YOUR COMPUTER IS ON FIRE

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THE CLOUD IS A FACTORY

Nathan Ensmenger

In the future histories to be written about the digital revolution of the late twentieth and early twenty-first centuries, there will inevitably appear a chapter on Amazon .com. One of the rare dot-com-era startups that survived beyond its infancy, Amazon leveraged its early success in its intended market space (book sales) into broader dominance in electronic retail more generally. Amazon is not only the largest of the top tech firms in both revenue and market value, but it competes successfully with traditional retail giants like Walmart.[1] On any given day, its founder and CEO Jeff Bezos stands as the richest man in America (on the other days he is second only to Bill Gates, who will no doubt also demand a chapter of his own in our imagined future history). The carefully cultivated story of both Bezos and the firm he created perfectly captures the dominant narrative of success in the digital economy (with the sole exception that Bezos actually managed to complete his Ivy League degree). If you were to ask the average American how daily life has changed for them in the internet era, they would almost certainly reference their experience with Amazon. And seemingly every day Amazon is expanding into new arenas, from entertainment to home automation to artificial intelligence.

And yet, despite Amazon's undisputed centrality in the contemporary digital economy, a close look at its core business model reveals it to be surprisingly conventional. At least a century prior to the invention of e-commerce, mail-order catalog companies like the Sears, Roebuck Company had accustomed American consumers to purchasing goods sight unseen from vendors with whom they communicated solely via information technology. Like Amazon, Sears neither manufactured goods nor owned inventory but functioned solely as information intermediary (and, as we will see shortly, a logistics and transportation company). What both companies provided was a layer of network infrastructure that links consumers to producers via a single unified interface. In the case of Sears, this interface was a paper catalog, for Amazon a website, but the basic services provided are identical. By organizing, consolidating, and filtering information, both the catalog and website served to simplify otherwise complicated and time-consuming informational activities and establish and maintain networks of trust across geographically dispersed networks of strangers. Concealed behind these seemingly simple user interfaces was a complex infrastructure of information-processing and communications systems, from display and advertising technologies to payment-processing systems to user support and service. And here again, it was arguably Sears a century earlier who was the most original and innovative; the systems that Amazon uses are perhaps more automated but are conceptually very similar (and, as in the case of the postal network, essentially unchanged). It is true that in the early twentieth century Sears handled "only" millions of commercial transactions annually, whereas today Amazon processes billions, but that is simply a difference in scale, not in kind.

But although both Sears and Amazon saw themselves essentially as information organizations, the messy reality of retail, even information-technology-mediated retail, is that eventually the goods need to be delivered. Although their sophisticated information systems could provide a competitive advantage when processing transactions, the costs associated with the management of information paled next to the costs of handling, storing, and transporting physical materials, and so both mail-order and e-commerce firms often find themselves reluctantly expanding along the distribution chain. For Sears, this meant coordination (and occasionally partnership) with railroad companies and national postal networks and the construction of massive warehouses and distribution centers. For Amazon, this meant the coordination with (or, increasingly, ownership of) trucking companies and shipping fleets, partnership with national postal networks, and the construction of massive warehouses and distribution centers. Within a decade of their establishment, both firms had reluctantly expanded out of informational space and into the physical environment. By 1904, Sears had purchased more than 40,000 square feet of office and warehouse space in Chicago alone; today, a single Amazon distribution center averages 100,000 square feet, and there are many hundreds of such centers in the United States alone. Eventually, Sears found itself constructing its own brick-and-mortar retail establishments to supplement its mail-order operations; recently Amazon, which allegedly triumphed over Sears because of its lack of such legacy brick-and-mortar, has begun doing the same.[2]

The degree to which Amazon is fundamentally in the business of managing the movement and storage of "stuff" (activities that our future business historians will no doubt refer to as transportation and logistics) cannot be overstated. In 2017 alone, Amazon shipped more than five billion packages via its Prime subscription service.[3] To accomplish this, Amazon has constructed more than 329 distribution centers in the United States, and another 380 worldwide.[4] These include massive, million-square-foot warehouses like that in Tracy, California, as well as smaller, more specialized sorting and delivery stations.[5] For delivery between its various facilities, Amazon relies on fleets of company-owned or leased vehicles.[6] For the so-called last mile, it relies (for the moment, at least) on delivery services like UPS or FedEx and—on extraordinarily favorable terms—the United States Post Office.[7] In order to further reduce its costs, Amazon has been developing an Uber-like system called Amazon Flex to further "disrupt" its dependence on third-party carriers.[8] And famously (and prematurely, perhaps perpetually), Amazon has announced plans to implement entirely automated drone delivery.[9]

