Writing the Big Story

Preprint – to be published in William Aspray (ed.) *Writing Computer and Information History: Approaches, Reflections, and Connections*, Rowman & Littlefield, forthcoming 2024.
Please quote and cite the published version which will differ.

Thomas Haigh
University of Wisconsin—Milwaukee & Siegen University

thomas.haigh@gmail.com www.tomandmaria.com/tom

In 2016 I began work with Paul Ceruzzi to update his book *A History of Modern Computing*, then twenty years old and firmly established as the most cited overview history of the electronic computer. Five years later *A New History of Modern Computing* was published, with me as the lead author.

It's neither a revised edition of the old book nor an entirely new one. I see it as a substantially new book. The chapter structure is completely different, but we incorporated fragments of the old text just as a new house might reuse elements of the building that was demolished to make room for it. It tells the story in a different way, or perhaps it tells a different story. In this chapter I'll be describing what we did and why.

Why Tell the Big Story?

Shortly after our book was published a fellow historian of computing suggested that this was an important but thankless job. Two years later, it's apparent that he was right on both counts. Overview histories of computing are not written by the faculty of elite history programs; in fact few of the people writing them are employed by history departments in any capacity. There's something a little suspect about writing a history of technology that centers on a technology. Attempting this is not quite reactionary but it is unmistakably old fashioned. The history of modern computing is long and broad; given the limited volume that can be accommodated in a single book it's a matter of physics that the narrative must in some sense be shallow.

So why bother? One case is the one we articulate in the book's introduction. In little more than 75 years the programmable electronic computer has gone from ENIAC, a one-off electronic monstrosity used by scientists and engineers to crunch numbers, to today's plethora of smartphones, servers, and embedded devices. Their material form, cost, social significance, mode of operation and user groups have changed utterly and repeatedly in a way that those of other technologies, such as cars, have not. In that respect the trajectory of the computer has been truly exceptional. Looking at that arc only one segment at a time makes the big story easy to miss.

We're a narrative-weaving species. Anyone who thinks or writes about the history of computing is going to construct some kind of framing story in their head to join whatever fragments they learn about. Without the context and scaffolding of a big picture story they are likely to join the pieces together haphazardly. Scholarship of the history of computing is increasingly migrating to information schools and media programs, where students and practitioners are unlikely to receive broad historical training. Readers and writers are likely to look at historical events in isolation from broader historical contexts and frame them directly against the concerns of the present day. They may miss the deeper historical roots of apparently new concepts like cloud computing, or jump over decades of intervening history to make misleading connections straight from famous

historical figures such as the women of ENIAC to the modern world. It's important that people with a deep and broad knowledge of the history of computing, and of the history of technology more generally, occasionally attempt to put the pieces together into a coherent and comprehensive story.

Early Narratives

What is the history of computing the history of? This question, above all others, must be answered by anyone attempting to write the big story of computing. Historian Michael S. Mahoney, who posed that question in one form or another in many of his papers, observed that "nothing is really unprecedented. Faced with a new situation, people liken it to familiar ones and shape their responses on the basis of the perceived similarities."[1] The search for precedent is a search for a narrative frame. Humans make sense of the world by telling stories to themselves and each other, and so to understand and explain the first electronic computers it was necessary to package them inside a story.[2] The computer's history has been told for as long as there have been computers. As historical work necessarily takes place sometime after the events concerned, we can trace the spread of computer technology in the changing narratives of the history of computing.

The early computer was most obviously a calculating machine, literally something performing computations. It was seen as a natural evolution of earlier calculating devices such as the hand cranked calculators widely used in business.[3] The most important early edited volume on the history of computing, *A History of Computing in the Twentieth Century,* was prepared by members of the Los Alamos scientific computing staff.[4] The first textbook for computer history, *The Computer from Pascal to von Neumann*, was a mixture of historical research and memoir from a close collaborator of von Neumann.[5]

Another answer is that the computer has always been an "information machine". This narrative was first adopted by Edmund Callis Berkeley's 1949 book *Giant Brains, or Machines that Think.* This was the first popular treatment of the new technology, giving a generation of impressionable youngsters an introduction to the hitherto obscure world of computing. It described in numbing detail computers of the 1940s such as the ENIAC, MIT's differential analyzer, and the series of machines built by Harvard and Bell Labs. But it also wove them into a grand narrative that stretched back into prehistory and forward to a future of highly intelligent machines. Berkeley called the computer a giant brain not because it could handle tasks of the kind later associated with artificial intelligence but because it "can handle information with great skill and great speed." (p. vii) In this narrative the digital computer was precedented by earlier machines and systems for handling information, such as nerve cells, cave paintings, beads on

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[1] Michael S Mahoney, "The Roots of Software Engineering," *CWI Quarterly* 3, no. 4 (1990):325-334, quote p. 326

[2] Karl E Weick, *Sensemaking in Organizations* (Thousand Oaks, CA: Sage, 1995).

[3] Most notably in Michael R Williams, *A History of Computing Technology* (Englewood Cliffs, NJ: Prentice-Hall, 1985).

[4] N Metropolis, J Howlett, and Gian-Carlo Rota, eds., *A History of Computing in the Twentieth Century: A Collection of Papers* (New York: Academic Press, 1980).

[5] Herman H Goldstine, *The Computer from Pascal to von Neumann* (Princeton, NJ: Princeton University Press, 1972).

strings, and human language (p. 10-13). But in "a deep break from the past," it could transfer "information from one part of the machine to another [with] flexible control over the sequence of its operation." (p. 5) In other words, it could execute a program.[6]

That framing of the computer was endorsed in the subtitle of *Computer: A History of the Information Machine* by Martin Campbell-Kelly and William Aspray.[7] First published in 1996, this remains one of the two standard histories relied by readers and instructors looking for a well-balanced, comprehensive, and reliable overview. By the 1990s historians began to explore the computer's administrative use and situate it in the context of earlier technologies like punched card machines and typewriters. *Computer* embodies this shift. On its publication the book's most novel feature was its insistence on the computer as primarily a tool for administrative coordination rather than scientific calculation. (In other words, its framing had caught up with the world of the 1960s rather than remaining in the 1940s). Although accessible it is not simplistic and nicely summarizes and connects key insights and stories from the secondary literature as it had developed to the early 1990s.

Computer has a finely crafted narrative structure that exemplifies the tendency of overview histories of computing to produce coherent narratives by exploring only one kind of computer platform in each time period: typically mainframes up to 1965, minicomputers from about 1965 to 1975, personal computers from 1975 to the mid-1990s, and the Internet since then. This simplifies the narrative, but at a cost: IBM still earns a significant share of its profits from its mainframe business, and minicomputers were much more important in the early 1980s, after personal computers were invented, than in the late 1960s. It's also an approach that is hard to extend to recent decades. Smartphones did not make other platforms go away, and the Internet can be traced further back in time than the IBM PC.

The other major overview history of computing was Ceruzzi's *A History of Modern Computing*, written in parallel with *Computer*.[8] Some years ago, when comparing the two books, I wrote that "Ceruzzi's book has less to say about applications, and skips the digital computer's forebears completely to launch the story in the mid-1940s. Ceruzzi provides more detail on the architectural development of computers and better coverage of the minicomputer, which he argues for persuasively as the source of today's personal computing technologies. His book focuses more on technical history and has a somewhat more episodic structure."[9] *A History of Modern Computing* offers some well-researched case studies of computer use, but at its heart is the story of the emergence of the modern computer as a packaged product and its subsequent evolution into new forms.

Both books were updated – *A History of Modern Computing* in 2003 and *Computer* in 2004 and 2014 (with the addition of Nathan Ensmenger and Jeffrey Yost as coauthors). These updates focused, as one would expect, on adding new material to better cover the Internet and the web.

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[6] Edmund C Berkeley, *Giant Brains or Machines That Think* (New York: John Wiley & Sons, 1949).

[7] Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (New York, NY: Basic Books, 1996).

[8] Paul E Ceruzzi, *A History of Modern Computing* (Cambridge, MA: MIT Press, 1998).

[9] Thomas Haigh, "The History of Information Technology," *Annual Review of Information Science and Technology* 45 (2011):431-487, quotation 339-340.

Neither book fully assimilated newer conceptions of the computer – which today is experienced more often as a media player, communication device, or control system than as a business tool or scientific calculator. Neither had much to say on the evolution of the personal computer after the mid-1980s, on video games, or on mobile computing. Both books cloistered software in a chapter of its own rather than integrating it into the main narrative.

Much changed in the twenty years after these books appeared but there was no serious attempt to challenge them. Walter Isaacson's startlingly old-fashioned but inarguably popular chronicle of brilliant inventors, *The Innovators*, is outselling both by several orders of magnitude but is not a serious history.[10] Strong overview business histories have appeared of specific sectors, most notably Martin Campbell-Kelly's history of the software industry and Jeffrey Yost's books on the computer industry and the computer services industry.[11]

There have been a couple of highly-compressed histories, most notably Ceruzzi's own *Computing: A Concise History* and a more recent *The History of Computing: A Very Short Introduction* by Doron Swade as well as a few others written to be accessible to high school students.[12] David Gugerli's *How the World Got Into the Computer* takes a thoughtful and application-oriented view of computers and their affordances but like Swade's book pays close attention only to the first decades of electronic computing.[13] Books continue to appear about the very early history of electronic computing, including George Dyson's engagingly and frustratingly eccentric *Turing's Cathedral*, and a shelf full of recent books that are (unlike Dyson's) actually about Turing.[14] Dyson squares his desire to make grand claims with the reality that he wrote a closely observed study of a single early computer project by rhetorically positioning the Institute for Advanced Studies computer as a "point source" for our "digital universe." By focusing on origins and first steps, most of these narratives imply that we can best understand today's computers by looking at the relatively distant past.

In the realm of full-length synthetic history, the duopoly of *Computer* and *A History of Modern Computing* endured for more than twenty years. This was a testimony to their considerable strengths and made the prospect of supplanting one of them a daunting challenge.

The Histories of Computing(s)

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[10] I've discussed some the limitations of Isaacson's view of history in Thomas Haigh and Mark Priestley, "Innovators Assemble: Ada Lovelace, Walter Isaacson, and the Superheroines of Computing," *Communications of the ACM* 58, no. 9 (Sep 2015):20-27.

[11] Jeffrey R Yost, *The Computer Industry* (Westport, CT: Greenwood Press, 2005). Jeffrey R Yost, *Making IT Work: A History of the Computer Services Industry* (Cambridge, MA: MIT Press, 2017). Martin Campbell-Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge, MA: MIT Press, 2003).

