# Becoming Universal: A New History of Modern Computing

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MIT Press, September 2021.Work began in 2016.

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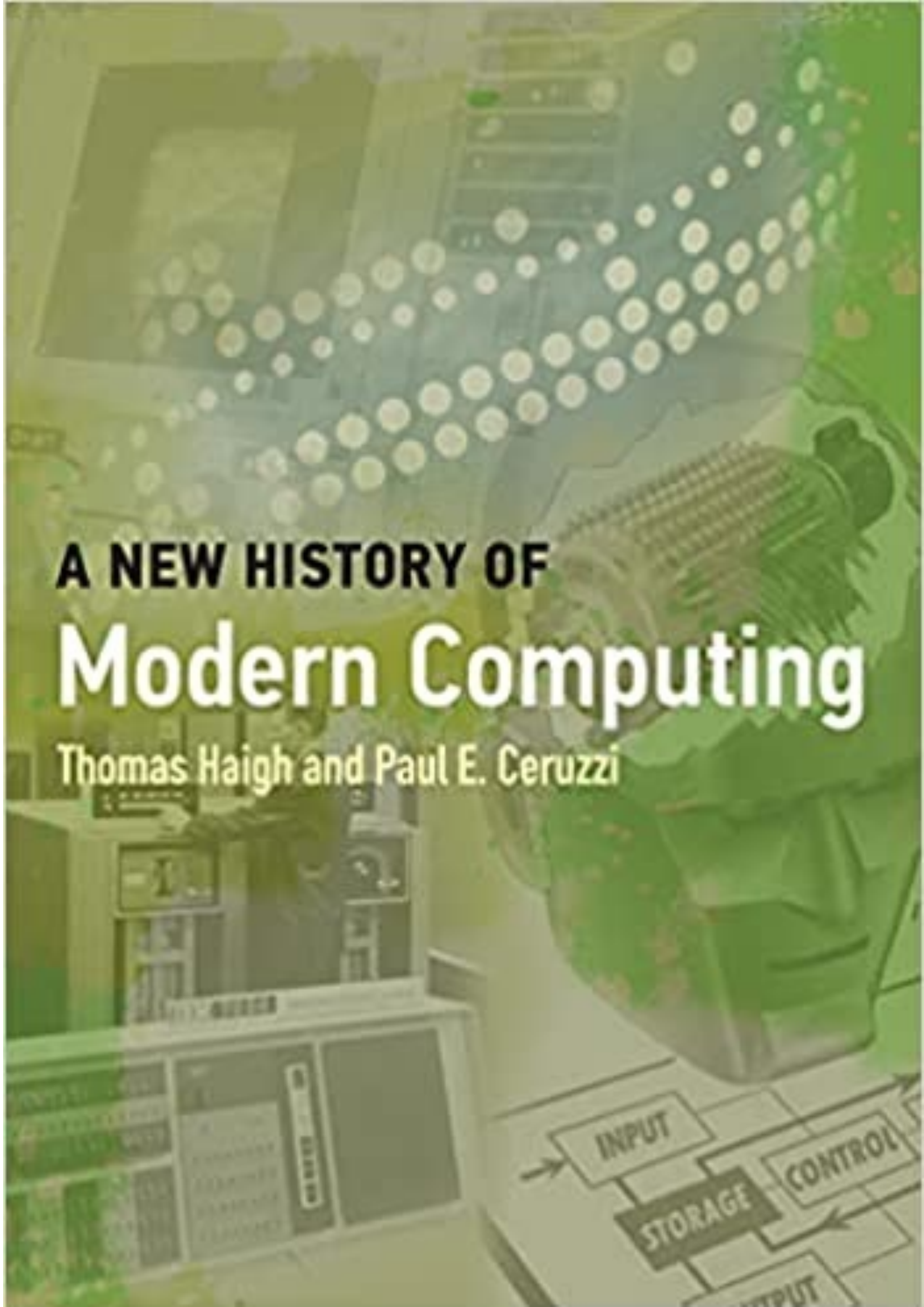
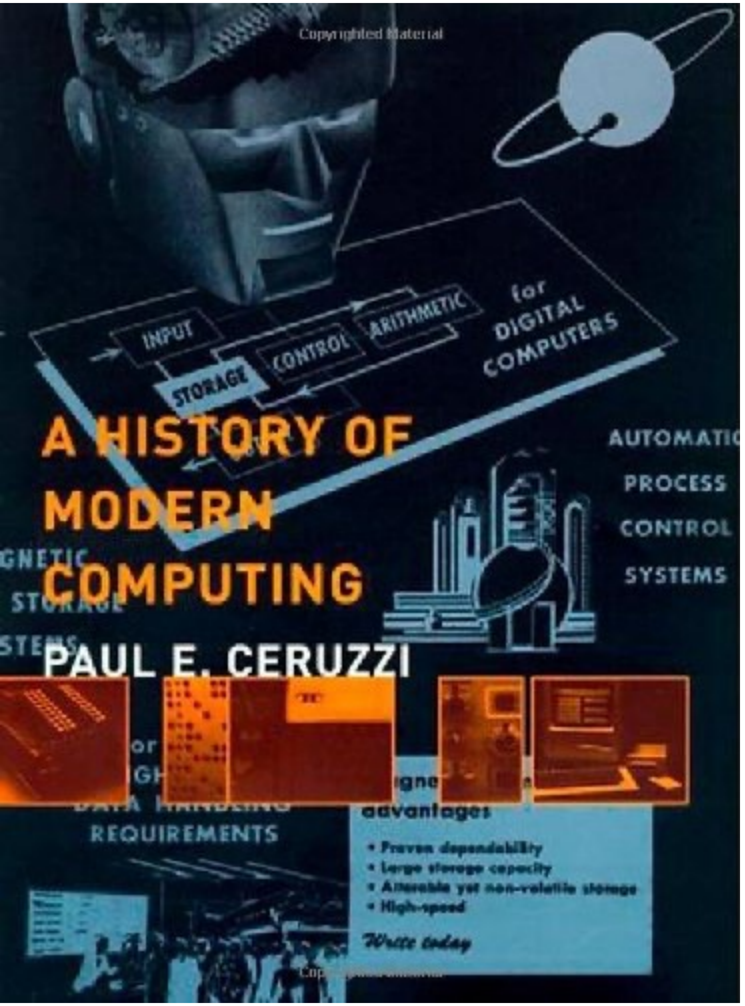