In its focus on the control and consolidation of transportation and distribution networks, Amazon resembles yet another of the early-twentieth-century corporate giants, namely Standard Oil (see fig. 1.1).[10] Although Standard Oil's dominance of the oil industry was due in part to its monopolistic consolidation of refineries, it was equally enabled by the firm's secret manipulation of the railroad network. Like Jeff Bezos, John D. Rockefeller recognized the value of vertical integration and the necessity of access to and control over critical infrastructure. Such integration is only ever in part a technological accomplishment, and it requires social, political, and financial innovation. In this respect, the continuity between the industrial-era giants and the "Big Five" tech firms (Alphabet, Amazon, Apple, Facebook, and Microsoft) is all the more apparent. When we consider the digital economy in general, and electronic commerce in particular, it seems that success is also dependent on access to infrastructure—proximity to key transportation networks like roads, bridges, and highways; the employment of large numbers of appropriately skilled (but reasonably inexpensive) labor; the ability to construct and maintain (or at least lease) physical plants and other facilities; and, of course, access to the large amounts of capital, credit, and political influence required to secure the aforementioned resources. This perhaps explains in part why, despite the emphasis in the digital economy on

Figure 1.1 Existing and projected Amazon small sortable fulfillment centers in the United States.

light, flexible startups, many sectors of that economy are controlled by an increasingly small number of large and established incumbents. The growing belief that the United States is in the midst of a modern Gilded Age is about more than concern about wealth inequity.[11]

Given the perceived shift in recent decades (in the Western world, at least) from an industrial to a postindustrial society, the continued dependence of information-economy firms like Amazon on material infrastructure and the manipulation of physical objects is surprising, if not paradoxical. Despite repeated claims that the defining characteristic of the information society is "the displacement in our economy of materials by information," as *Wired* magazine editor Kevin Kelly has described it—or, in the even more succinct and memorable words of MIT professor Nicholas Negroponte, the inevitable shift "from atoms to bits"—what has in fact occurred is a massive *increase* in our interaction with our physical environment.[12] Information technologies allow humans to visualize, explore, and exploit our environment more efficiently. We travel more (and more broadly), consume more (and more globally), pollute more (and more pervasively). The amount of material moving around the planet has increased exponentially in recent years, arguably as a direct consequence of the digital revolution.[13] In fact, this increase is not only enabled by information technology but *required* by it.

Consider, for example, the one aspect of Amazon's business model that is truly different from that of its historical counterparts in the industrial-era retail economy: namely, its integration of sophisticated computational technologies at every level of the firm, from customer-facing web interfaces to back-end databases to global positioning systems. It is because of its use of these technologies that we think of Amazon as a key player in the digital economy in the first place. And, indeed, Amazon's implementation of these technologies was so successful that the company soon decided to package them for sale as commodity computational services and infrastructure. Unlike Amazon's retail operations, the provision of these services and infrastructure are highly lucrative, bringing in more than $17 billion in revenue annually and comprising the majority of the company's overall profits.[14] Within the computer industry, these products are known collectively as Amazon Web Services. Colloquially, the commodity computational infrastructure that these services comprise is known simply as "the Cloud." Of all of the elements of the contemporary digital ecosystem, none is more associated with the claims of present or imminent technological, economic, and political revolution than the Cloud.[15] If trucks and warehouses are the legacy technologies that ground e-commerce companies like Amazon to materiality and geography, the invisible and ethereal infrastructure of the Cloud seems to point the way toward a truly postindustrial and entirely digital economy.

What exactly is the Cloud? At its most basic, the Cloud is simply a set of computational resources that can be accessed remotely via the internet. These resources are generally associated with particular services, such as web hosting, server-based applications, database access, or data warehousing. The value of these resources is that they are available as discrete and idealized abstractions: when the user purchases access to a Cloud-based photo-sharing service, for example, they need know nothing about how that service is provided. They do not need to purchase a computer, install an operating system, purchase and install applications, or worry about software maintenance, hardware failures, power outages, or data backup. All of this equipment and labor is located and performed elsewhere, and as a result is rendered effectively invisible to the end user. In fact, it is this quality of seamless invisibility that most defines the Cloud as a form of infrastructure; as Susan Leigh Star reminds us, the whole point of an infrastructure is that you never really have to worry about what makes it all possible.[16] No one gives much thought as to how their electricity is generated, or where, or by whom; we simply expect that when we plug in our appliances or devices that the required electrons will be available. We only notice the massive size and complexity of the underlying electrical grid when it is broken or otherwise unavailable. The same is true of all infrastructure, from sewer systems to roads and bridges to our freshwater supply—and, increasingly, the internet and the Cloud.

