order to do their job effectively these "brokers" had to be part of two different work communities simultaneously: their employing organization on the one hand, and the "developers of the technology in a wider and more diffuse technical community" on the other. The technicians acted as "linguistic interpreters of a sort." Problems could arise in this relationship, however, because the technicians' "critical position is not matched . . . with high status in the organization." Zabusky concluded that the technicians were "in an ambivalent space at the crossroads of vertical and horizontal divisions of labor," simultaneously "regarded as servants because their work was considered mundane and routine," and "regarded as specialists . . . because their knowledge was integral to a work system which depended on the distribution and coordination of expertise." This contradiction was well expressed in the title often given to such workers: "support specialist."[75]

Analysts can only notice such contradictions once they begin looking for them. William Mitchell admitted in his *City of Bits* that "I have never laid eyes on the machine that gives me access to the network. I suppose it is in some back room at MIT. There is no reason for me to seek it out." But at the same time he expressed awe at the power of the sysop: "Whoever runs a machine that serves as a network node can grant or deny user access to that node and can switch on or black out whatever subnetwork that node runs. Sysops can control the inflow of bits into a machine, decide which bits

75. Stacia E. Zabusky, "Computers, Clients, and Expertise: Negotiating Technical Identities in a Nontechnical World," in Barley and Orr, 129–53.

get stored there and which do not, determine which bits can be processed and in what ways, and control the outflow."[76] This is why it is important to investigate the relationship between the spaces of flows, where high-status information laborers work to increase production and profits, and the "places of flows," where lower-status information laborers work to keep the higher-level spaces on-line.

Historical studies that draw on both ethnography and geography show that the spaces of internetworked technology are inhabited by particular workers in particular ways. Different spaces within internetworks reflect not only different work roles but also different class, age, and gender roles—in essence, different levels of social power.[77] One hundred years ago, telephone operators were constructed as young women and telegraph messengers were constructed as even younger boys. Today such segregated divisions of labor might be rarer or harder to justify; nevertheless, remote data-entry "telework" is pitched to stay-at-home mothers while downtown data-design programming remains demographically male by a wide margin.[78] Distinctions of gender, age, and mobility demand the inclusion of labor markets in the analysis—labor markets that are also grounded in space, where potential workers may have specific characteristics tied to a myriad of locational differences.[79] To the degree that people are the ones creating and populating the virtual spaces of information networks, the physical location of those networks depends in turn on where those people live and how easily they can get to their network-maintaining jobs.[80] Thus where a network is grounded—whether in a suburban office park, an inner-city "smart building," or a free trade zone "teleport" overseas—may have everything to do with who is there on the ground to operate it.[81]

76. William J. Mitchell, *City of Bits: Space, Place, and the Infobahn* (Cambridge, Mass., 1995), 9, 149.

77. One of the best examples of this is a historical analysis not of a communications network, but of a distribution network. Susan Porter Benson has shown how the job category of the department store salesgirl was constructed to fill the border space between the affluent customer and the behind-the-scenes buyer. But being in this space meant mediating between the gender and class expectations of both groups. See *Counter Cultures: Saleswomen, Managers, and Customers in American Department Stores, 1890–1940* (Urbana, Ill., 1986).

78. See, for example, Heidi I. Hartmann, Robert E. Kraut, and Louise A. Tilly, eds., *Computer Chips and Paper Clips: Technology and Women's Employment*, 2 vols. (Washington D.C., 1986–87). Even computer-simulated human interactions on the Internet—such as a robotic voice reading a text article—are currently constructed with gender stereotypes firmly in mind. See Anne Eisenberg, "Mars and Venus, On the Net: Gender Stereotypes Prevail," *New York Times*, 12 October 2000.

79. See, for example, Susan Hanson and Geraldine Pratt, *Gender, Work, and Space* (London, 1995).

80. As David Harvey has wryly observed, "Unlike other commodities, labor power has to go home every night," *The Urban Experience* (Baltimore, 1989), 19.