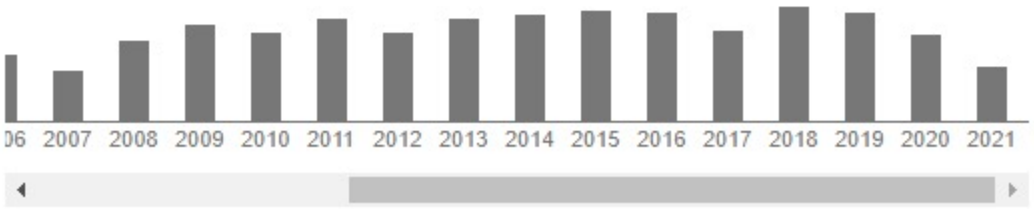

Replaces
Paul’s classic
1998 book
<<-

# Build on Strengths of the Original Book

- Most widely cited overview history of computing
- Engagement with computer architecture
- Focus on minicomputers, UNIX, and interactive computing
- Treatment of early personal computing and calculators
- Widely used for teaching
  - Esp. for computing students

A history of modern computing

| | |
|---|---|
| Authors | Paul E Ceruzzi, E Paul, William Aspray |
| Publication date | 2003 |
| Publisher | MIT press |
| Description | From the first digital computer to the dot-com crash--a story of individuals, institutions, and the forces that led to a series of dramatic transformations. This engaging history covers modern computing from the development of the first electronic digital computer through the dot-com crash. The author concentrates on five key moments of transition: the transformation of the computer in the late 1940s from a specialized scientific instrument to a commercial product; the emergence of small systems in the late 1960s; the beginning of personal computing in the 1970s; the spread of networking after 1985; and, in a chapter written for this edition, the period 1995-2001. The new material focuses on the Microsoft antitrust suit, the rise and fall of the dot-coms, and the advent of open source software, particularly Linux. Within the chronological narrative, the book traces several overlapping threads: the evolution of the computer's internal design; the effect of economic trends and the Cold War; the long-term role of IBM as a player and as a target for upstart entrepreneurs; the growth of software from a hidden element to a major character in the story of computing; and the recurring issue of the place of information and computing in a democratic society. The focus is on the United States (though Europe and Japan enter the story at crucial points), on computing per se rather than on applications such as artificial intelligence, and on systems that were sold commercially and installed in quantities. |
| Total citations | Cited by 1824 |




| | |
|---|---|
| Scholar articles | A history of modern computing<br>PE Ceruzzi, E Paul, W Aspray - 2003<br>Cited by 1824 Related articles All 8 versions |

# Multiple Readerships Want Different Things

- Undergraduate students, assigned the book in class
- Graduate students looking for an introduction to the history of computing and its literature to frame their own research
- Scholars working on related topics in areas such as STS or Internet Studies who need a quick grounding in relevant history
- Members of the public, who likely work with computers themselves
- Computer scientists, though this is a history of computing technology, practice, and applications
  - Only incidentally a history of computer science

# 1: Two Senses of “Universal”

# The Computer as a "Universal Machine"

- Turing 1936 "On Computable Numbers…"
  - Describes a "universal computing machine" which can "be used to compete any computable sequence"
  - Essentially, it takes as part of its data input a description of the rules of another computing machine



machine uniquely. The machine whose D.N is $n$ may be described as $\mathcal{M}(n)$.

To each computable sequence there corresponds at least one description number, while to no description number does there correspond more than one computable sequence. The computable sequences and numbers are therefore enumerable.

Let us find a description number for the machine I of § 3. When we rename the $m$-configurations its table becomes:

| | | | |
|---|---|---|---|
| $q_1$ | $S_0$ | $PS_1, R$ | $q_2$ |
| $q_2$ | $S_0$ | $PS_0, R$ | $q_3$ |
| $q_3$ | $S_0$ | $PS_2, R$ | $q_4$ |
| $q_4$ | $S_0$ | $PS_0, R$ | $q_1$ |

Other tables could be obtained by adding irrelevant lines such as

$$q_1 \quad S_1 \quad PS_1, R \quad q_2$$

Our first standard form would be

$$q_1 S_0 S_1 R q_2;\ q_2 S_0 S_0 R q_3;\ q_3 S_0 S_2 R q_4;\ q_4 S_0 S_0 R q_1;.$$

The standard description is

*DADDCRDAA*;*DAADDRDAAA*;

*DAAADDCCRDAAAA*;*DAAAADDRDA*;