But despite its relative invisibility, the Cloud is nevertheless profoundly physical. As with all infrastructure, somewhere someone has to build, operate, and maintain its component systems. This requires resources, energy, and labor. This is no less true simply because we think of the services that the Cloud provides as being virtual. They are nevertheless very real, and ultimately very material. For example, a typical large data center of the kind that Amazon operates draws between 350 and 500 megawatts of power; collectively, such data centers consumed 70 billion kilowatt-hours of electricity in 2016 in the United States alone.[17] This represents close to 2 percent of the nation's entire electricity consumption—roughly the equivalent to the output of eight nuclear power plants. Considered globally, the amount of power used by data centers approaches 1.4 trillion kilowatt-hours. And while some of this electricity is no doubt provided by renewable resources, much of it derives from sources that are so old-fashioned as to be prehistorical, such as coal, oil, natural gas, and uranium. According to a 2014 Greenpeace report, if the Cloud were a country, it would be the sixth largest consumer of electricity on the planet.[18] As these resources are consumed, they return carbon back into the atmosphere—something on the order of 159 million metric tons annually—and so the Cloud is also one of the world's largest polluters.[19]

Given its insatiable demand for electricity, there is at least one sense in which the Cloud is more than a metaphor. Cooling a typical data center requires roughly 400,000 gallons of fresh water daily. A very large center might require as much as 1.7 million gallons.[20] This is independent of the massive amount of clean, fresh water that is required to manufacture the data center's computer equipment in the first place. The Cloud is a heat machine designed to circulate cool air and moisture, creating its own carefully controlled microclimate and contributing to climate change in the larger environment.

Heat, air, and water are only a few of the material resources that the Cloud hungrily devours. Also present in these computers and their associated display screens are dozens of elements, some of them rare, some of them dangerous, all of which must be painstakingly mined, purified, transported, and manufactured into finished products—processes that also involve material resources, human labor, and multiple layers of additional infrastructure, many of which are controlled by some of the least stable and most exploitive political regimes on the planet.[21] All of which is to say that just as Amazon's e-commerce operations are revealed to rely to a remarkable degree on traditional, decidedly nondigital technologies like trucks and warehouses, so too are even its most high-tech and allegedly virtual services ultimately constructed around industrial-era systems, processes, and practices.

Which brings me to the main provocation of this chapter: namely, the claim that the Cloud is a kind of factory. In making this claim, my goal is to explore the potential benefits, analytically, politically, and otherwise, of resituating the history of computing within the larger context of the history of industrialization. In the early decades of the digital economy, the material dimensions of our emerging informational computational infrastructure were captured in the concept of the "computer utility."[22] Today, the metaphor of the Cloud erases all connection between computing services and traditional material infrastructure (as well as the long history of public governance of infrastructural resources). As a result, the computer industry has largely succeeded in declaring itself outside of this history, and therefore independent of the political, social, and environmental controls that have been developed to constrain and mediate industrialization.[23] By describing itself as an e-commerce entrepreneur and not simply an email order company, Amazon was awarded a decades-long tax subsidy that allowed it to decimate its traditional competitors.[24] In claiming to be an internet service provider and not a telecommunications carrier, Comcast can circumvent the rules and regulations intended to prevent monopolies.[25] By transforming its drivers from employees into contractors, Uber can avoid paying Social Security benefits.[26] In rendering invisible the material infrastructure that makes possible the digital economy, the metaphor of the Cloud allows the computer industry to conceal and externalize a whole host of problems, from energy costs to e-waste pollution. But the reality is the world is burning. The Cloud is a factory. Let us bring back to earth this deliberately ambiguous and ethereal metaphor by grounding it in a larger history of technology, labor, and the built environment—before it is too late.

To begin our interrogation of the claim that the Cloud is a factory, let us return for a moment to the earliest of the information organizations that I have thus far identified, namely, the Sears, Roebuck company. Of the many industrial-era corporations with which we might compare Amazon and other Silicon Valley tech firms, Sears stands out as the most relevant: not only did it share a business model with Amazon, but it survived long enough into the twenty-first century to be a competitor. Like electronic commerce today, the mail-order-catalog industry of a century ago reveals the essential continuities between the industrial and informational economies.