81. We could even take this one step further: information networks themselves may

Both because of the space- and time-transcending goals that differentiate all networks from generic technological systems and because of the fact that, unlike technological systems, internetworks are less designed as artifacts and more produced through ongoing labor processes, the technological systems methodology is insufficient to study internetworks. Using geographical theories and ethnographic methods is essential to understanding how the disparate networks of an internetwork compete and cooperate with each other. Individual information networks are both grounded in material spaces and produce new virtual spaces themselves, so when studying the interactions between such networks researchers must pay careful attention to the spaces between those networks, the borderlands where they connect, and the work that is performed there. Only by tracing changes in the functions that internetwork boundary workers serve can one fully understand the historical changes in technologies, institutions, and commodities that are taking place to create and perpetuate such internetworks in the first place.

I have argued that using such methods in the historical study of the turn-of-the-century telegraph, telephone, and Post Office networks suggests that together those three networks operated as an internetwork as well, functionally similar to but technologically distinct from the Internet. Whether this argument is convincing or not, the point of carrying it through this essay has been to show how reconceptualizing old technological phenomena in a new way can lead to new insights.[82] There are certainly good reasons to argue that my analog internetwork is nothing of the sort; on the other hand, there are also good reasons to push the definition of today's digital internetwork farther from the bounds of electronic communication and into the realm of private package delivery, considering the

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affect the ability of laborers in different or distant markets to access job information about production facilities, or even to access those facilities remotely themselves through "telework." Thus information networks are grounded in labor markets, but may affect those labor markets dialectically, so the spatiality of the problem comes full circle. For recent research on such questions of telecommunications and urban space, see Stephen Graham and Simon Marvin, *Telecommunications and the City: Electronic Spaces, Urban Places* (London, 1996). For a sample of the range of such studies in the pre-Web years, see W. H. Dutton, J. Blumler, and K. Kraemer, eds., *Wired Cities: Shaping the Future of Communications* (Boston, 1987); Mark E. Hepworth, *Geography of the Information Economy* (New York, 1990); John Brotchie, Michael Batty, and Peter Hall, eds., *Cities of the 21st Century: New Technologies and Spatial Systems* (London, 1991). For post-Web studies, see Peter Droege, ed., *Intelligent Environments: Spatial Aspects of the Information Revolution* (Amsterdam, 1997); John Downey and Jim McGuigan, eds., *Technocities* (London, 1999); Wheeler, Aoyama, and Warf (n. 9 above).

82. Even today, researchers exploring the diffusion of early-twentieth-century communications technology in late-twentieth-century developing countries realize that telephone and postal services still substitute for each other, so that it makes sense to analyze the whole communications sector together. See Robert J. Saunders, Jeremy J. Warford, and Björn Wellenius, *Telecommunications and Economic Development* (Baltimore, 1994).

dependence of hardware makers, software vendors, and e-commerce retailers on Federal Express and United Parcel Service (not to mention the urban bicycle courier services). Either way, in working through those arguments scholars can hopefully move closer to a more productive definition of what an internetwork is and how it must be studied.[83]

As David Nye has put it: "Who is using the Internet? Governments, universities, international corporations, hackers, criminals, the CIA, and millions of individuals. The world they create with it will be no better than they are."[84] But I would like to ask, "Who is operating the Internet?" and "Where is that operation taking place?" Though these may be geographical questions, as geographer David Harvey notes, "[T]he question of space is surely too important to be left exclusively to geographers. Social theorists of all stripes and persuasions should take it seriously."[85] The Internet exists in the windowless offices and basements and closets of suburban start-ups just as the telegraph system existed in the skyscraper basement ready rooms where the messengers sat on their benches, waiting for the next buzz of the call box. What these workers do, and where they do it, is fundamental to any history we might write.

83. For my own part, conceptualizing the telegraph as part of an analog internetwork has allowed me to write a vastly better history of the telegraph messengers than I could have otherwise.

84. Nye (n. 8 above), 1087.

85. Harvey, *The Urban Experience*, 5.