A description number is

31332531173113353111731113322531111731111335317

and so is

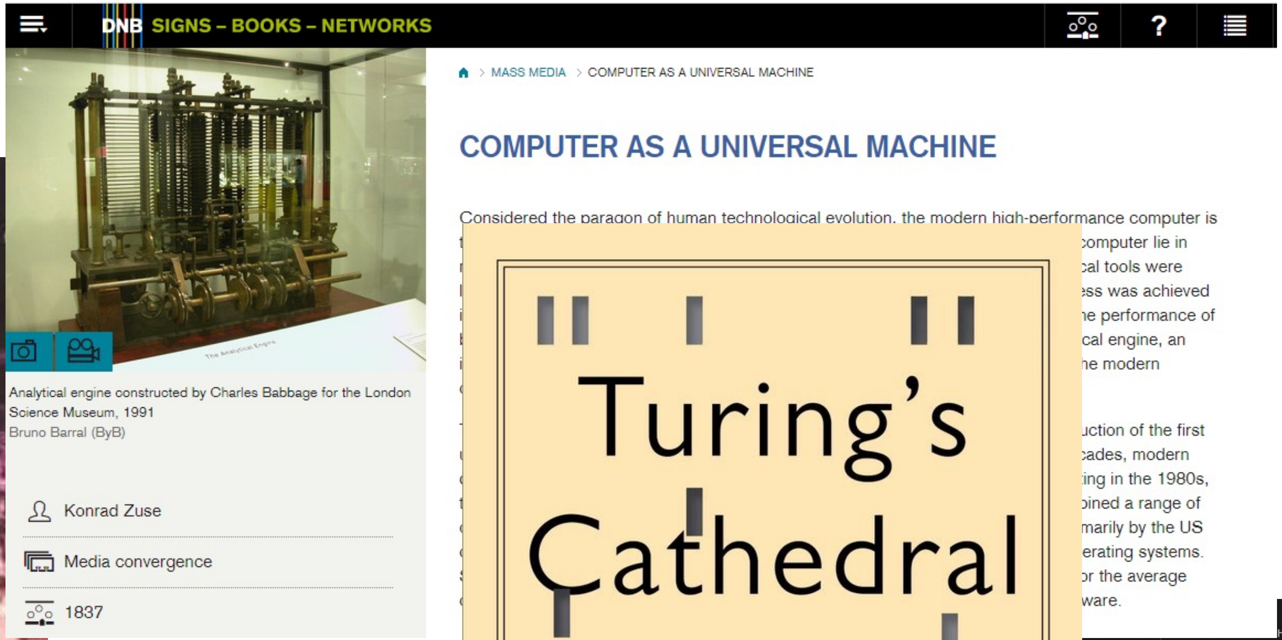
3133253117311335311173111332253111173111133531731323253117

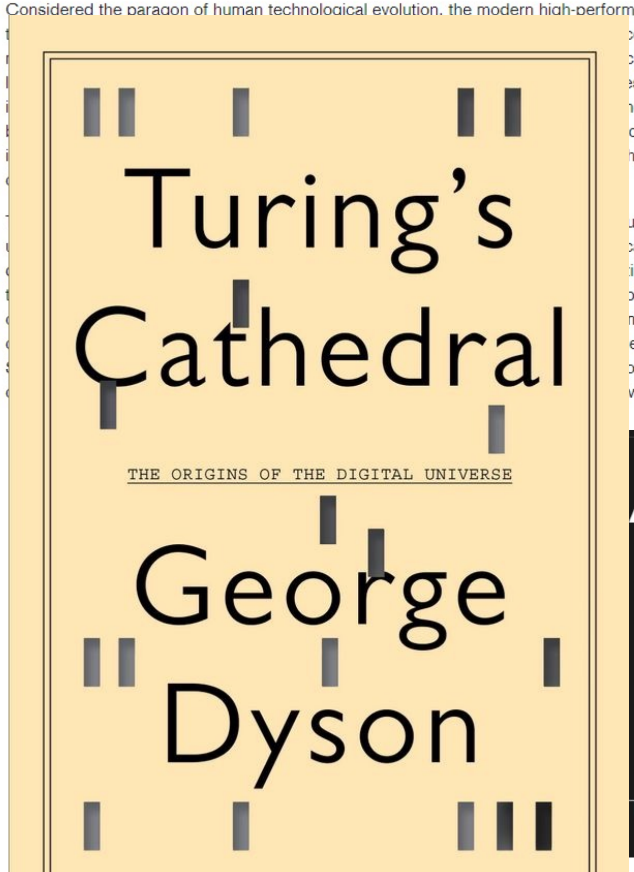
A number which is a description number of a circle-free machine will be called a *satisfactory* number. In § 8 it is shown that there can be no general process for determining whether a given number is satisfactory or not.

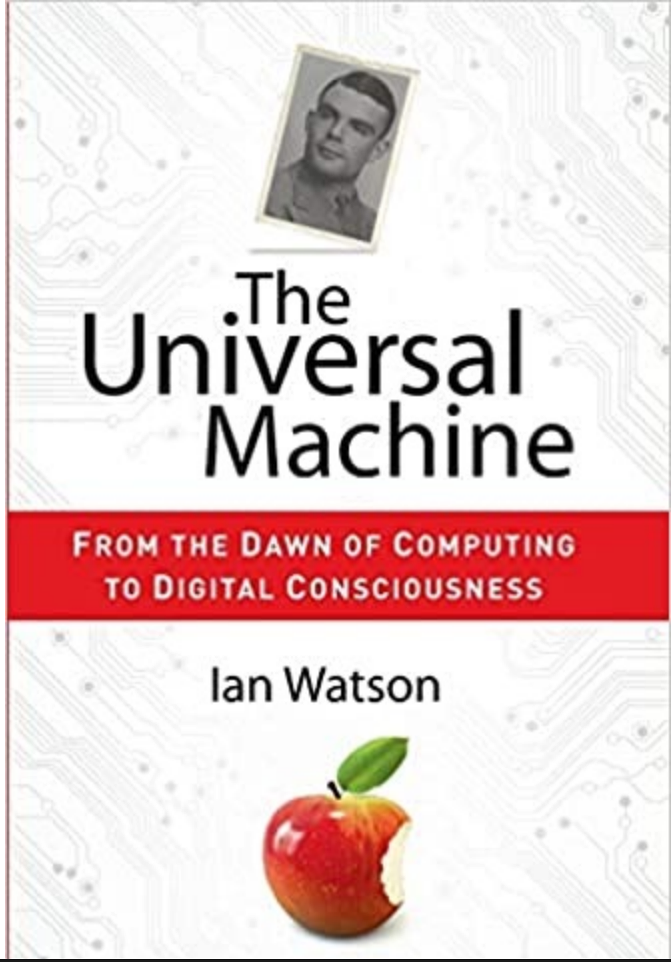
## 6. *The universal computing machine.*