Sears was not the first of the mail-order-catalog companies: that honor goes to Montgomery Ward, whose founder, Aaron Montgomery Ward, issued in 1872 a one-page catalog that listed some items for sale and provided information on how to order them. But the company that Richard Sears and his business partner, Alvah Roebuck, founded in 1891 quickly emerged as a leading competitor to Ward and was, by 1897, delivering a 500-page catalog to 300,000 American homes, offering up everything from bicycles to bonnets to bedroom furniture to two-bedroom homes. By 1913, Sears was issuing more than twenty-six million catalogs annually and on any given day was able to fulfill more than 40,000 orders and process 90,000 items of correspondence. While this is not even close to contemporary Amazon volume, it is nevertheless significant. It is certainly indisputable that Sears circa 1913 was a full-fledged information organization. They had solved all of the key challenges facing an essentially virtual corporation—or a corporation that was at least as virtual as any contemporary e-commerce company. How they solved these challenges is illustrative, and suggests further questions to ask of the Cloud-as-factory hypothesis.[27]

One of the key problems facing all retailers is the problem of trust. Once the scale of the market economy has increased to the extent that consumers no longer have a direct connection to producers (that is to say, they are not personally familiar with the local butcher, baker, or candlestick maker), it can be difficult for them to evaluate the quality of goods that they are purchasing. In traditional retail, the problem of trust is in large part solved by the physical presence of a local intermediary. The buyer might not know the farmer who grew the corn that was turned into the flour that was baked into the bread that she bought at the grocery store, but at least she could see the product before she purchased it, had a long-term relationship with the grocer who was selling it, and had someone and somewhere to return the product if it turned out to be unsatisfactory. Convincing that same consumer to send her money in the mail to a retail agent she had never met located in a city she had never visited for a product she had never seen in person made the need for trust even more apparent.

There are many ways to solve the problem of trust. The establishment of brand identity—made possible in large part by the technology of advertising—was one way, as were responsive customer service departments. The latter solution not only generates much more data to be processed but also requires human intervention. In the early years of Sears customer service workers would not only have to enter customer correspondence data into a form that could be processed by the information systems that the company used to manage its internal databases but would also then copy their responses by hand as a means of establishing a more personal relationship to their otherwise unknown and invisible consumers. A century later Amazon would solve the same problem using human call center operators, many of them originally hired out of local Seattle-area coffee shops in order to provide a more recognizably "authentic" interaction.[28] Even in the era of online feedback and user ratings, the human element required to establish and maintain trust remains a necessary—and extremely expensive—component of even the most highly automated high-tech operations.[29] Amazon was notorious in its early years for the ruthless efficiency with which it ran its customer service operations. Using techniques developed for the assembly line of the early twentieth century (already, by the 1930s, the subject of scathing social critique by Charlie Chaplin in his film *Modern Times*), Amazon monitored, measured, and regimented every interaction and movement of its call center workers, from how long they spent with each customer to how many minutes they spent in the lavatory.[30]

Essential to the establishment of trust in mail-based (or, for that matter, online) retail is the ability to leverage the trustworthiness of other networks and institutions. What made the early mail-order companies viable was the emergence, in the middle of the nineteenth century, of an inexpensive, universal, and reliable postal network.[31] Both buyer and seller could be confident that any money or products that they sent through the mail would arrive on time and untampered with. If this trustworthy communications and transportation infrastructure had not yet been established, Sears would have had to construct it, which would have been cost-prohibitive. The same is true of Amazon, which relies heavily on the government-established (and publicly subsidized) United States Postal Service to provide timely, inexpensive, and ubiquitous delivery service.[32] And of course the postal network is itself dependent on other infrastructures (particularly transportation and communication networks) to maintain its own high standards of reliability.[33] Equally essential were trustworthy infrastructures for handling remote financial transactions, from telegraph-enabled electronic transfers to modern credit-card processors. In the low-margin world of mass-market retail, it is hard to imagine either Sears or Amazon being able to construct and maintain these critical infrastructures *ex nihilo*.[34] From advertising to finance to customer support to supplier relations, once you start unraveling the layers of material infrastructure that make supposedly “immaterial” information economy possible, it turns out to be turtles upon turtles, all the way down . . .