[12] Paul E Ceruzzi, *Computing: A Concise History* (Cambridge, MA: MIT Press, 2012). Eric G Swedin and David L Ferro, *Computers: The Life Story of a Technology* (Westport, CT: Greenwood Press, 2005), Doron Swade, *The History of Computing: A Very Short Introduction* (New York:: Oxford University Press, 2022) is an example of an overview history aimed at high school students.

[13] David Gugerli, *How the World Got into the Computer: The Emergence of Digital Reality* (Zurich, Switzerland: Chronos Verlag, 2022).

[14] If you want to know more on my opinion of Dyson's book, you'll find it at https://sinews.siam.org/Details-Page/an-unconventional-history-of-the-early-ias-computer.

So what's *new* about *A New History of Modern Computing*? Its expanded content reflects both the many things that have happened in the past two decades and the burgeoning secondary literature that's helped us think about old events in new ways. But if you place the book next to its predecessor the most obvious change is the narrative structure.

As we looked through Paul's earlier book we realized that its chapter structure was not holding up as well as Paul's analysis and selection of topics. We weren't always sure why the topics in a chapter were grouped together or why one topic followed another. In some places the chronology was confusing. Several things were dealt with in two separate places. We decided to impose an entirely new chapter structure on the existing material.

A strict chronological organization with five years covered in each chapter would be the easiest way to structure a book like this. Looking up the date on which something occurred would tell us which chapter it was part of. But to update the reader on what happened within each area between, say, 1975 and 1980, we would have had to constantly cycle between areas such as minicomputing, scientific supercomputing, business data processing, and personal computing. That structure would also have made it very hard to engage with computer users and use practices, which have become increasingly central to scholarly work on the history of computing during the past twenty years.

Here's what we did instead. Within each chapter one moves forward in time, anywhere between ten and thirty years from beginning to end. But the stories told in each chapter overlap in time with those told in other chapters.

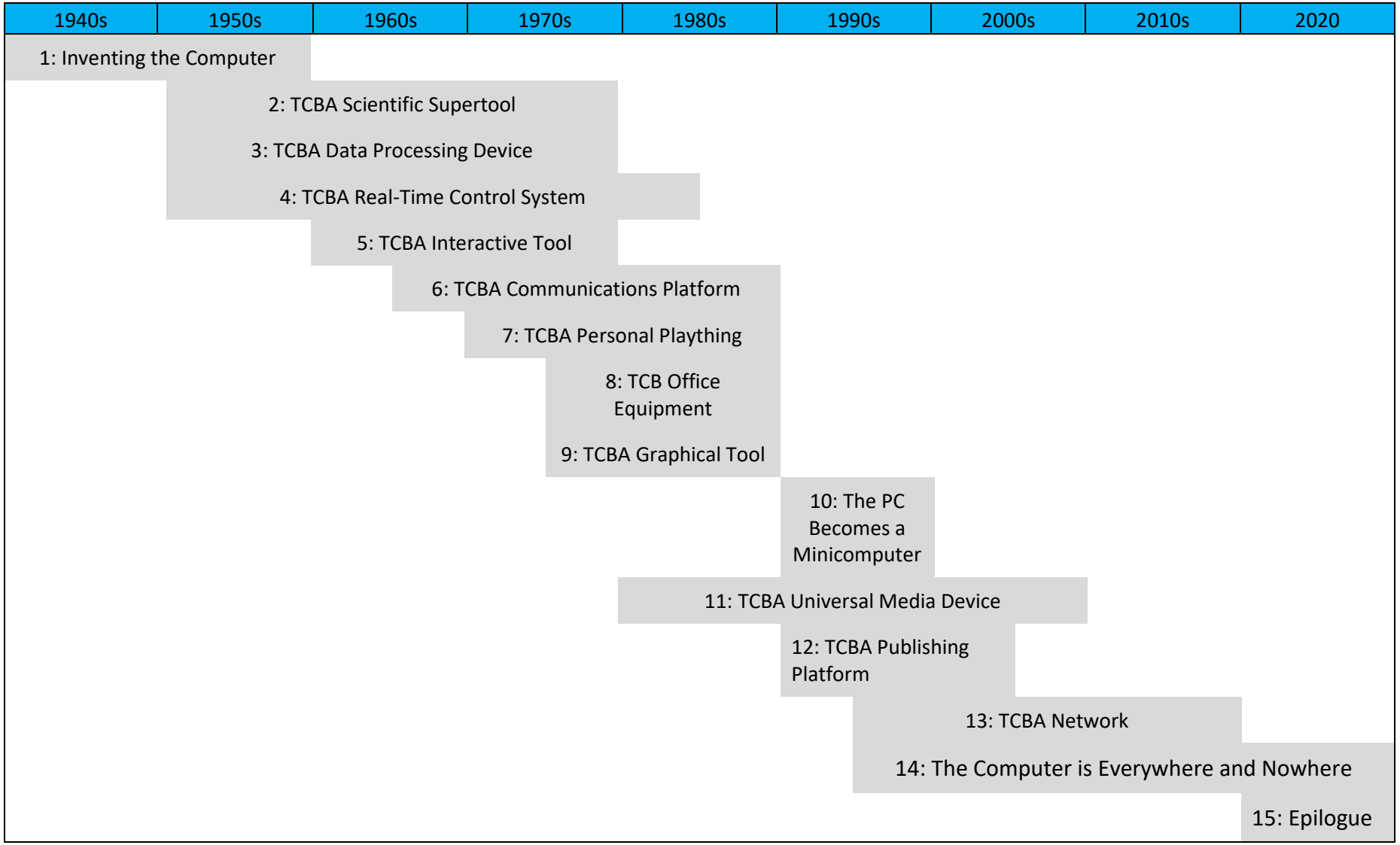

Table 1: Chapter titles and temporal coverage.
Most titles start with "The Computer Becomes a…" which is shortened here to TCBA.

There are three main sections to the book. Chapters two to six look at the development of computer from the 1950s to the 1970s. Within this section, a three chapter sequence explores the new capabilities of real time operation, interactive use, and interpersonal communication. Chapters seven to nine focus on personal computing in the 1970s and 1980s. The year 1990 serves as a kind of pivot point with only one chapter crossing that divide. The post-1990 chapters focus on the further development of personal computing, the

Every narrative needs a protagonist. Ours, as the table of contents makes clear, is *the computer*. There is not, and has never been, any such entity. Computers are very different from each other. As well as the machines themselves differing hugely, from video game consoles to supercomputers to smartphones, their users, producers, and associated social practices and cultural meanings are utterly different. From one chapter to the next we see profound discontinuities in users and applications. Even the kinds of user we are writing about shift. Some are specific institutional users with the ability to specify their needs, such as the Department of Defense. Others are communities of enthusiasts, individuals, or small businesses that exert influence through consumption patterns or bottom-up creativity. Some users are figments of the imagination of the designers of technologies that never find broad use.[15]

Our protagonist has a rich career full of adventures. In each chapter something happens to *the computer* and in most of them it "becomes" something. The very idea that one can structure a meaningful story around *the* computer might seem a ridiculous conceit. Yet on the level of technology and architecture there are very real continuities between the chapters. In our story, *the computer* is not just a piece of hardware but a cluster of technologies and techniques – hardware, software, architectural features, programming languages, ideas, and practices. This assemblage moves from one chapter to another, accreting capabilities as it goes.

In the first chapter *the computer* is born, or rather invented. Each subsequent chapter engages with a different domain of use within which it is remade. It enters one realm of human existence after another. In each realm it becomes an essential and transformative part of technical practice, making possible things that would not otherwise be possible. As it transforms practices it is itself transformed. *The computer* is taught new tricks and given new capabilities to meet the specific demands of its new environment.

The Histories of Computing(s)

There's a particular reason this project daunted me. I have repeatedly questioned whether it is possible to reconcile the urgent need for the history of computing to focus on users and applications with the creation of a single coherent history of computing narrative. In 2001 I wrote

> "The use of computer technology in a particular social space (such as the laboratory, office, or factory) cannot be addressed without also studying the earlier history of this setting, the people in it, and the objectives to which the machine is put. So, while coherent one-volume histories of the computer hardware industry and its technologies

[15] For example, the imagined users of Doug Engelbart's influential but never commercialized NLS system, as explored in Thierry Bardini, *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing* (Stanford, California: Stanford University Press, 2000).

> can be written, it seems unlikely that we can produce a single coherent narrative about the use of computers….."[16]

Returning to the theme in a 2011 review essay, I observed that "a one volume synthetic history that takes the use, work, and social dimensions of information technology seriously is probably impossible given the proliferation of computer technology in recent decades." [17] Thus I started work on the new history backed into an intellectual corner.

My path out of that corner was inspired by Michael Mahoney's discussion of a "communities of computing" approach in his classic paper "The Histories of Computing(s)."[18] Mahoney responded to my point about the impossibility of writing one volume computer use with a provocative claim:

> "As [James W.] Cortada, Haigh, and [Jon] Agar suggest, the histories and continuing experience of the various communities show that they wanted and expected different things from the computer. They encountered different problems and levels of difficulty in fitting their practice to it. As a result, they created different computers or (if we may make the singular plural) computings."[19]

Mahoney's declared interest was in the programming work needed to transform what he called the "protean machine" of the modern computer into a useful tool within each community. Our goals were broader and so we took the idea that "different computers" were created for and by different communities somewhat more literally. We were interested in how both hardware and software were reshaped to meet the needs of particular communities, and in how those innovations then became part of computing as experienced in other communities. Weaving those separate stories into a coherent overall narrative meant doubling down on a distinctive feature of Paul's earlier book: its engagement with computer architecture. Architectural features originally developed to meet the needs of one kind of user, for example, Los Alamos, eventually show up in smartphones even though Cray supercomputers, with their hand-wired circuits and exotic cooling systems, would never fit in your handbag.

Our chapters overlap a great deal in time. For example, the second, third, and fourth chapters cover much the same time period. In that sense are like the parallel arrows Mahoney drew (figure 1) to represent the histories of technology and practice in areas such as management, data processing, and military communications as parallel stories that are all eventually transformed by the introduction of computer technology.

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[16] Thomas Haigh, "The Chromium-Plated Tabulator: Institutionalizing an Electronic Revolution, 1954-1958," *IEEE Annals of the History of Computing* 23, no. 4 (October-December 2001):75-104, page 95

[17] Haigh, "The History of Information Technology", quote p. 441.