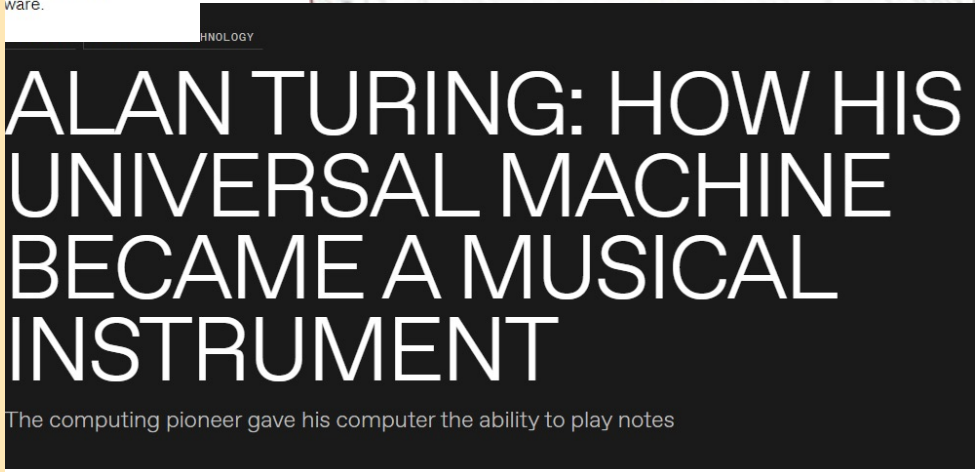
It is possible to invent a single machine which can be used to compute any computable sequence. If this machine $\mathcal{U}$ is supplied with a tape on the beginning of which is written the S.D of some computing machine $\mathcal{M}$,

# Conflation of Computers with UTMs

# Turing as the Inventor of the Computer

- Claims made by, for example,
  - Martin Davis (logician)
  - Jack Copeland (philosopher)
  - George Dyson (son of Freeman)
  - Alvy Ray Smith (computer scientist)
- That Turing invented the “stored program computer” in 1936
- That this inspired a “race” to build actual manifestations of Turing Machines in the 1940s
- And that all others (e.g. von Neuman and the ENIAC team in the “First Draft of a Report on the EDVAC”) did was reduce Turing’s ideas to practice

# Guess my thoughts on those claims

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Thomas Haigh

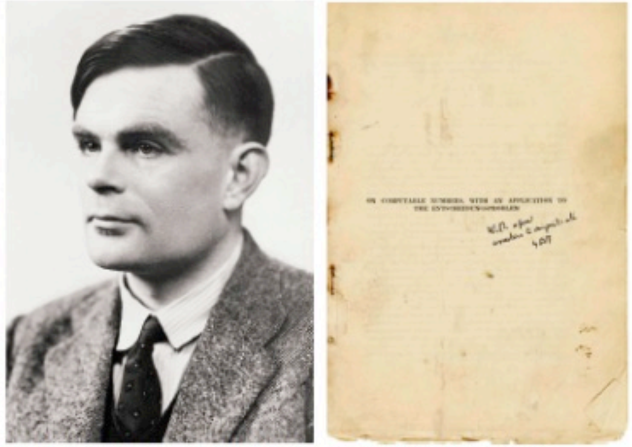
## Historical Reflections

# Actually, Turing Did Not Invent the Computer

*Separating the origins of computer science and technology.*

THE 100TH ANNIVERSARY of the birth of Alan Turing was celebrated in 2012. The computing community threw its biggest ever birthday party. Major events were organized around the world, including conferences or festivals in Princeton, Cambridge, Manchester, and Israel. There was a concert in Seattle and an opera in Finland. Dutch and French researchers built small Turing Machines out of Lego Mindstorms kits. Newspaper and magazine articles by the thousands brought Turing's life story to the public. ACM assembled 33 winners of its A.M. Turing Award to discuss Turing's ideas and their relationship to the future of computing. Various buildings, several roads, and at least one bridge have been named after him.

Dozens of books with Turing's name in the title were published or reissued. Turing was so ubiquitous that even George Dyson's book about John von Neumann was titled *Turing's Cathedral*, becoming the first book on the history of information technology to reach a broad audience since the one about Nazis with punched card machines. Publishers are well aware there is a strong audience for books about Nazis. The public's hunger for books about mathematicians and computer scientists is less acute, making Turing's newfound commercial clout both unlikely and heartening.



Alan Turing (left); the cover page of Turing's paper "On computable numbers, with an application to the Entscheidungsproblem" (right).

Still, as this flood of Turing-related material begins to recede it is time to clean up some of the rather bad smelling historical claims left in our metaphorical basement. Column space is short, so I will focus here on the idea that Turing invented the computer. Very short version: it is wrong.