In addition to solving the problem of trust, Sears also had to solve the problem of data management. Although they would not have referred to their solution to the data management problem as a “computer” (though the term was already widely used by the early twentieth century), they did call it “data processing.” And, in fact, the technology that today we refer to as a computer was originally described as a mechanism for performing “electronic data processing,” a direct reference to the continuity between its intended function and the systems developed decades earlier at information organizations like Sears. As was mentioned earlier, by the first decade of the twentieth century, the Sears data-processing division processed hundreds of thousands of data-related operations every day. They accomplished this remarkable throughput by organizing into an efficient assembly line a hybrid system of information-processing technologies and human operators that can unambiguously be identified as an “information factory.” It is with the establishment of such information factories that the information revolution of the twentieth century truly begins: without reference to such factories, the history of computing is incomplete and perhaps inexplicable.

For anyone familiar with the popular history of computing, the claim that there was computing before there were computers might seem ridiculous. Such histories are typically told in terms of a series of inventions (or innovations, as the most recent bestseller in this genre would describe it). The focus is generally on the development of the first electronic digital computers of the mid-twentieth century, although the authors of such histories will often allow for the inclusion of some earlier “proto-computer” curiosities. But the emphasis is always on inventions that most closely resemble the modern understanding of what constitutes a computer and on inventors who most conform to the popular narrative of the heroic “computer nerd turned accidental billionaire.” Such stories are almost too good not to be true, and they provide clear and simple answers to the question about how the computer so quickly and profoundly has come to define our modern information society.

But a closer look at how pre-electronic computing but nevertheless information-centric organizations like Sears solve their data-processing problems provides a radically different interpretation of the history of computing that focuses less on specific technological innovations and more on larger social, political, and economic developments. In such explanations, terms like “industrial” define not a particular historical era or economic sector but rather an approach to the organization of work that emerges out of very specific historical context but would soon become (and remains to this day) the dominant method for approaching problems involving large-scale production or processing.

It is important to note that although we often think of the classic Industrial Revolution that reshaped Western society in the early modern period as being driven by mechanization (with the machines themselves being driven by new forms of power), in fact, industrialization is better understood as a combination of mechanization, organization, and labor. An industrial textile mill, for example, differs from its predecessor in terms of how machines are used (and not necessarily in terms of the presence or absence of machines), how those machines are organized, and who does the labor. The paradigmatic textile worker in Britain in the preindustrial period was a male artisan who worked with hand-powered and general-purpose machines to transform raw materials into finished products. The typical worker in an industrial textile factory was a woman who operated a highly specialized machine to perform *one* specific task within a rigidly organized division of labor. The new machines did not replace human workers; they created new forms of work that required (or at least enabled) the mobilization of new types and categories of labor. Whether it was the new machines that drove the search for new labor or the availability of new labor that encouraged the development of new machines is not relevant. The elements of the new industrial order were dependent on one another. That is what industrialization meant: the recombination of new machines, new organizational forms, and new forms of labor.[35]

For a variety of reasons, some economic, others social and political, industrialization emerged in the early seventeenth century as a compelling approach to large-scale production and manufacturing challenges. This included the production and manufacturing of data. For example, when the Emperor Napoleon charged the mathematician Gaspard de Prony with overhauling the tax system in France along scientific (and metric principles), de Prony adopted an industrial approach to solving the massive computational problem posed by the need to produce in a timely fashion entire volumes of new logarithm tables. At the time, the cutting edge of industrial practice involved the division of labor proposed by Adam Smith in his 1776 classic, *Wealth of Nations*. De Prony duly constructed a method for dividing up the cognitive work associated with computing logarithms, known as the difference method, and mobilized the labor of recently unemployed (and therefore inexpensive) hairdressers (whose aristocratic patrons had been lucky to escape the recent revolution with their heads intact, much less their fancy hairstyles). This was perhaps the first industrial-era information factory, but it was a harbinger of subsequent developments to come.[36]

Several decades after de Prony, the English mathematician and astronomer Charles Babbage, faced with a similar need to quickly and efficiently generate large numbers of mathematical tables, also turned to contemporary industrial manufacturing practices. After making an extended tour of European industrial centers, he published *On the Economy of Machinery and Manufactures*, the most comprehensive study of industrialization to date. By that point, the focus of industrial development had turned from the division of labor to water-driven mechanization. Babbage adapted de Prony's method of differences to this new industrial regime and in the latter half of the 1820s designed his Difference Engine, which was explicitly modeled after a contemporary industrial granary. Like the granary, it had a mill, a store, and a central shaft that could be driven by a waterwheel. The fact that it would mill mathematical tables instead of flour was irrelevant. The two problems were seen as essentially similar.