[18] Michael S Mahoney, "The Histories of Computing(s)," *Interdisciplinary Science Review* 30, no. 2 (2005):119-135.

[19] Ibid., here 127.

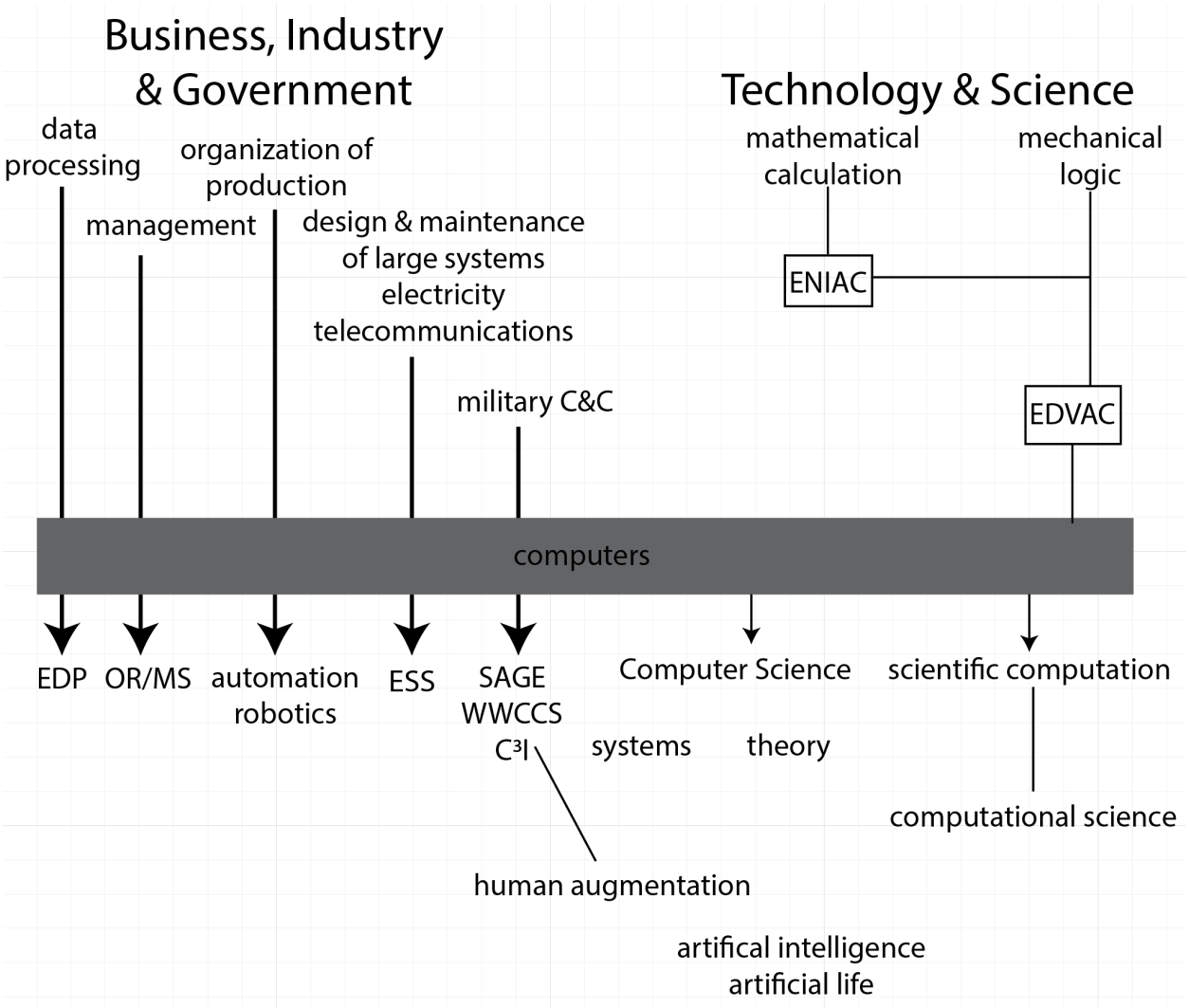

Figure 1: Mahoney's visual depiction of the "communities of computing" conception of the core history of computing story, in which stories of the adoption of computer technology unfold in parallel and largely independently.

Much of what happens in each chapter is specific to the needs of a particular community. For example, Chapter 4 explains how the specific needs of the SAGE air defense project led to computers so large that they filled the entire floor of a building, and how NASA's hopes that the space shuttle would be a reliable "space truck" led to the installation of five redundant flight computers in each orbiter, any one of which could have landed it. Neither approach would translate directly into other contexts. Yet many of the technologies developed for these real-time aerospace projects quickly become part of *the computer.* High reliability electronics, silicon chips, prioritized interrupts for real time operations, and computer graphics all made the transition from exotic novelties into core features of *the computer* as later introduced into homes and offices.

We haven't managed to square the circle by figuring out how to write a satisfactory one volume history of computer use. I still think that's impossible. The social and cultural histories of the computer have so many strong discontinuities between eras, social spaces, and nations that

there's little to be gained from trying to torture them all into a single volume. Only technologically grounded history can create enough of a substantive narrative connection to justify the exercise.

Each chapter in our book centers on a story that could, and indeed should, be told elsewhere as a book of its own. This would permit a different kind of narrative, focused throughout on a coherent set of users and applications. Such a book could explore the setting before the introduction of computer technology and look at a succession of technologies applied in that single space. Think, for example, of JoAnne Yate's *Structuring the Information Age* which looked at the life insurance industry through many decades and several technological eras.[20]

What we have, I hope, managed to design is a one volume history of computing that takes the interplay of use and innovation seriously by exploring the process in which the computer is successively remade through its encounters with different communities of users. In other words, *A New History of Modern Computing* does not aspire to comprehensively explain how "the computer changed the world."[21] It does aim to explain how specific aspects of the world changed *the computer*.

Inching Toward Universality

Any overview history of computing faces the daunting challenge of shifts over time in scale and perspective. In the 1940s perhaps a few hundred people worked directly with programmable electronic computers. Today most of the people in the world use smartphones daily. Their cost, physical form, modes of use, social and economic significance, and cultural meaning have changed beyond all recognition.

Many histories of computing written by computer scientists or mathematicians have positioned actual computers as physical instantiations of the "universal machine" described by Alan Turing in the 1930s. To them almost any machine able to branch could, with sufficient time and storage, duplicate the work of any other computer. In that sense, even ENIAC was universal back in 1946. From the viewpoint of practice, however, things look very different. ENIAC had a writable memory of only 200 decimal digits, was challenging to reprogram, filled around 2,000 square feet, and cost (allowing for inflation) many millions of dollars. It could output results only by flashing lights and punching cards. It ran numerical computations and simulations, mostly for military and atomic projects. In any meaningful sense it was a highly specialized machine.

Today, more than half of the people in the world use smartphones. They are universal in a practical sense because we use them for almost everything: step counting, chatting with friends, watching movies, listening to music, banking, finding sexual partners, shopping, and interacting with co-workers. Other computers, from supercomputers and cloud systems to embedded microcontrollers, collectively carry out a still broader range of tasks. Our book tells the story of that big transformation as the result of a series of smaller transformations. There was nothing natural about this. As several observers have noticed the seemingly scientific nature of Moore's Law hides the vast amounts of money, human labor, and incremental innovation that were

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[20] JoAnne Yates, *Structuring the Information Age* (Baltimore: Johns Hopkins University Press, 2005).

[21] That's (almost) the question that Tom Misa challenged the history of computing community to explain, Thomas J. "Understanding 'How Computing Changed the World'." IEEE Annals of the History of Computing 29, no. 4 (Oct-Dec 2007): 52-63.

needed to keep increasing transistor densities.[22] Now that heat dissipation issues, physical challenges, and the enormous cost of constructing next generation chip manufacturing facilities have slowed that advance we can better appreciate how exceptional this era was. The rapid proliferation of ever more powerful computers wasn't just an inevitable playing out of the universality inherent in a Turing machine.

We wanted to look systematically at the development of different modes of computing over time, not just at their moment of invention. That meant, for example, talking about how the IBM PC and Macintosh platforms evolved from the 1980s onward rather than just describing their initial introductions in 1981 and 1984 respectively. The fixation on invention over adoption and use is seen most clearly in Walter Isaacson's *The Innovators*, which despite its titular claim to be about innovation, the broad process by which new technologies become successful, actually has a narrow focus on invention.[23] Isaacson loses interest in technologies long before they move into the world and become consequential. He follows the development of programmable computers only into the early 1950s, the development of the microprocessor only as far as the Intel 4004 in 1971, the development of what becomes the Internet as far as 1973, and the development of web search up to 1998. His discussion of personal computing focuses overwhelmingly on the 1970s with brief asides on the IBM PC and the first Macintosh.

Back in 1988 Mahoney complained that the emerging scholarly literature "stops at the point where computing becomes a significant presence in science, technology, and society." Yet somehow popular histories of computing technologies stop the story of each technology well before that point.

Beginnings and Endings

As Pulp's Jarvis Cocker so memorably sang, "I don't know why, but I had to start it somewhere, so it started [slight pause] there."[24] We started in 1946, when the front page of the *New York Times* featured a computer called ENIAC built at the University of Pennsylvania. Paul's original book had also started in the 1940s, bucking the tradition of spending early chapters with Charles Babbage, with office machines, or with mechanical calculators.

Providing that long history has become increasingly hard now that computers have supplanted so many other technologies. Mahoney's diagram encapsulates his insistence that the parallel stories of the communities of computing should be told separately, looking in each case at their practices before and after the introduction of computer technology. We cannot hope in one book to do justice to the stories of all these domains of use. To follow the path of each community before and after the horizonal bar that Mahoney labelled simply as "computers" would take 14 books, not 14 chapters. Why talk about adding machines but not movie projectors; filing cabinets but not pinball machines; or astrolabes but not telephones? No single book has room to do justice to all those things, and ours is already big enough.

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[22] Cyrus C M Mody, *The Long Arm of Moore's Law* (Cambridge, MA: MIT Press, 2017). Ethan R Mollick, "Establishing Moore's Law," *IEEE Annals of the History of Computing* 28, no. 3 (July-Sept 2006):62-75.

[23] Walter Isaacson, *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution* (New York: Simon and Schuster, 2014).

[24] Pulp, "Common People," 1995.