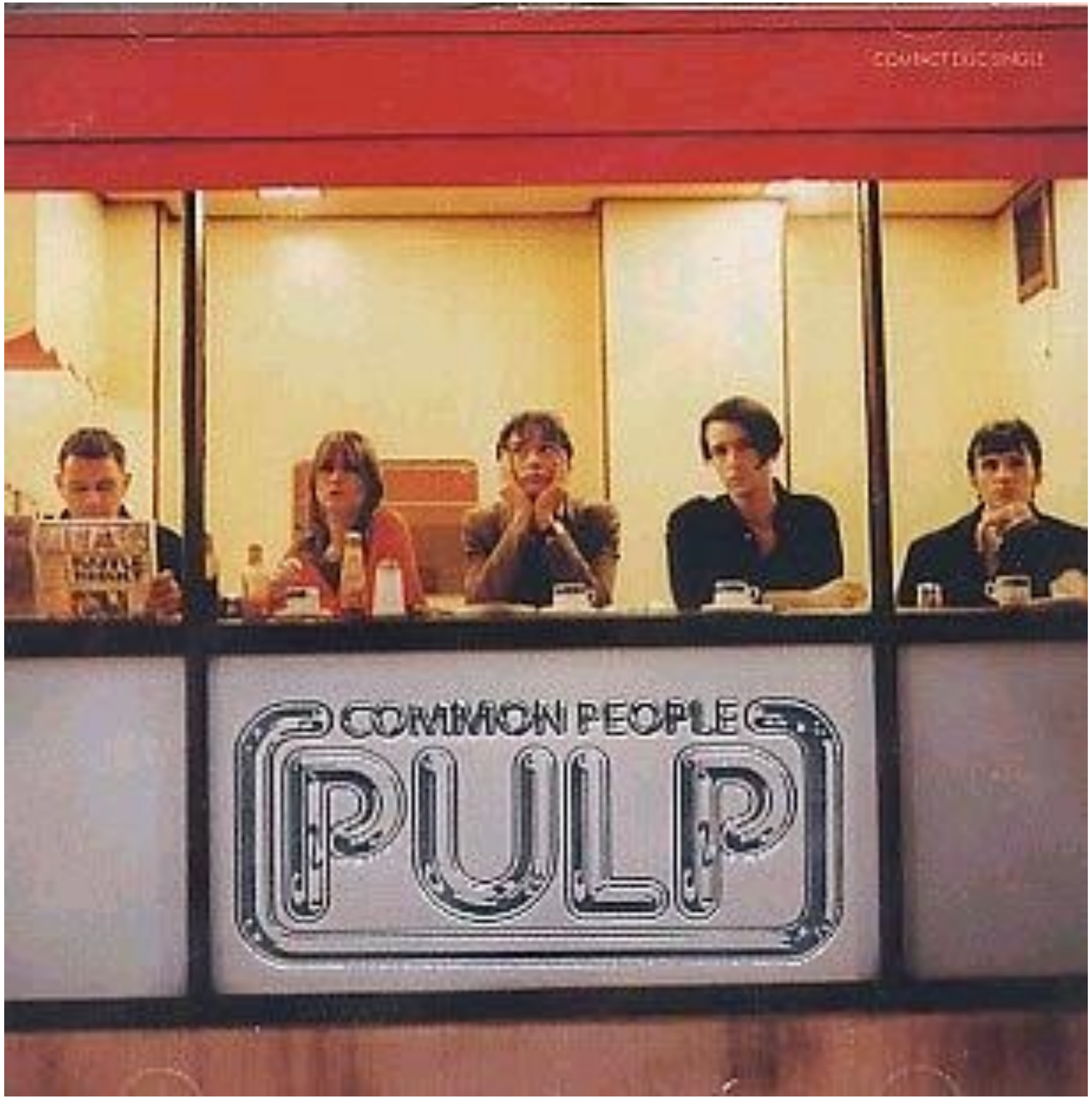
In case you spent 2012 in a maximum-security prison or meditating in a Tibetan monastery, let me briefly summarize the computer-related high points of Turing's actual career. In 1936, just two years after completing his undergraduate degree, he introduced the concept now called the Turing Machine in a paper called "On computable numbers, with an application to the Entscheidungsproblem." This has since become the main abstract model of computation used by computer scientists. During the Second World War Turing made several vital contributions as part of the British team try-

# From page 20:

was slower but simpler. Most parallel-word computers used Williams tubes, which could retrieve all the bits in a word of memory simultaneously.[20]

You may have noticed that we have not yet mentioned two of the most famous figures in the history of computing: Charles Babbage and Alan Turing. Babbage's efforts a hundred years earlier to build a mechanical computer were remarkable but had no direct influence on work in the 1940s; the ENIAC team didn't know about them and even Howard Aiken, who helped to revive Babbage's reputation as a computer pioneer, designed his computer in ignorance of the details of Babbage's work.[21]

Alan Turing's conceptual work on computability carried out in the 1930s was later foundational to the development of theoretical computer science. While von Neumann was aware of, and intrigued by, Turing's concept of a "universal machine," we see no evidence that it shaped his design for EDVAC.[22] In 1946, however, Turing proposed a radical reinterpretation of the EDVAC approach for the computer project at Britain's National Physical Laboratory. His ACE design coded every operation as a transfer between delay lines. Some transfer destinations carried out special operations, such as adding the number it received. The architecture was commercialized on some early British machines, which were simple and fast but very hard to program because programmers had to track exactly when each value they wanted to work on would be emerging from a delay line and time their code accordingly.[23]


COMPACT DISC SINGLE
COMMON PEOPLE
PULP

# Our book starts with ENIAC in 1946

- First programmable electronic computer
- 200 decimal digits or writable storage
- 3,000 multiplications a second
- Input: digit switches & numerical punched cards
- Output: digit lights & numerical punched cards
- Consumed 150KW of electricity
- Programmed by wiring logical pathways & setting switches

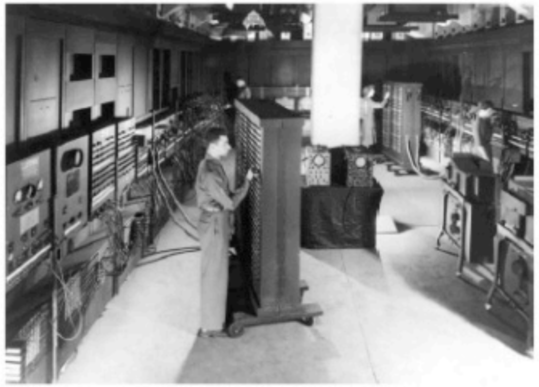


**Figure 1.1**
ENIAC as installed at the University of Pennsylvania, in a US Army photograph used by the New York Times in its 1946 report. This image defined public ideas of what an electronic computer looked like. The machine was configured by setting switches and wiring connections between its many panels, which collectively established a room within a room in which its operators and associated punched card machinery worked. Corporal Irwin Goldstein, an Army maintenance technician, is in the foreground setting data on a "portable function table" later used to hold encoded program instructions. Technician Homer Spence and two operators, Frances Bilas and Betty Jean Jennings (later Jean Bartik), work in the background.

**ENIAC**

ENIAC's place in computer history rests on more than being the first device to merit check marks for *electronic* and *programmable* on a comparison sheet of early machines. It fixed public impressions of what a computer looked like and what it could do. It even inspired the practice of naming early computers with five- or six-letter acronyms ending with *AC*. During a period of about five years as the only programmable electronic computer available for scientific use, ENIAC lived up to the hype by pioneering applications such as Monte Carlo simulation, numerical weather prediction, and the modeling of supersonic air flow.