Babbage never got around to actually constructing his Difference Engine, nor its intended successor, the Analytical Engine. Because of its conceptual similarities to a modern computing device, the Analytical Engine is often identified as an important precursor to the modern computer revolution. This it almost certainly was not, but as a reflection of the interrelationship between industrialization and computation, it is highly significant. De Prony designed his information factory in the style of the early Industrial Revolution, Babbage according to the fashion of a later era. But they shared the impulse to industrialize, as would later innovators.

By the end of the nineteenth century, contemporary industrial manufacturing practices had begun to incorporate electricity. In 1888, the head of the United States Census Bureau, faced with the impossible task of enumerating a large and growing population using existing methods of data processing, held a competition to stimulate innovation in this area. The winner was a young engineer named Herman Hollerith, who created a new type of machine (the punch card tabulator), a new form of encoding information (the digital punch card), and a new system of organizing and automating these cards. As with most industrial systems, then and now, the work was not fully automated, and so Hollerith also created a novel form of clerical worker, the punch card tabulator operator. The company that Hollerith founded and the technology he created would, in the 1920s, form the basis of the International Business Machines Corporation. By the 1930s, IBM had already become a globally dominant information-technology company—several decades before it would produce anything remotely similar to a modern electronic digital computer. Once again, Hollerith innovated by industrializing information processing, inventing not only new machines but also new forms of labor and organization.

These are only three examples of the larger pattern that played out throughout the late nineteenth and early twentieth century, as the management of large amounts of information became a central feature of science, business, and government. In almost every case, the best model for understanding how to address such informational challenges is not the modern digital computer but the ongoing practice of adapting industrial methods and organizations to complex problems of almost every description. And for the most part, this process of industrialization involved a combination of mechanization, organization, and new forms of labor. As with industrialization more generally, very often these new forms of labor were women. The first factory workers in the United States were women, and so were the first information factory workers. Consider the typewriter, for example, which allowed for the mechanization of document production by combining technical innovation (the typewriter) with the division of labor (the separation of the cognitive labor of authorship from the routine clerical labor of transcription). As the work of the head (authorship) was divorced from the labor of the hand (typing), the job of clerk was fundamentally transformed, becoming at once low-skill, low-wage, and almost entirely feminized. As with many industrial processes, an increasing level of mechanization almost inevitably implied a corresponding reduction in skill, and workers with other options (which in this historical period generally meant men) would explore new opportunities. The typewriter was simultaneously a machine, a person, and a new job category.

It is in this period that we can identify the early origins of what would become the computer revolution. The industrial organization of informational work, when it was found in the corporation, was generally referred to as data processing. In science, it was called computing. And while it is true that the nature of the problems in these two domains differed in significant ways (data processing often involved the manipulation of words, and scientific computation focused mainly on numbers), the actual practices and techniques involved were generally quite similar. The informational task would be organized and divided in such a way as to allow large numbers of inexpensive (female) laborers to perform machine-assisted calculations or manipulations. These machines might be typewriters, punch card tabulators, adding machines, or calculators, depending on the context, but the basic approach was identical. By the early twentieth century, data-processing work had become almost entirely feminized, and the word “computer” was universally understood as referring

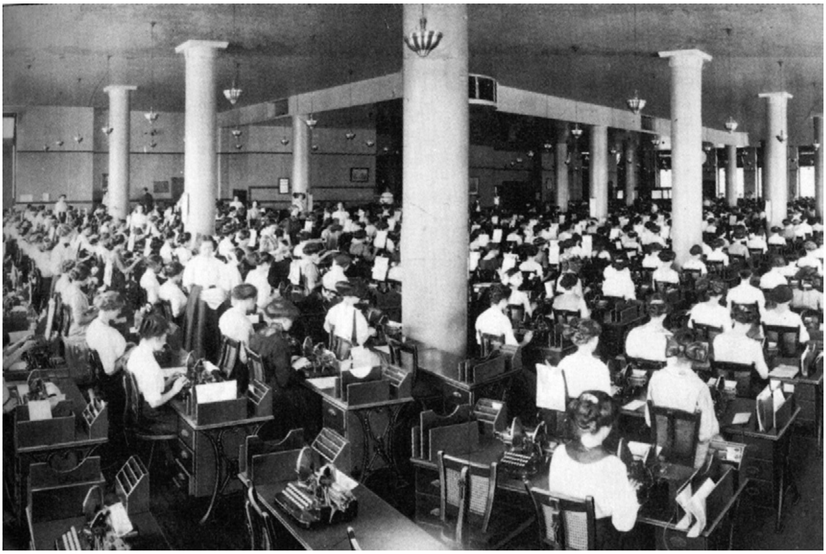

Figure 1.2 Sears, Roebuck Company data division, ca. 1908.

to a female mechanical calculator operator. The origins of the computer industry can only be understood in terms of the larger history of industrialization; otherwise, the large number of women workers and the particular organization of labor are inexplicable.