The question "what is the history of computing the history of" cannot be given a single answer. To fill in the arc of history needed to frame the computer as, for example, as a business machine, is to forgo the opportunity to frame it in another way, for example, as a media device. The computer has become too many different things, been put to too many uses, and taken the place of too many other technologies.

When Paul wrote his book dominant computing platforms were shifting rapidly and figuring out which developments really mattered was very difficult. He acknowledged this in the introduction the second edition: "There is a finite time between sending a completed manuscript to the typesetter and the delivery of a book or journal article to the reader. When the subject is computing, Zeno's paradox takes control: enough happens in that brief interval to render what was just written obsolete."[25] Computing was changing so fast that no history could ever get to the present day, however hard its author tried to close the distance.

By the time we began work on the new book the story of *the computer* had begun to seem like something with a recognizable end as well as a clear beginning. Computers were big boxes with lights and switches, into which people plugged peripherals like disk drives, monitors, and keyboards. Over time the boxes got smaller and their capabilities changed, but *computer* was a fairly robust category from the 1940s all the way to the early 2000s. Even when laptops came along, people recognized them as miniaturized and portable versions of the computer that used to sit on or under their desks.

From the viewpoint of the computer scientist, there are more computers around than ever. Smartphones are computers, and so are televisions, tablets, thermostats, GPS systems and dozens of other things in cars, Fitbits, smart watches, cameras, and Bluetooth speakers. But nobody ever pulled out their cellphone to send a text and said "I need to do some computing" or invited a prospective sexual partner over to "compute and chill" with a streaming movie. The amount of time people spend using devices they conceptualize as computers is dropping. That's why the title of our final narrative chapter, which centers on the smartphone and other mobile devices, is "The Computer is Everywhere and Nowhere."

Technology has not stopped changing, but the innovations are coming mostly in new applications of the Internet and machine learning technologies. Today's big technology news stories still have a lot of drama: Will Uber ever become profitable? Can crypto enthusiasts find a compelling and legal application for their technology? Is the metaverse anything more than a multibillion dollar demonstration of the folly of letting founders exercise unfettered control over major public companies? Yet none of those questions need to be resolved for us to sketch the technology and platforms that underlie mobile apps, self-driving cars, and cloud-based social media platforms.

Scale and Scope

We began our project doing something authors often dread: reading Paul's reviews on Amazon. To judge from their comments, readers continued to enjoy the book, but were eager above all to see its story continued into the current century. A positive (four star) 2016 Amazon review called the book "a delightful read" nevertheless notes that the book's "closing date… seems to be a long time ago," so that topics such as the commercial Internet, smartphones, and digital

[25] Ceruzzi, Paul E. A History of Modern Computing (second edition). Cambridge, MA: MIT Press, 2003: ix.

photography are not addressed. The reviewer observes that "'communicating,' 'doing work' and 'having fun' are at the core of today's computer applications, and these central uses do not emerge from Ceruzzi's history of manufacturers and model numbers."[26] The reviewer issued us a number of challenges and the new structure of the book addresses them by bringing the book's coverage of computing fully up to date, and by restructuring the work around the co-evolution of computing platforms with new applications, from scientific computation to video games and personal media consumption.

Our first step was to set up the new structure as a hierarchy of headings and subheadings. We made a first effort on a clean sheet of paper. We then cross-referenced the new outline with Paul's existing text to see which topics were already covered and which would need to be written from scratch. Next we reassembled chunks of the existing text in the new structure. After this some chapters were already too long while others were largely empty. As we worked there was constant interplay between the "bottom up" development of the text and the "top down" refinement of the new outline.

A History of Modern Computing was written during the early- and mid-1990s. Its narrative stopped in 1995 with Netscape's IPO, but other than a few pages on the Internet, it did not have much to say about events after the mid-1980s. Even if we take 1945 as the origin of the first edition (the story nominally started a little later with the first Univac, but much of the first chapter consists of flashbacks) and 1995 as its end point then its text covered fifty years in 400 pages. Our new history runs through 2020 – a span of seventy-seven years. So, by this crudest of measures, we had at least 50% more history to cover. The second edition added a bonus chapter consisting of an essay on several important tends of the late 1990s: Linux, Java, the Microsoft antitrust trial, and the commercialization of the web. This now seems much more dated than anything else in the book, precisely because it dealt with material from which he had no historical distance.

The second edition of *A History of Modern Computing* covered forty years in 400 pages, or approximately 150,000 words. Should our replacement cover sixty years in 225,000 words to retain all the existing text and cover new development to a comparable level of detail? No. The existing text was already close to the limits of what readers and publishers could be expected to tolerate. And it wasn't just the last twenty years that needed attention. Even in the time periods covered by the earlier book we had a lot of new material to add. Only a few topics dealt with in that book have vanished completely from the new text, but many of them are appearing in new contexts. As in any area of history, from the vantage point of a different present we see new things in the past. The ARPANET was only briefly mentioned in Paul's original text. In the new one it is the centerpiece of a chapter called "The Computer Becomes a Communications Medium." However, we are also alert to the dangers of Whig history – the same chapter includes online services, bulletin boards, BITNET, USENET, Minitel, and the other forms of online communication that were more representative of computing practice in the 1970s and 1980s.

Excluding bibliography and index, our new book weighs in at around 187,000 words for a net gain of around 25%. That's not a small volume, but it does reflect several rounds of relentless

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[26] Review by Paul F. Ross, May 7, 2016. https://www.amazon.com/History-Modern-Computing/dp/0262532034/ref=mt_paperback?_encoding=UTF8&me=

cutting that eliminated many tens of thousands of words. Even portions based on material from Paul's earlier book were heavily trimmed and rewritten line-by-line.

New Topics

With respect to the history of computing technology, the book is as close to comprehensive as reasonably practical. There are hundreds of topics our readers would reasonably expect to turn up at some point in the narrative, each of which becomes an obligatory point of passage. Leave out Unix, OS/360, COBOL, or ENIAC and people will notice. To write the big story of computing is like being handed a bunch of jigsaw pieces and asked to figure out a way to fit them together into a plausible picture.

This time around there were many pieces to add to the jigsaw. As the Amazon review quoted above made clear, today's readers would also expect to encounter digital media devices, videogames and smartphones. The Commodore 64 home computer, which sold more units than any other desktop computer, was not mentioned in *Computer* or *A History of Modern Computing*.

When Paul wrote his book in the mid-1990s, he faced the challenge of writing a synthetic history of a gigantic and amorphous topic with an underdeveloped literature. So did Martin Campbell-Kelly and Bill Aspray when they wrote the first edition of *Computer*. I read it after I had done most of my graduate coursework but before I really delved into my dissertation research. The specific assortment of topics seemed idiosyncratic, but a little later when I spent a few days in the library methodically flipping through the two-decade run of *Annals of the History of Computing* I realized that the contours of that book closely followed that of the literature from which it had been synthesized. Things like Charles Babbage, SAGE, SABRE, ERMA, and the IBM System/360 were there not just because they were historically important, but also because they had been written about.

Paul relied less on the secondary literature, though parts of his book stick closely with stories told, for example, in the monumental IBM histories produced by participants.[27] In other places he drew on original research carried out for the book, or oral history interviews, to cover topics like the history of minicomputers, UNIX workstations, or SDS timesharing computers, which had not then been adequately treated in the secondary literature. A lot of good history appeared over the next 20 years, letting us put coverage of topics like Plato, SAGE, the Internet, and ENIAC on a stronger foundation by engaging with and summarizing the conclusions of that research.[28]

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[27] Charles J Bashe et al., *IBM's Early Computers* (Cambridge, MA: MIT Press, 1986) and Emerson W Pugh, Lyle R Johnson, and John H Palmer, *IBM's 360 and Early 370 Systems* (Cambridge, MA: MIT Press, 1991).

[28] Among the texts, many of them now classics, we leaned on heavily in improving coverage were Julien Mailland and Kevin Driscoll, *Minitel: Welcome to the Internet* (Cambridge, MA: MIT Press, 2017), Jonathan Sterne, *MP3: The Meaning of a Format* (Durham, NC: Duke University Press, 2012), Joy Lisi Rankin, *A People's History of Computing in the United States* (Cambridge, MA: Harvard University Press, 2018), Matthew G Kirschenbaum, *Track Changes: A Literary History of Word Processing* (Cambridge, MA: Harvard University Press, 2016), Janet Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), Paul N Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996), Yost, *Making IT Work: A History of the Computer Services Industry* and Nick Montfort and Ian Bogost, *Racing the Beam: The Atari Video Computer System* (Cambidge, MA: MIT Press, 2009).

We made the decision to cover events as close to the present as possible, and to cover each decade in roughly the same detail. The last five narrative chapters of *A New History of Modern Computing* consist almost entirely of events since 1990. Their topics are less familiar, neglected not just in Paul's original book and its main competitors but in many cases by the scholarly history of computing as a whole.

"The PC Becomes a Minicomputer," looks at the maturing during the 1990s of personal computer hardware and software to replace other computing categories such as graphical workstations. It begins with the limitations of MS-DOS computing before following the development of the PC platform from Windows 3.0 and the 386 through to Windows 2000 running on a Pentium III laptop. The speed of that development was quite remarkable and set a foundation for personal computing in the twenty years since. Intertwined with that are the stories of the RISC challenge to Intel and the evolution of the PC itself from compatibility with specific IBM models to a cluster of open standards maintained by industry groups. This story has not previously been told by professional historians, but it's a crucial pivot point in the history of computer technology.

"The Computer Becomes a Universal Media Device," looks at the digitization of media consumption, with the addition of multimedia capabilities and 3D graphics to conventional personal computers, the rise of on-demand streaming video, and the integration of embedded computers in digital cameras and digital audio players. Media theorists have written about many of these topics, so our contribution here is more to broaden the scope of the core history of computing narrative by integrating some of their findings than to break new ground for media studies.

"The Computer Becomes a Publishing Platform," focuses on the commercialization of the Internet and the rise of the World Wide Web as a universal platform for electronic publishing and online commerce. At a time when both *Internet history* and *Web history* often signify scholarly communities with little connection to the broader history of computing, our challenge was not just to cover the development of the Internet but to do so in a way that makes clear the benefits of taking a longer perspective. One of the benefits of starting in 1946 rather than 1991 is to uncover all the ways in which the Web rested on existing hardware and software infrastructures. These were shaped in turn by the academic context of the original ARPANET. In particular, the lack of integrated security and the lack of an inbuilt billing mechanism, both unnecessary in the original context, have had profound implications for things like spam, online fraud, and the devastation of the traditional news industry (and liberal democracy) when online publishing settled on an advertising-supported model.