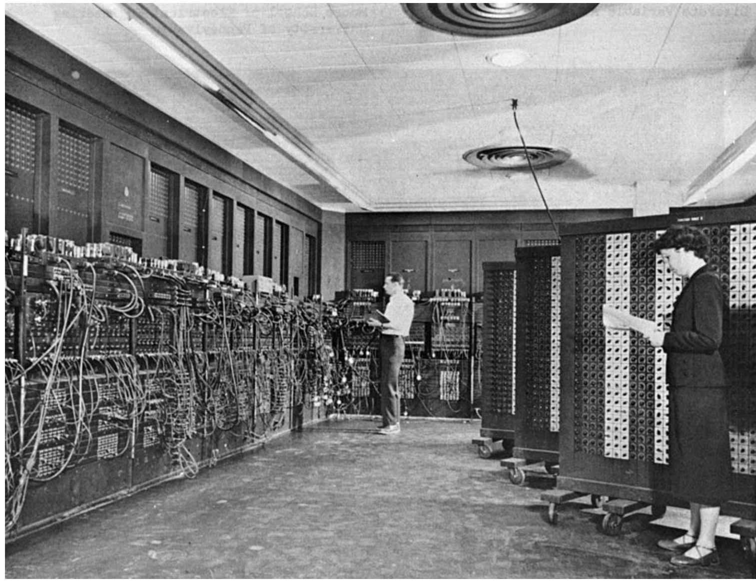
**Programmability**

We should explain what we mean when we say that ENIAC was programmable. The idea of defining and following a program does not originate with automatic computers. Earlier meanings of *program* included a concert program, the program of study for a degree, and the programming of radio stations. In each case the program defined a sequence of

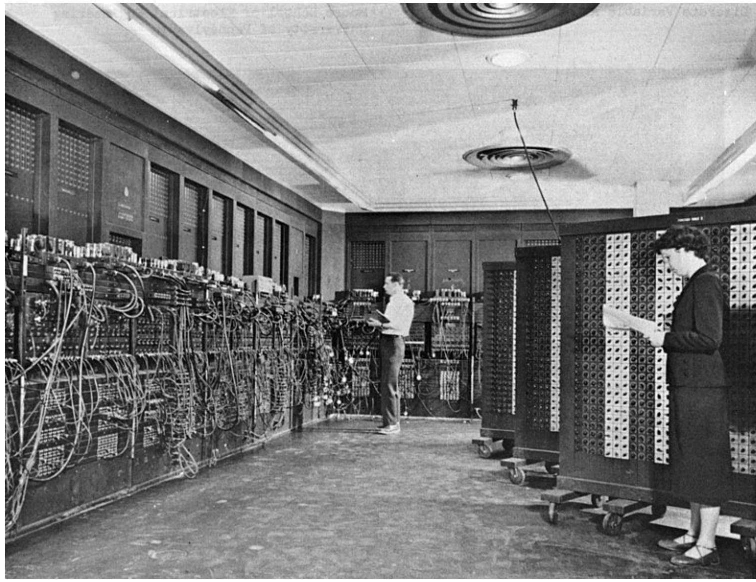
10 *Chapter 1*

# Cars vs. Computers

# Cars vs. Computers



# Cars vs. Computers



# Cars vs. Computers



# General Purpose Technology

- Concept from Economics…
  - Technologies that have a major impact across the entire economy
  - Because they are flexible enough to be applied to many different tasks
- Classic examples:
  - Steam power
  - Electrical power
  - Internal combustion engine
- The computer seems to be even more general purpose than the others
  - Can we call an "exceptionally general purpose technology" practically universal? Or universal in practice/

# So when does the computer become universal?

- Davis: Always, even before it existed.
  - Turing invented the stored program computer in 1936
  - Physical computers like ENIAC inherit universality from the abstract machine
  - All practical programmable computers are universal (given sufficient time and storage)

# So when does the computer become universal?

- Davis: Always, even before it existed.
  - Turing invented the stored program computer in 1936
  - Physical computers like ENIAC inherit universality from the abstract machine
  - All practical programmable computers are universal (given sufficient time and storage)
- My answer: Never, but they do approach the status of a universal technology more closely with time.
  - 1946: ENIAC is a very specialized technology used by a few dozen people to automate  (mostly numerical) mathematics
  - 2021: Most people on earth use smartphones to do almost everything
    - And with embedded systems there are far more computers than people on Earth

# Becoming Universal

- We see the overall arc of the story as a movement towards “practical universality” as
  - Some individual devices (personal computers, smartphones) mediate a broader range of social processes,
  - But also (and more importantly): computers become COLLECTIVELY able to underpin ever more human activities
  - Even as individual computers are usually highly specialized embedded systems
- Computer technology becomes a “universal technological solvent” able to replace the internal workings of televisions, phones, music players, etc.

## BECOMING UNIVERSAL: INTRODUCING A NEW HISTORY OF COMPUTING

This book is a comprehensive reimagining of *A History of Modern Computing*, first published in 1998 and expanded with a new chapter in 2003. A lot has changed since 1998 when the Web was a novelty, iPhones didn't exist, and the founders of Google and Facebook were in graduate school and high school, respectively. Doing justice to those changes required more than just adding a few more chapters at the end of the book. For example, as the first edition was being written and conceived, the Internet was still quite an obscure system. Today we view the development of computer communications as a central thread in the history of computing, not just in the 1990s but also in the 1960s and 1970s. The wholesale shift of video and music reproduction to digital technologies likewise challenges us to integrate media history into the long history of computing. Since the original book was written, the computer had become something new, which meant that the book also had to become something new.