It was the industrialization of information processing in the late nineteenth century that allowed Sears to compete economically with traditional retail. Photographs from this period of the Sears data division reveal the obviously factory-like nature of the contemporary information enterprise: row upon row of identical (and interchangeable) female machine operators tending highly specialized technologies, the entire operation intended to standardize, routinize, and automate as much as possible tasks that had previously required time-consuming and expensive cognitive labor. To the degree that the Sears data division performed the same function for which Amazon today relies on the Cloud, this early version of the Cloud was clearly a factory (see fig. 1.2).

When in the 1930s the looming threat of war inspired the United States military to invest in the latest generation of industrial technology, namely electronics (not to be confused with the earlier use of electrification), they modeled the first generation of electronic "computers" after their human equivalents. John Mauchly, head of the ENIAC project at the University of Pennsylvania, quite explicitly described his project as an "automated form of hand computation."[37] It is no coincidence, therefore, that the first operators of these new machines—what today we would call programmers—were women recruited directly from the human computing department. The centrality of women in early computing was neither an accident nor a wartime exigency. The first electronic computers were electronic information factories, and the female computer programmers were their first factory workers. As I have written elsewhere, it would be several decades before the work of computer programming was made masculine and elevated to its current status as the epitome of (generally male) cognitive labor.[38]

All of this is to establish that it is impossible to understand the emergence of the modern information society without reference to the larger history of industrialization. Why is this significant? Because industrialization is fundamentally as much a social and political project as it is technological or economic. The ostensible driving force behind industrialization is the pursuit of efficiency, but the actual history of how, when, and why certain economic sectors chose to industrialize suggests otherwise. New techniques and technologies do not emerge out of nothing to revolutionize work practices; they are designed explicitly to do so. Machines are designed by humans to accomplish human agendas, and as such it is essential to always ask why industrialization is happening, to what ends, and for what purposes. This is particularly true in the history of computing. It is quite clear from the business literature of the 1950s what the new technology of electronic computing was intended to do. It was meant to do for white-collar labor what the assembly line had done for the automobile industry: namely, to transform a system in which skilled human labor was central into one in which low-wage machine operators could accomplish the same basic objective.[39]

And so let us return again to the central conceit of this historical thought experiment: what happens when we consider the Cloud as a factory, and not as a disembodied computational device?

1. We restore a sense of place to our understanding of the information economy. Despite repeated claims that "distance is dead," "the world is flat," and that geography (and therefore the nation-state) is irrelevant, cyberspace is surprisingly local.[40] Ironically, this is perhaps most true in Silicon Valley, the place that makes the technologies that ostensibly make location irrelevant, and yet where geographical proximity is so obviously essential that firms and individuals will go to great expense and inconvenience to live there. When Amazon recently encouraged cities to bid for the privilege of hosting their "second headquarters," they were clearly pushing for

those cities with well-established physical and social infrastructures: housing, highways, schools, restaurants, and recreational facilities. When Microsoft or Facebook looks to locate a new data center, they require easy access to inexpensive electricity, a plentiful water supply, and an appropriately skilled labor force.[41] It is any surprise that these data centers are often located in the same places that housed industrial-era factories just a generation ago?

2. Closely associated with the recognition of the significance of space and place is an appreciation of the importance of infrastructure. When it is made clear that despite the ethereal implications of its defining metaphor, the Cloud is actually a ravenous consumer of earth, air, fire, and water, the essential materiality of the virtual becomes undeniable. If within a few years of its invention, the Cloud is already the sixth largest consumer of electricity on the planet, what might we imagine about the implications for the future? In the face of climate change driven by humankind's industrial activity, can we continue to ignore and externalize the environmental costs of our online activities? Given the looming global shortage of clean, fresh water, ought we not reevaluate our allocation of this precious resource to a data storage facility? At the very least, no matter how much of our activities seem to relocate into cyberspace, we will need to continue to invest in and maintain our traditional physical infrastructure. It turns out the Cloud needs roads and bridges and sewer systems just as much as humans do.