"The Computer Becomes a Network," explores cloud computing and the remaking of the web into a universal front end for online applications of all kinds rather than a platform for electronic publishing. Web browsers essentially replaced the terminals of earlier generations as a way of rendering the dynamically generated output of software running in remote data centers. There's a lot being written about the cloud, but we follow historians such as Martin Campbell-Kelly by positioning this in the broader history of interactive computing (going back to timesharing and teletypes).

"The Computer Is Everywhere and Nowhere," looks at the growth of new, mobile networked computing platforms such as smartphones and tablets. These have largely subsumed the brief proliferation of specialized gadgets such as GPS receivers and personal digital assistants. Earlier

overview histories have had little or nothing to say about smartphones. Our aim was to contextualize these recent events in the longer history of computing rather than to attempt a definitive history of the smartphone.

These new chapters stretch the chronology of the core narrative of the history of computing. The Apple II, for example, appeared closer in time (1977) to the first Univac (1951) than we are to the debut of Windows 95. Yet earlier histories tended to put the Univac close to the beginning, look in comparative detail at the years between that and the Apple II, and then collapse everything from the 1980s to the present day into the last chapter or two. This is made apparent in table 2, which documents the point in the narrative at which the authors of several overview histories of computing placed some of the most prominent of the jigsaw pieces we mentioned above.

	Computer (3rd edition)[29]	*A History of Modern Computing* (2nd edition)	*How the World Got Into the Computer*	*A New History of Modern Computing*
ENIAC	4 of 12	1 of 10	2 of 6	1 of 14
Univac I	5 of 12	1 of 10	2 of 6	1 of 14
SAGE	7 of 12	2 of 10	4 of 6, footnote	4 of 14
IBM 360	6 of 12	5 of 10	5 of 6	3 of 14
DEC PDP-8	9 of 12	4 of 10	5 of 6	5 of 14
ARPANET	12 of 12	6 of 10	6 of 6	6 of 14
Unix	9 of 12	5 of 10	N/A	5 of 14
Xerox PARC	11 of 12	8 of 10	6 of 6	9 of 14
Apple II	10 of 12	8 of 10	6 of 6	7 of 14
IBM PC	10 of 12	8 of 10	6 of 6	8 of 14
Netscape	12 of 12	9 of 10	N/A	12 of 14
Windows 95	11 of 12	10 of 10	N/A	10 of 14
iPhone	12 of 12	N/A	N/A	14 of 14

Table 2: Chapters in which key technologies are introduced in the most recent editions of several overview histories of computing. The technologies are in approximate chronological order.

Our decision came with a cost. Whereas earlier chapters each have pages of citations to scholarly works, the last few muster only a smattering of citations and those mostly to newspaper and magazine articles. The new chapters will again be the quickest to go out of date and will need the most attention in any future revision as historians finally get to grips with personal computing, smartphones, and the Web.

[29] Late in the production of this chapter a fourth edition of *Computer* was published. It keeps the existing chapter structure largely as-is, but adds two new authors and a new section consisting of three chapters titled "Globalization," "The Interactive Web" and "Computing and Governance." These focus primarily on events since the 1990s and have a different character to the rest of the book.

Confronting Progress

Herbert Butterfield long ago warned against the dangers of the "Whig Interpretation of History," a caution against the construction of teleological narratives that has been taken to heart most strongly by historians of science. For example, if we believe that the big story of the history of computing is about explaining how we got to the iPhone we might be tempted to pick out historical details and arrange them in a path that runs straight to Cupertino, leaving out all the messiness of actual history. Butterfield warned that the danger was most acute for projects of the kind that we are undertaking: "There is a tendency," he warned, "for all history to veer over into whig history," but history becomes "more whig in proportion as it becomes more abridged."[30]

The challenge of avoiding a triumphalist narrative of progress looms particularly large because we are dealing with a technology that has effectively come to define progress in the modern world. Moore's Law is held up as a challenge to other technologies and as an explanation for all kinds of cultural and economic phenomena. Paul has even argued for Moore's Law as a reason to take seriously the unfashionable idea of "technological determinism."[31] Institutions and industries are compared to an idealized version of Silicon Valley and are criticized for making too little progress or being insufficiently disruptive. The dramatic advance of computer and communication technology is used to justify claims that society is being transformed by technology at an unprecedented rate, even though technological change and productivity growth in recent decades were slower than at any time since the Industrial Revolution.

The new structure gives us some scope to address this challenge. Over time our protagonist, *the computer*, really does become spectacularly cheaper, smaller, and faster even as it develops remarkable new capabilities. We can't deny that computer technology has followed a unique path, and it would strain even the most determined skeptic to deny that this constitutes a kind of technical progress. Within chapters, however, our narrative has space for paths not taken in computer architecture, business models, and applications. Entire classes of machine, like graphics workstations, minicomputers, and single processor supercomputers come and go from the narrative. Technologies introduced for one purpose find unexpected applications, and predictions for the future are usually wrong.

Neither is it at all clear that the social and economic changes facilitated by these new technologies will make the world a better place. The ending of the book underscores the outsized importance of Silicon Valley (and the Seattle area) to our lives and to the global economy. Most of the companies we talked about in our final chapters were headquartered within a short drive of the original Tesla factory. In the book's epilogue we look briefly at these changes and at role of the COVID pandemic in heightening our dependence on computer systems. As computers have expanded their roles so profoundly, they've come to matter in different ways. For most of the book, IBM was the only major global firm involved in the computer industry. The fate of firms like Apple and Commodore in the 1980s mattered greatly to their fans, but less so to the world as a whole. In contrast, the last few years have seen a growing "techlash" against firms like

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[30] Quoted in William Cronon, "Two Cheers for the Whig Interpretation of History," *Perspectives on History* (September 2012), https://www.historians.org/publications-and-directories/perspectives-on-history/september-2012/two-cheers-for-the-whig-interpretation-of-history.

[31] Paul E Ceruzzi, "Moore's Law and Technological Determinism: Reflections on the History of Technology," *Technology and Culture* 46, no. 3 (2005):584-593.

Facebook and the enormous power their leaders exert over our lives. The first five companies to reach market valuations of $1 trillion were Apple, Microsoft, Amazon, Alphabet, and Tesla.

Perhaps the style, indeed the genre, of historical writing must also change as the book progresses. It is almost a twist ending. While critics were of course warning about the perils of computer technology all along, our narrative mostly followed the development of computer technology without editorializing. Was our protagonist secretly evil all along? Some readers will wish we'd been focused on oppression and inequality all along, while others may wish we'd stuck with bits and bytes to the very end. But the change of focus does highlight the sudden realization of many in the computing field that they are no longer plucky underdogs and that it is past time to take some responsibility for the state of the world.

Imagined Readers

A book like *A New History of Modern Computing* has multiple readerships with their own distinct needs. The interests of these different readers pull in different directions. No single book could fully satisfy all of them, and indeed to inch closer to making one of them happy is likely to annoy others. Trying to accommodate all of them, as we did, runs the risk of creating a book that is a jack of all trades but master of none.

Paul's original book wasn't a textbook in the usual sense, with a high price tag, exercises, bullet points and supporting materials. But as history of computing classes are neither plentiful enough nor standardized enough to justify creation of an actual textbook it was often used as one. Indeed, the textbook market prompted MIT Press to request that Paul produce a new edition of this book. On the positive side this made it easy for us to publish the new history as a larger and heavily illustrated book than a typical academic monograph. It also naturalized the otherwise unusual practice of incorporating chunks of an old book into a new one. On the other hand, thinking of it as a textbook made the press assume it would be best launched as an expensive paperback and limited the potential to promote it more broadly.

One imagined reader was therefore a student assigned the book in class, as a first and perhaps only exposure to the scholarly history of computing. To these readers we owed a clearly told story without too much academic jargon that can be digested, with supplemental readings, in a single semester. We could assume little background knowledge of computing, or indeed anything else. I am currently teaching an undergraduate seminar with the book, which constantly reminds me of how much undergraduates don't know. To pick just from the topics discussed in chapter seven, most have not heard of Moore's Law, Microsoft BASIC, the Apple II, or the Velvet Underground though the *Oregon Trail* game seems to have almost universal recognition among Americans regardless of age. It also seemed important to trace the story close enough to the present to reach the technologies this audience could remember using.

Another imagined academic reader is a graduate student looking to do research in the history of computing or a topic that touches on it. Books like this are useful early in the process as a grounding in the bigger story and a gateway to relevant literatures. They help students identify research topics and shape their own work in response to stories that have already been told. As these more scholarly readers are more likely to follow up citations they would expect us to identify, summarize and cite important work. For these readers it was important for us to offer clear narratives within or against which new work could be situated. Our new book has already been citated in one dissertation just to point out that it doesn't mention a certain topic, continuing an important role served by Paul's book in legitimating dissertation research to fill its gaps.

A related group are scholars, perhaps already well established, working in areas such as science and technology studies or internet studies who find themselves in need of a quick grounding in the history of computing for a particular project. *A History of Modern Computing* currently has 1,946 citations tallied by Google Scholar. The citation pattern shows many citations from computer scientists, media scholars, economists, and business scholars.

The book might also be useful to historians focused on other areas of science or technology looking for a one-stop way to catch up with the history of computing literature, or for historians working in other fields entirely who need to engage in some way with information technology. These audiences might expect explicit historiographical discussion, narrative driven by people rather than machines, and a focus on the analytical categories foregrounded in their own subfields (knowledge, for example, or oppression). The demands of these historical traditions would be hard to square with each other, or with those of other readers.

On the less academic side, it's clear from their Amazon review pages that Paul's original book and our new one both found substantial non-academic audiences. From the reviews, many of those readers appear to be older people who worked with computers and lived though some or all of the history described. These readers have the most patience with technical details, and indeed are likely to complain if topics close to their heart are left out or, as is inevitable, simplified. Input from some of them while the book was in draft form helped us fine tune the book. I've been pleased by their generally enthusiastic response to the book, though of course being too close to the viewpoint of one's historical actors is not always a good thing. The most flattering responses have come from readers who say that we tell a story that was both startling and convincing, making them reassess the meaning of their own life experience.

Some of those veteran readers are computer scientists, though (as I discuss below) this is a history of computing practice, technology, and applications. It is only incidentally a history of computer science, in places where ideas and technologies nurtured within the discipline prove important in the broader world. As neither computer scientists nor computer users typically have much idea of how and when computer science has mattered to the broader world, looking for ways to make those connections seemed important.