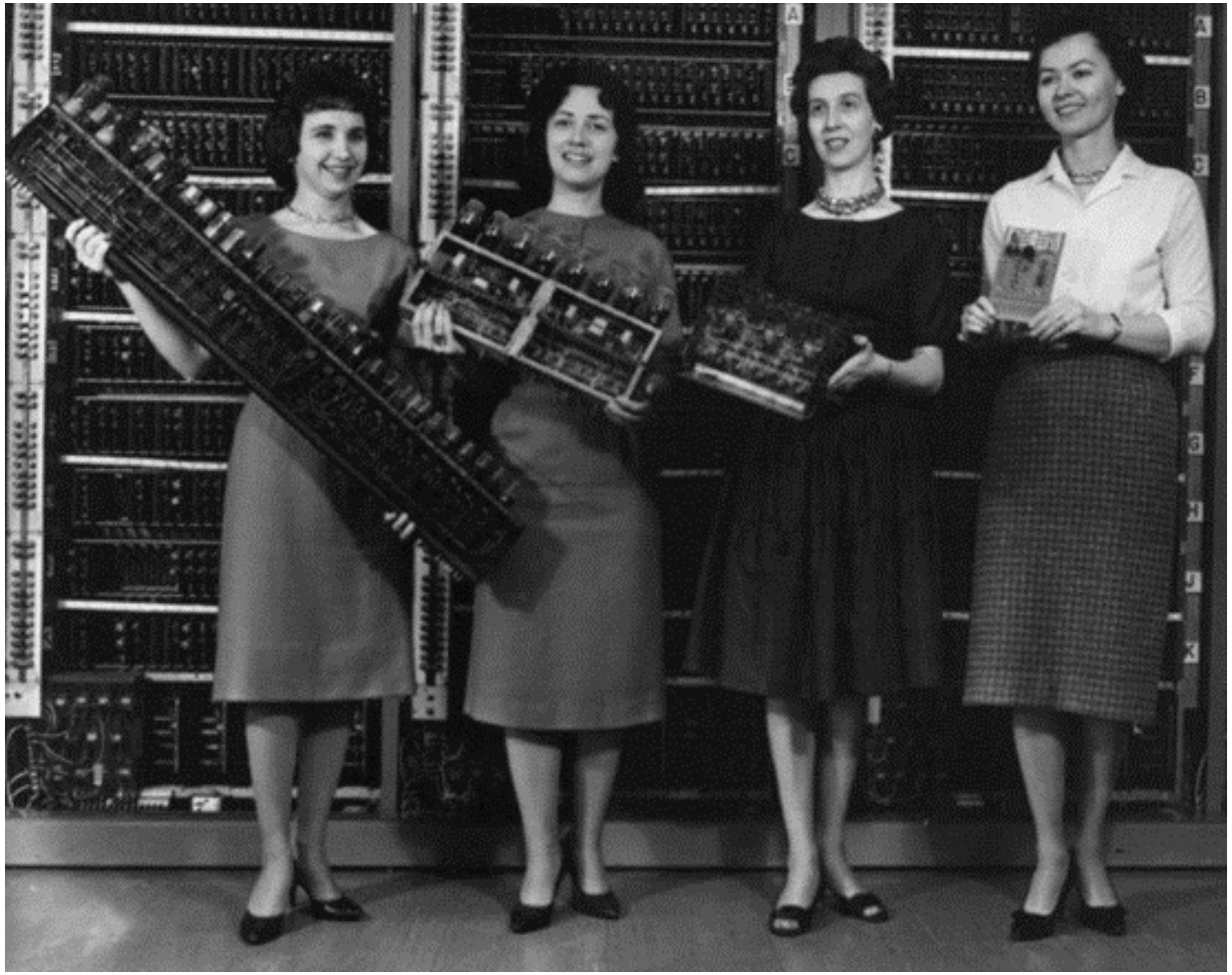
The unmistakable importance of the Internet, digital media devices, and video games to modern life has driven public interest in their stories. Yet this discussion is rarely grounded in the longer and deeper history of computer technology. For example, as we finalized our revisions to this book, one of us chanced upon *How the Internet Happened: From Netscape to the iPhone* by Brian McCullough, a tech industry insider.[1] It is readable, admirably tight, and solidly researched—based on two hundred interview podcasts McCullough recorded with company founders. We recommend it to you. Yet we were also struck by how little engagement such approaches to history have with the larger story of computing. As his title suggests, McCullough starts the story of the Internet in 1994 with the first commercial Web browser, giving only occasional flashbacks to the first twenty-five years of the Internet (and its precursor, the ARPANET). He says little about where the core technologies, protocols, or algorithms of the Web came from, or about the evolving technologies personal computing, such as new processors and operating systems, that made the rapid spread of Web browsers possible. He

# Relationship between the two universalities

- The programmability of computers is essential to the development of the technology as very general-purpose technology
  - But it is not sufficient

# Miniaturization and exponential growth

- Moore's Law, obviously
- But even before semiconductors
    - Continual growth in available computer power
    - Continual reduction in size
    - Continual reduction in cost
    - Continual increase in power efficiency