3. It is also essential that we recognize the fundamental interconnectedness (and interdependencies) of all of our infrastructures, including our virtual infrastructures. One of the most currently overhyped technologies in the computer industry is the virtual and distributed trust infrastructure known as the blockchain. This technology is attracting a massive amount of attention (and a slightly less massive amount of investment capital), and its financial and technological viability is entirely dependent on the mistaken assumption that the computational resources provided by the Cloud are essentially free—or will eventually be free in some unspecified and indeterminate future. This ignores the fact that the only significant implementation of the blockchain, which is the virtual cryptocurrency Bitcoin, is deliberately and irredeemably energy-inefficient. By design it is an almost infinite sink for computer power and, by extension, coal, oil, water, and uranium.[42] Already the Bitcoin network, which does not and cannot provide even basic functional financial services, is one of the largest consumers of computer power on the planet, with an annual appetite for electricity approaching that of the entire nation of Denmark. There are multiple ways to implement blockchain technology, of which the proof-of-work

algorithm used by Bitcoin is by far the least desirable, at least from an environmental point of view. For anyone cognizant of the relationship between virtual and physical infrastructure, the fact that Bitcoin is not only not regulated but rather actively encouraged is astonishing.

4. From infrastructure our attention moves naturally to the supply chain. The computing devices that comprise the Cloud are truly global commodities, containing among other elements lithium from South America, tin from Indonesia, cobalt from the Democratic Republic of Congo, and a variety of rare earths whose supply is almost exclusively controlled by China. Each one of these resources and resource chains represents a set of stories to be told about global politics, international trade, worker safety, and environmental consequences. Cobalt is a conflict mineral; tin is deadly to humans and animals alike; China has already declared its monopoly over rare earths to be even more economically and geopolitically significant than that of the Middle East over oil. The need for companies like Tesla to secure access to South American supplies of lithium invokes the specter of a similar history of corporate meddling by the United Fruit Company or US Steel. But, in any case, following the supply chain that enables the Cloud as factory is a reminder that the digital economy is a global phenomenon, whether or not the actors involved in that economy are consciously aware of it. Seen from this perspective, lithium miners in Bolivia and e-waste recyclers in Ghana are as much a part of the digital economy as software developers in Silicon Valley.

5. Although we often associate factories with jobs, historically speaking human labor is only one component of industrialization. Some factories create work for humans; others eliminate it. Some machines enhance worker productivity, autonomy, and creativity, but this is the exception and not the rule. At the very least, industrialization changes work and the composition of the workforce. As we imagine the Cloud as a factory, we must ask what kind of factory it is intended to be. As in more traditional manufacturing, the Cloud as factory consumes local resources and pollutes the local environment. But compared to traditional manufacturing, does having such a factory in one's town provide compensatory benefits in terms of jobs, tax income, or the development of new infrastructure? In the industrial era, social and political mechanisms were developed for the negotiation between private and public interests. Do such mechanisms still apply to the information economy? Are they even available as a resource to governments and citizens? In addition to thinking about what might be gained by positioning the Cloud as a factory, we might consider what opportunities we have lost in not doing so.

6. In addition to thinking about the work that happens in and around the Cloud facility itself, we might also consider the changes to work that the Cloud enables in other industries. For example, automated vehicles are made possible in no small part by the computational activities that happen in the Cloud. In this sense, the Cloud is an element of the larger technological environment in which autonomous vehicles operate. Are they all part of the same factory? And if so, what does it mean for the trucking industry—and for the truck drivers whose jobs will soon be automated out of existence by this new technology? In thirty of the fifty United States, the single most common occupation for men is truck driver.[43] What are the social and economic ramifications of the industrialization and computerization of such an industry?

It is clear from the comparative histories of Sears and Amazon that despite the latter's high-tech veneer, the fundamental business model of the two firms is surprisingly similar. Does this make Sears an early predecessor of the information economy or Amazon a lingering relic of the industrial era, with its focus on the movement of materials and the construction and maintenance of physical capital? Is this even a useful question to ask, or is it an artifact of the artificial distinctions that are often drawn between the old and new economy? My argument has been that by focusing on the similarity between the two firms, and the continuity across different economic epochs, we can ask new and provocative questions about the history of modern computing, including questions of political economy, labor history, and the history of capitalism. Because it is clear that the Cloud is more than just a technical term or even a series of overlapping infrastructures. It is a metaphor, an ideology, and an agenda, which means that it is a tool for both understanding the past and present as well as for shaping the future. The Cloud is a factory. But a factory for what, and for whom, and for what purposes?

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