How Else Could It Be Done?

Our goal, then, was to produce a comprehensive and scholarly narrative history of the computer that could work as an introduction for general readers, a textbook, or a one-stop solution for scholars looking to get a handle on how their specific topic fits into the broader story. Paul's original book worked in all three roles. It could be that today the time for such a book has past, and that in the future it will be necessary to aim squarely at one of the three audiences.

Public curiosity is today more likely to be satisfied by a trade press publication, such as Isaacson's *The Innovators* or by other books on allied topics such as the history of Silicon Valley or the history of Apple. Paul's original book was greeted by reviews in venues such as *Linux Journal, The Economist, New Scientist, PC Today, Nature, The Washington Post, Publishers Weekly* as well as a broad range of academic journals. This reflected unmet public curiosity in the topic. Our new book has sold respectably for an academic title but received no comparable attention. (Of course, in the intervening period the technologies we write about have obliterated the book reviewing ecosystem).

Neither does a book of this kind set the scholarly world alight. There are three journals focused on the history of information technology: *IEEE Annals of the History of Computing*, *Information and Culture*, and *Internet Histories*. None of them have reviewed it, though it did receive strongly positive evaluations for technical audiences in *SIAM News* and *Computing Reviews*. Two years after publication it has received only two reviews in historical journals. I was pleasantly surprised that *Isis*, a pillar of the history of science establishment, reviewed it. Victor Petrov gave it a very strong endorsement: "the standard by which other general histories are measured."[32] My own community, the Society for the History of Technology, was less impressed. Writing in its journal *Technology & Culture*, Martina Hessler complained that when it came to "conceptual issues" we "aren't tackling any at all."

A similar sentiment came up in one of the few tweets (technically a subtweet) that greeted the arrival of the book, posted by historian of science Patrick McCray. According to McCray, an unnamed "newly revised master narrative history of computing book… reverts in many places to – dare I say – internalist history of tech." The word "revert" is a revealing one, suggesting a faith in the unidirectional workings of progress that historians would be unlikely to sanction in any area except scholarship in their own field. Hessler similarly identified the question of "how much technical knowledge does the history of technology need" as one of three particularly pressing conceptual challenges we'd failed to address. I had throught this was something we tackled showing rather than telling, but to clarify: I believe that the unique trajectory followed by computer technology versus other complex mechanisms challenges historians to get to grips with what's happening inside the box.

The ongoing shift of gravity among people gainfully employed in writing the history of computing towards media and communication programs will likely accelerate the shift to other modes of historical writing. While some media traditions are more open than present-day history of science and technology to engagement with materiality and affordances, writing in these areas tends towards narratives that jump around in time and connect topics in ways that differ from the causal explanations favored by traditional historical approaches. The shift seems likely to emphasize cultural histories, particularly those where the underlying logic is exploring technology to explain intellectual trends, artistic movements, or cultural theories.

Even professional historians looking to tell big stories are more likely to do it by choosing a set of tightly focused chapters that taken together illustrate some kind of historical arc than by following our approach of attempting a comprehensive history that goes through dozens of required passage points and connects a lot of dots. One popular recent mode has defined projects along the lines of "A History of [Topic] in [Small integer] [Object Class]." Jacob Gaboury's recent *Image Objects* seems an exemplary application of this kind of approach to the history of computing.[33] Books that give snapshots over time in the evolution of programming practice, computing labor, user experience and so on might offer detailed case studies from different decades rather than connect all the intervening dots. Yet to select and contextualize their examples the authors of such narratives would need deep knowledge, so I hope our own book will be a useful resource in their creation.

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[32] Victor Petrov, "Review of A New History of Modern Computing," *Isis* 114, no. 1 (2023):219-220.

[33] Jacob Gaboury, *Image Objects: An Archaeology of Computer Graphics* (Cambridge, MA: MIT Press, 2021).

The Missing Chapters

For the rest of this essay, I'll be focusing largely on what we didn't do in the book and why we didn't do it. This might seem eccentric, but from my perspective any book is an engineering project that involves a set of inescapable trade-offs. This is clearest in a big and broad book like ours. Anyone writing a review is likely to have two impulses: to complain about the length and to confront us with a list of important topics we left out. Something I took from my engineering training was the importance of including in the specification for a project an explicit statement of the goals it will not attempt to meet. In this case I think it's instructive to give a sense of how we approached those trade-offs. What would we have included if we had space, if we were better qualified or had a secondary literature to draw on, or if we had a little more historical distance? When we took one perspective over another, was it because we were blinkered or because we couldn't figure out how to integrate something important into the structure of the book?

We chose the stories told in the book to give us the materials we needed to make sense of the development of computer technology. Inevitably we left out many of the communities and contexts of computer use. Hessler complained that the book shirked the "essential" task of including the history of robotics and AI, through which "computers have started to perform inherently physical activities… since the 1980s."[34] If we could squeeze in another chapter and had the secondary sources to base it on, a chapter titled "The Computer Becomes an Industrial Control Technology" would indeed cover an important application area. From the viewpoint of the development of the core features of *the computer*, however, a chapter on industrial automation and robotics would have been duplicative since chapter four, "The Computer Becomes a Real Time Control System" explores the processes by which computer technology was remade from the 1950s onward to control air defense systems, missiles, planes, and space probes. These are the same affordances required for industrial control.

Looking at the burgeoning literature on the history of computer security, I am beginning to imagine a chapter called "The Computer Becomes Mostly Secure and Highly Reliable." This would combine the history of computer security, an important field we barely mention, with the history of fault tolerant systems, redundancy, transaction processing, and efforts to produce reliable, bug-free systems. This chapter would give another opportunity to show ways in which work by computer scientists on techniques like model checking and the creation of software development methodologies has had a real world impact. It would also look at the development of the hacker as a cultural role. In any revised version of the book this chapter would fit well because of our focus on the creation of core capabilities that become part of the standard stacks of computer technology.

One could go on forever imagining new chapters, but crypto enthusiasts would no doubt bemoan the absence of a chapter called "The Computer Becomes Money." We could certainly tell the story of computerized banking infrastructures, from ERMA through ATMs, credit card networks, the push for a "cashless society" (which I've written about elsewhere), electronic payment systems, and so on.[35] But despite the huge wave of crypto hype it's not yet clear that

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[34] Martina Hessler, "Review of A New History of Modern Computing, by Thomas Haigh and Paul E. Ceruzzi," *Technology and Culture* 63, no. 2 (April 2022):580-581.

[35] Bernardo Batiz-Lazo, Thomas Haigh, and David Steans, "How the Future Shaped the Past: The Case of the Cashless Society," *Enterprise and Society* 36, no. 1 (March 2014):4-17.

cryptocurrency will ever find real applications beyond crime and fraud. Bitcoin itself seems entirely and irredeemably useless; blockchain technologies more generally may one day find applications but so far haven't. We just don't yet have enough historical distance on this story.

The contributions of the artificial intelligence community to computing practice are real but consisted, until recently at least, primarily of developments in computing infrastructure, algorithms, and so on rather than through the creation of thinking machines. One prominent AI researcher described the story of his field as "a history of failed ideas."[36] If we did add a chapter on twentieth century AI the most obvious title would be "The Computer Fails To Become a Thinking Machine." The recent proliferation of AI-branded automatic learning systems is already reshaping the capabilities of computer technology and any future revision of our book will have to deal with this technology, though at present the technologies and applications are changing so rapidly that no history could hope to properly document them. Artificial intelligence deserves its own overview history, and in fact I am currently writing a concise history of the topic which I see more as an intellectual brand than an historically stable set of technologies.

This Is NOT the History of Computer Science

AI would have an important part in any broad history of computer science, but ours is a history of computer technology and use. Let me explore that distinction. What Paul and I tried to produce is a history of computer technology and practice that is engaged with understanding how computer systems work, meaning that we talk about computer scientists only when their work leads directly to changes in computing practice. Donald Knuth famously complained that the shift of "historians of computer science" away from technical material had reduced him to tears.[37] My response then was that very little work on the history of computing actually fell into that category of "history of computer science," because neither the history of science community nor the computer science community could offer a plausible career path to somebody who identified thusly.[38] On the copy of the new history I sent to Knuth, I wrote "This is not the history of computer science, but I hope you like it anyway."

There have been no broad histories of computer science or scientific computing. Princeton historian Michael S. Mahoney spent many years contemplating the writing of a history of theoretical computer science but produced only a set of densely suggestive essays.[39] Instead the history of computer science has been told only in fragments where it touches other stories such as the development of biomedical science, the Internet, the Association for Computing Machinery, programming work, bioinformatics, computer graphics, missile defense, computational support for natural science, logical inscriptions, automated proof, artificial

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[36] Michael Wooldridge, *A Brief History of Artificial Intelligence: What It Is, Where We Are, and Where We Are Going* (New York: Faltiron Books, 2021).

[37] Donald E Knuth and Leonard Shustek, "Let's Not Dumb Down the History of Computer Science," *Communications of the ACM* 64, no. 2 (February 2021):33-35. For Knuth's full talk, see https://www.youtube.com/watch?v=gAXdDEQveKw.

[38] Thomas Haigh, "The Tears of Donald Knuth," *Communications of the Acm* 58, no. 1 (Jan 2015):40-44.

[39] Michael S Mahoney and Thomas Haigh (ed.), *Histories of Computing* (Cambridge, MA: Harvard University Press, 2011).

intelligence, or timesharing systems.[40] Though the last decade has seen a move towards technically engaged history, most of this work has focused on the two decades immediately prior to the firm establishment of computer science as a discipline in the mid-1960s.[41] With the exception of several studies of funding agencies, little has been written about the era in which computer science did exist.[42] More scholarly attention has been paid to the meaning of Soviet efforts to conceptualize computer science as part of cybernetics than to the core story of the growth of computer science in the US. [43]

A history of computer science that took an approach comparable to the one we took in the new history would look at the growth of the academic displine, leading university programs, key areas of research, changes in career patterns and funding, relations between industry and academia, and above all at the rise and fall of areas like artificial intelligence, computer graphics, computer architecture, and numerical analysis within the loose federation of research

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[40] Joseph November, *Biomedical Computing: Digitizing Life in the United States* (Baltimore, MD: Johns Hopkins, 2012) Abbate, *Inventing the Internet* Nathan Ensmenger, *The Computer Boys Take Over: Computers, Programmers, and the Politics of Technical Expertise.* (Cambridge, MA: MIT Press, 2010) Hallam Stevens, *Life Out of Sequence* (Chicago, IL: University of Chicago Press, 2013) Gaboury, *Image Objects: An Archaeology of Computer Graphics*, Rebecca Slayton, *Arguments that Count: Physics, Computing, and Missile Defense, 1949-2012* (Cambridge, MA: MIT Press, 2013) Atsushi Akera, *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S. Cold War Research* (Cambridge, MA: MIT Press, 2007) Thomas J Misa, ed., *Communities of Computing: Computer Science and Society in the ACM* (San Rafael, CA: Morgan & Claypool (ACM Books), 2017) Donald MacKenzie, *Mechanizing Proof* (Cambridge, MA: MIT Press, 2001). AI has been a boom area recently, with completed dissertations from Stephanie Dick, Jonnie Penn, Xiaochang Li awaiting publication as books and many more dissertations currently underway. Its literature seems destined to substantially outweigh work framed as the history of computer science, even though AI has intellectually and institutionally existed primarily as a subfield of computer science.

[41] For example: Thomas Haigh, Mark Priestley, and Crispin Rope, *ENIAC In Action: Making and Remaking the Modern Computer* (Cambridge, MA: MIT Press, 2016), Liesbeth De Mol, Martin Carlé, and Maarten Bullynck, "Haskell before Haskell: An Alternative Lesson in Practical Logics of the ENIAC," *Journal of Logic and Computation* 25, no. 4 (August 2015):1011-1046, Mark Priestley, *Routines of Substitution: John von Neumann's Work on Software Development, 1945-1948* (Cham, Switzerland: Springer, 2018), David Nofre, Mark Priestley, and Gerard Alberts, "When Technology Became Language: The Origins of the Linguistic Conception of Computer Programming, 1950-1960," *Technology and Culture* 55, no. 1 (January 2014):40-75, David E Dunning, "The Work of Writing Programs: Logic and Inscriptive Practice in the History of Computing," *IEEE Annals of the History of Computing* 43 (Oct 2021):27-42. Not to mention work focused on earlier forms of computation, such as Matthew L Jones, *Reckoning with Matter: Calculating Machines, Innovation, and Thinking about Thinking from Pascal to Babbage* (Chicago, IL: University of Chicago Press, 2016) and many books on Alan Turing and John von Neumann, whose work was foundational to computer science but were not themselves ever part of the discipline.

[42] Funding-centric histories include Alex Roland and Philip Shiman, *Strategic Computing: DARPA and the Quest for Machine Intelligence* (Cambridge, MA: MIT Press, 2002), Arthur L Norberg and Judy E O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (Baltimore: Johns Hopkins University Press, 1996) and Peter A Freeman, W Richards Adrion, and William Aspray, *Computing and the National Science Foundation, 1950-2016* (New York: Association for Computing Machinery, 2019). Sam Franz, a graduate student at the University of Pennsylvania, is looking squarely at the disciplinary evolution of computer science but as I write has yet to publish.

[43] On Soviet cybernetics, see Benjamin Peters, *How Not to Network a Nation: The Uneasy History of the Soviet Internet* (Cambridge, MA: MIT Press, 2016), Slava Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics* (Cambridge, MA: MIT Press, 2002), Ksenia Tatarchenko, "'A House With the Window to the West': The Akademgorodok Computer Center (1958-1993)," (Princeton dissertation, 2013).

communities that calls itself computer science. No such history exists. The closest thing we have, useful but schematic, comes from a computer scientist rather than a professional historian.[44]

Why are there no overview histories of computer science? Let me point to the *science* in computer science. In the US, the histories of science, technology, and business are separate communities with their own journals and conferences (albeit with some overlap in membership). Of the three, the history of science is the highest status field, with the clearest potential path to academic employment, the strongest institutional support, and the clearest connection to elite institutions. In contrast, authors who have produced broad scholarly histories of computing technology and industries, such as William Aspray, Martin Campbell-Kelly, JoAnne Yates, James Cortada, Paul Ceruzzi, and Jeffrey Yost do not hold faculty positions in elite history or history of science programs. Like me, they identified more with the history of technology and business than with the history of science. While historians of science often interpret their mandate to apply broadly across *technoscience*, authorizing them to write about technology and business, the reverse is rarely true. Historians of technology are likely to leave the core narratives of scientific disciplines to others. [45]

Even a historian of twentieth century science with no interest in computing itself might be drawn to questions posed by the federated nature of computer science, its assemblage from a scattered array of disciplinary traditions, its relationship to computer technology and practice, and its rise to become one of the most popular fields of undergraduate study. I'm not close enough to the history of science community to explain with confidence why its members have not told these stories. My impression is that the history of science long ago shifted its emphasis away from ploddingly comprehensive histories of disciplines, professional societies, or academic departments and towards more intellectually exciting studies of culture and epistemology. Historians of science are today unlikely to identify themselves as historians of particular scientific disciplines. Those transitions mirrored a more general shift within the historical profession during the 1980s towards richly detailed, narrowly drawn studies that uncovered the agency of overlooked actors and argued against simplistic generalizations. For topics such as the history of evolution, quantum mechanics or the scientific revolution where well-trodden narratives were ripe for reinterpretation the new approaches worked well. Yet because scholarly incentives no longer rewarded the production of comprehensive narrative histories of scientific disciplines there was never a grand narrative of the history of computer science, or any of its constituent communities, for ambitious young scholars to audaciously undermine on their way to tenured positions at great universities.[46]

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[44] Matti Tedre, *The Science of Computing: Shaping a Discipline* (New York, NY: CRC Press, 2015).The history of computer science literature is reviewed in Stephanie Dick, "Computer Science", in *A Companion to the History of American Science*, ed. Georgia M Montgomery and Mark A Largent (Malden, MA: Wiley-Blackwell, 2016):55-68.

[45] But if historians of science also write about technology, what grounds do I have for saying that they do not by this very act become historians of technology? In a sense they do, but for the purpose of demarcating the two social communities I'm crudely conceptualizing historians of science as people who attend the History of Science Society and publish in journals with science in the name and historians of technology as people who attend the Society for the History of Technology meeting and publish in journals with technology in the name. Some scholars are both, of course.

[46] Something similar stymied Mahoney's efforts to write the history of theoretical computer science. In introducing his papers I noted his debt to Thomas Kuhn, his dissertation advisor, and observed that Kuhn's approach was hard to

I've also heard it said that the history of science is increasingly focused on contemporary history and on making explicit connections with present-day controversies. To the extent this is true, we might expect it to follow science studies in focusing disproportionately on hot topics, such as AI today or nanotechnology a decade ago, rather than bigger long-term narratives. Particularly given the difficulty in producing big narratives without a large mass of more specialized studies to synthesize.

Globalizing the History of Computing

The US will, naturally loom large in any overview history of computing. It installed far more computers in the 1950s than the rest of the world combined, and in later decades US firms such as IBM, DEC, Microsoft, Apple and Google exerted an outsize impact in shaping the hardware and software platforms used worldwide. Any history concerned primarily with explaining where widely used technologies come from must grapple with this. Paul's existing text included important case studies of US-based user organizations such as NASA and the IRS, which we recycled for the new book. Some of these could have been replaced with non-US examples, as David Gugerli did in his recent book, though Gugerli's overall narrative appeared to be a universal one illustrated with US and German examples.[47]

Back in 2011 I was a little snarky about the conflation of global and American narratives in the history of computing:

> American scholars tend to view the history of information technology as a fundamentally American narrative. The US is the only country with a sufficiently central role in most of areas of information technology that a coherent (if skewed) overall history of computing can, and often has, been written with minimal reference to the world outside its borders. There are a few Englishmen who force their way into the narrative: Charles Babbage, Alan Turing, the teams behind the Manchester Mark 1 and the EDSAC, the LEO group that pioneered administrative computing, and Tim Berners-Lee. Konrad Zuse flies the flag for Germany. Jacquard's automatic loom earns France a paragraph somewhere in an early chapter. But these can be dismissed in passing as brilliant figures whose seminal technical accomplishments quickly passed into the hands of Americans for practical exploitation. The history of personal computing, in particular, is told by Americans entirely without reference to the existence of a world beyond the oceans, or in most cases beyond the Valley.
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> Historians based in the United States have therefore been much less likely than those working in other countries to attempt to isolate peculiarities of their own national experience or relate the development of information technology industries to the influence of government policy…. Scholars in other countries have tended to focus on

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apply to the history of computing science because of the lack of existing written historical narratives. Mahoney "wrote as if he had in mind an audience for whom the broad outline of early computer science, its theorists, ideas, and milestones, were already familiar. Much is alluded to rather than explained. Instead Mahoney worked to challenge our presumed assumptions about how all these things fit together, disrupting and rearranging a received narrative that has, alas, never been written in the first place…." Haigh, Thomas, "Unexpected Connections, Powerful Precedents, and Big Questions: The Work of Michael Sean Mahoney on the History of Computing", in *Histories of Computing*, ed. Haigh Thomas (Cambridge, MA: Harvard University Press, 2011):1-18.

[47] Gugerli, *How the World Got into the Computer*.

> national narratives, generally framed with perceived differences between local developments and those in America.[48]

Given the opportunity to create a new kind of history of computing narrative what did we do? In all honesty, the US story remains our default, perpetuating an awkward hybrid of national and global history. We go overseas more often than previous overview histories, but we still make the journey only when necessary to illustrate the origins of some important new application of computer technology. For example, we visit the UK for LEO, the early computers at Cambridge and Manchester, the Sinclair and Acorn machines of the 1980s and the BBC's computer literacy project, ARM, and so on. Continental Europe shows up mostly for CYCLADES, Minitel, and the World Wide Web while the USSR, which contributed far more to computer science than computer technology, exists mostly as an off-stage bogeyman to justify US government spending. East Asia shows up later in the narrative, as the new home of microelectronic manufacturing, a source of challenges for text input and display and, eventually, as the world's most important ecommerce marketplace. Africa is mentioned only very briefly, as a pioneer of cellphone-based financial transactions. India appears only as a growing center for the outsourcing of software development. As the secondary literature matures I hope that authors will document other unique forms of computer use in non-Western contexts.

Any future iteration of our book might most obviously benefit from the inclusion of a chapter called "The Computer Becomes Globally Inclusive" or perhaps "The Computer Becomes Non-Western," Early machines were hardcoded to Latin character sets, with minor national differences. Representing Greek, Cyrillic, Hebrew, and in particular Chinese and Japanese characters was a major challenge, central to the accessibility of computers and smartphones to most of the world's population (or, viewed from another perspective, the survival of those modes of writing in an Internet world).[49] Its resolution was tied to fundamental changes in user interface technology, graphics, hardware capabilities, and software infrastructures. Hints of that story show up occasionally in our book but it would fit well with our focus on the interplay between users and core capabilities and should be told properly.

Centering our book on the emergence of core computing technologies and platforms compounded the issue. Several countries had significant national mainframe and minicomputer industries that go unremarked on in our book. Early computers were hand built in the USSR, Israel and Australia, while Western-built machines were exported to Africa, Asia and the Eastern Bloc from the 1960s onward. Yet the existing literature does not demonstrate that these machines introduced important new architectural features to computing, or that, for example, Western and South American applications of mainframes and minicomputers created new capabilities. For example, two of the most acclaimed books on non-Western computing are framed around systems that never came into being. Eden Medina looked at Chile's doomed dream of building a management information system to facilitate cybernetic socialism, while Ben Peters asked why

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[48] Haigh, "The History of Information Technology".

[49] Thomas S. Mullaney, "QWERTY in China: Chinese Computing and the Radical Alphabet," *Technology and Culture* 59, no. 4 (October 2018):S34-S65.

the USSR didn't build an Internet. Neither absence offered an obvious hook for integration into our narrative.[50]

The Missing Perspectives

As well as missing chapters, we might think productively about missing perspectives. An obvious omission, and one I hope to remedy in any future edition, is discussion of the environmental costs of computing. Historians of computing have traditionally had little to say on computer manufacturing, or, following the material components of computer systems up the supply chain, about the creation of chips and other components or the mining, refining, and synthesis of the materials that go into those components. But work on the environmental cost of the materials that go into iPhones and batteries is starting to pile up, as is analysis of the environmental degradation of Silicon Valley back when silicon chips were made there. The materiality and geopolitics of semiconductor production have recently returned to the headlines, making me uncomfortably aware that we had little to say about those topics after the 1970s.

Aside from an apocalyptic epilogue set amidst the techlash and the pandemic, we generally avoid overt editorializing about the social consequences of the adoption of computer technology. Astute readers will notice the prevalence of military and aerospace applications in the early chapters, driving everything from the invention of the modern computer to the SAGE project, Minuteman missiles, and the earliest markets of silicon chips. Yet we did not, for example, include discussion of the role of statistics and big data in racist social and criminal justice policies or the political agendas of US computer companies. Neither do we get far into discussing the role of IT in economic transformations that have increased inequality. As these topics are explored in the historical literature I hope to find ways to integrate them more fully into any future revision of the book.

Gender, race, and sexuality are becoming increasingly central to the history of computing. We acknowledged them more fully than previous overview histories, but that's a low bar. For example, we discussed gendered labor in data processing, around the ENIAC project, and in the computerization of office work. We included Grindr as an example of location-based smartphone applications built on cloud infrastructures. Race is even less prominent, though the social historian in me did feel obliged to note racial disparities in the adoption of personal computers and the Internet in American households. Given our organizing principles such asides inevitably work more as garnishes than structural elements.

This absence is a little wrenching for me. My most frequently taught class is an undergraduate survey on the history of race and health in the US. I regularly teach another on the history of capitalism. Race, class, and gender are structural to the narratives told in both classes, just as they have been to mainstream scholarly understandings of US history for many decades. And yet, here I am as the lead author of a big heavy book which is by no stretch of the imagination structured around class or race and is only intermittently concerned with gender. There is a trade-off though. While racial, ethnic and caste-based discrimination is found around the world and throughout history, the specific history and construction of race in the US is distinct even from that of other rich countries. Histories of gender and sexuality have likewise played out differently

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[50] Peters, *How Not to Network a Nation: The Uneasy History of the Soviet Internet*; Eden Medina, *Cybernetic Revolutionaries Technology and Politics in Allende's Chile* (Cambridge, MA: MIT Press, 2011).

around the world. Aligning the structure of a book more closely with the American history of those categories would push against the impulse to globalize the history of computing. I do not see how both could be accomplished by the same book.

Even the communities of computing that we do explore may appear abstractly, as the sources of new requirements rather than fully depicted social spaces. We do have a chapter "The Computer Becomes Office Equipment" but Hessler faulted it for failing to offer a "well-rounded description of the transformation in office work" by looking at different appropriations of the computers by office workers, resistance by workers, and so on. To that I must plead guilty as charged. I had dealt with all those issues in an earlier paper but found it structurally impractical to engage with them in synthetic book of this kind.[51]

Neither did we get to grips with the overwhelming whiteness of our cast of characters. There's no obvious template for dealing with this. We could comment frequently on the sexism, privilege, racism, heteronormativity, masculinity, and whiteness of the communities we are describing. Joy Rankin does this in her book on the history of educational timesharing usage, and the effect is bracing.[52] These asides situate her characters in the larger narratives of US history and undercut heroic narratives around computer technology. Yet emulating this might be hard to integrate with our structural focus on the development of computer technology. Rankin's asides function more as critical judgements on the dominant cultures of post war America, which permeated computer-using communities, than as insights into why computer technology was shaped in one direction over another. Fully integrating the stories of technological and cultural development is a daunting challenge, and one that probably needs to be met by a range of specialized studies before it can realistically be attempted in an overview history.

Embodiment is an interesting category, and one that makes me realize how little concerned narratives around the history of computing have usually been with the biological materiality of human existence. This perspective has been central to the work of Elizabeth Petrick on the history of accessibility in computer interfaces and I was struck by the response of my students to Laine Nooney's recent essay on ills wreaked on human bodies by the demands of computer technologies.[53] Embodiment has an obvious connection to the history of gender and sexuality. Yet we all have bodies, which differ of course but as variations on a common theme, so perhaps working them more systematically into the history of computing might offset both the persistent hostility to the realities of human existence found in geek culture and the difficulties of writing history across lines of class, race, gender, nationality, and sexual orientation.

Centering the Computer – Is That Bad?

The ongoing protagonist that ties together the many chapters of our book is *the computer* itself. If, as discussed above, *the computer* now seems to belong more to the past than the future, how stable is *computing*, the putative object of study for the *history of computing*? And should the

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[51] Thomas Haigh, "Remembering the Office of the Future: The Origins of Word Processing and Office Automation," *IEEE Annals of the History of Computing* 28, no. 4 (October-December 2006):6-31.

[52] Rankin, *A People's History of Computing in the United States*.

[53] Laine Nooney, "'Have Any Remedies for Tired Eyes?' Computer Pain as Computer History", in *Abstractions and Embodiments: New Histories of Computing and Society*, ed. Janet Abbate and Stephanie Dick (Baltimore, MD: Johns Hopkins University Press, 2022):416-433.

history of computing community follow Eden Medina's influential suggestion that we "decenter the computer"?[54]

It is of course true that the history of computing should be far more than the study of computer hardware, and that examinations of the historical use of computer technology can and should be structured around people, cultures, institutions, practices, and the like. The *history of computing* identity was chosen to be broader than the *history of computers*, which already sounded dry and trivial in the 1970s. Most histories of computing explore specific, focused topic with the aim of better understanding aspects of human life rather than improving our understanding of computer technology.

As a verb, *computing* mandates attention to the use of technology, but it has no resonance with public or humanities audiences that might have some interest in history but don't think of what they do with their phones, games consoles, or cars as *computing*. In truth the rhetoric of *computing* never resonated far beyond the professionalization discourse of computer science. For organizations like the ACM and the long-defunct AFIPS, computing worked as an inclusive description of computer use that spanned many otherwise distinct human domains. The involvement of these groups the history of computing has ebbed, and even computer scientists are highly specialized these days and thus less likely to offer pronouncements about computing as a whole.

The history of computing never institutionalized very successfully. The few institutions founded to pursue it include the journal *IEEE Annals of the History of Computing*, SIGCIS, the Computer Museum (replaced by the Computer History Museum), the Charles Babbage Foundation (now the IT History Society) and the Charles Babbage Institute. In one way or another, each has broadened its scope beyond history, struggled to stay in business, or both. Given that many of the institutions most associated with the history of computing are decentering not just computers themselves but also computing and history, I suspect that *historian of computing* is not a scholarly identity that's ever going to loom particularly large.

Most historians of computing, broadly conceived, who have found gainful employment in recent years have done so in media or communication programs where foregrounding media theory or currently fashionable objects of study has far more professional utility than aligning oneself with the study of computing. The same is true for those who have won recognition from inside our professional community, for example the recent winners of the book (Computer History Museum Prize) and article (Mahoney Prize) awards from SIGCIS. There must already be more people in the world who identify themselves primarily as historians of video games, algorithmic inequality, platforms, Silicon Valley, artificial intelligence, and big data than as historians of computing.

With respect to *A New History of Modern Computing*, I hope you have been convinced that exceptional trajectory of computer technology from 1945 to 2020 justifies at least one book centered on the computer and the ways in which its affordances developed over time. But should the history of computing as a whole center the computer? In a way, it is the willingness to do so

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[54] Eden Medina, "Forensic Identification in the Aftermath of Human Rights Crimes in Chile: A Decentered Computer History," *Technology and Culture* 59, no. 4S (2018):S100-S133. The concept was discussed in Janet Abbate and Stephanie Dick, "Introduction: Thinking with Computers", in *Abstractions and Embodiments: New Histories of Computing and Society*, ed. Janet Abbate and Stephanie Dick (Baltimore, MD: Johns Hopkins University Press, 2022):1-19.

that might cause someone to identify as a historian of computing. The thing that defines the scope of the history of computing is, unavoidably, the movement of *the computer* into new social spaces over time.

Historians of all kinds who work on our current era will have to grapple with the role of information technology in the stories they tell. Given that computer technology today mediates so much human activity, the potential scope of the history of computing edges ever closer to being the history of everything. But not even I believe that a significant fraction of them will ever choose to identify as *historians of computing*. For example, Medina's own MIT home page identifies her as a scholar of the history of science and technology in Latin America. It includes the words "history of computing" only to describe the Computer History Museum Prize.[55]

The small group of people who do identify as historians of computing is, by definition, a community constituted by our shared connection to the computer even if we often decenter it in our individual studies. We have the collective responsibility of interpreting computer technology in ways that can inform the work of the much larger population of historians who need to understand its role in their own narratives. As for those broader historical communities, they cannot decenter something that they would never have contemplated centering in the first place.

[55] https://edenmedina.mit.edu/