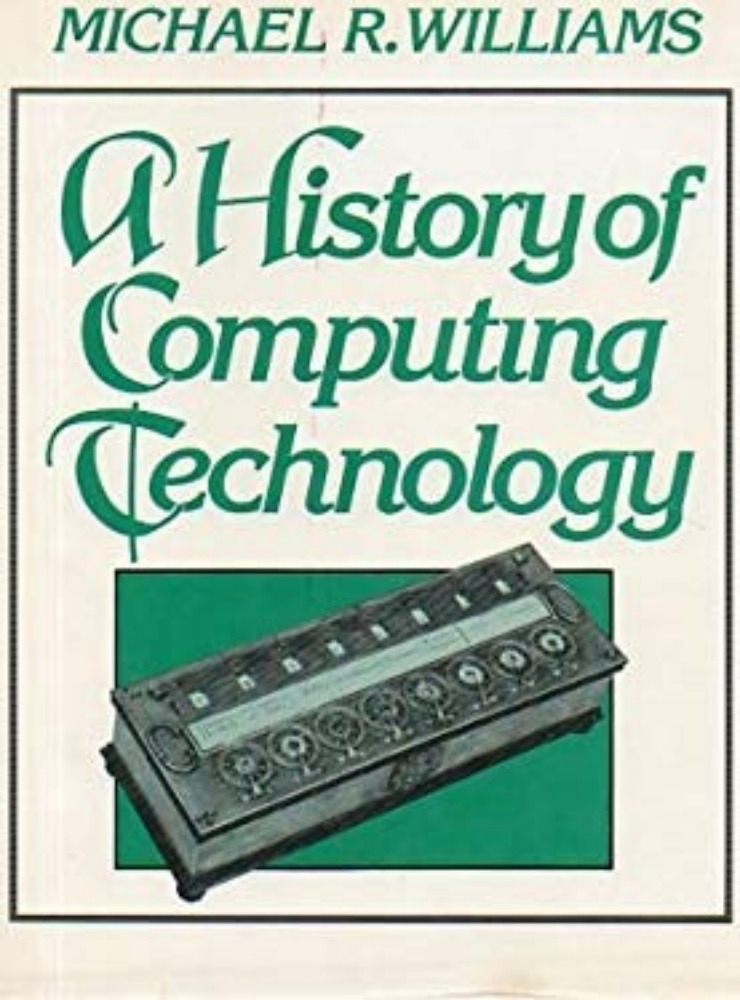


# Other subtle changes

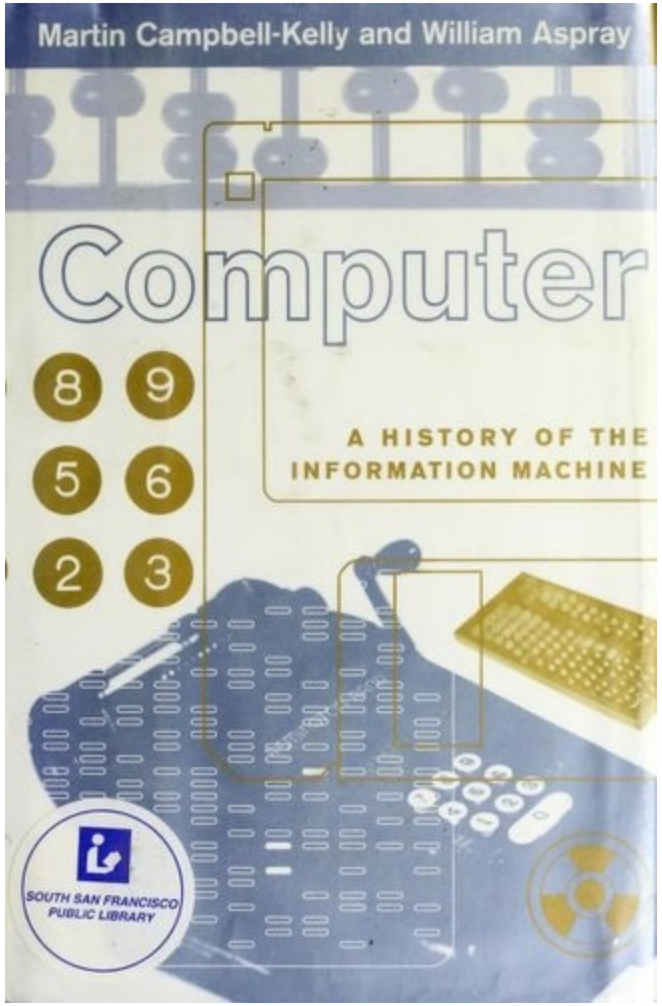
- Many other developments underpin the transformations
  - Architecture
  - Communications
  - Storage
  - Miniaturization
  - Graphics and visualization
  - User interfaces
  - Algorithms, etc.
- Each innovation inspired by the needs of a particular class of user (business admin, nuclear simulation, etc.)
- But becomes part of the core package of the computer
- So “the computer” is not just one thing, but an ever growing stack of hardware, architecture, software and techniques

# 2: Structure of the New Book

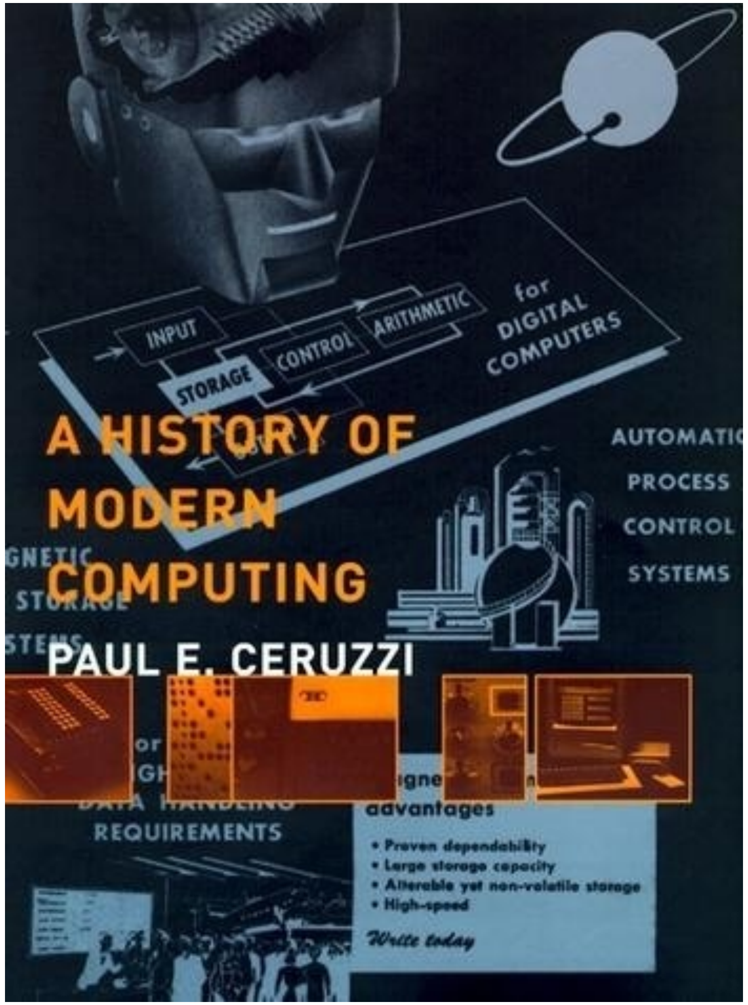
# Existing Overview Histories Rooted in 1980s/90s




1985



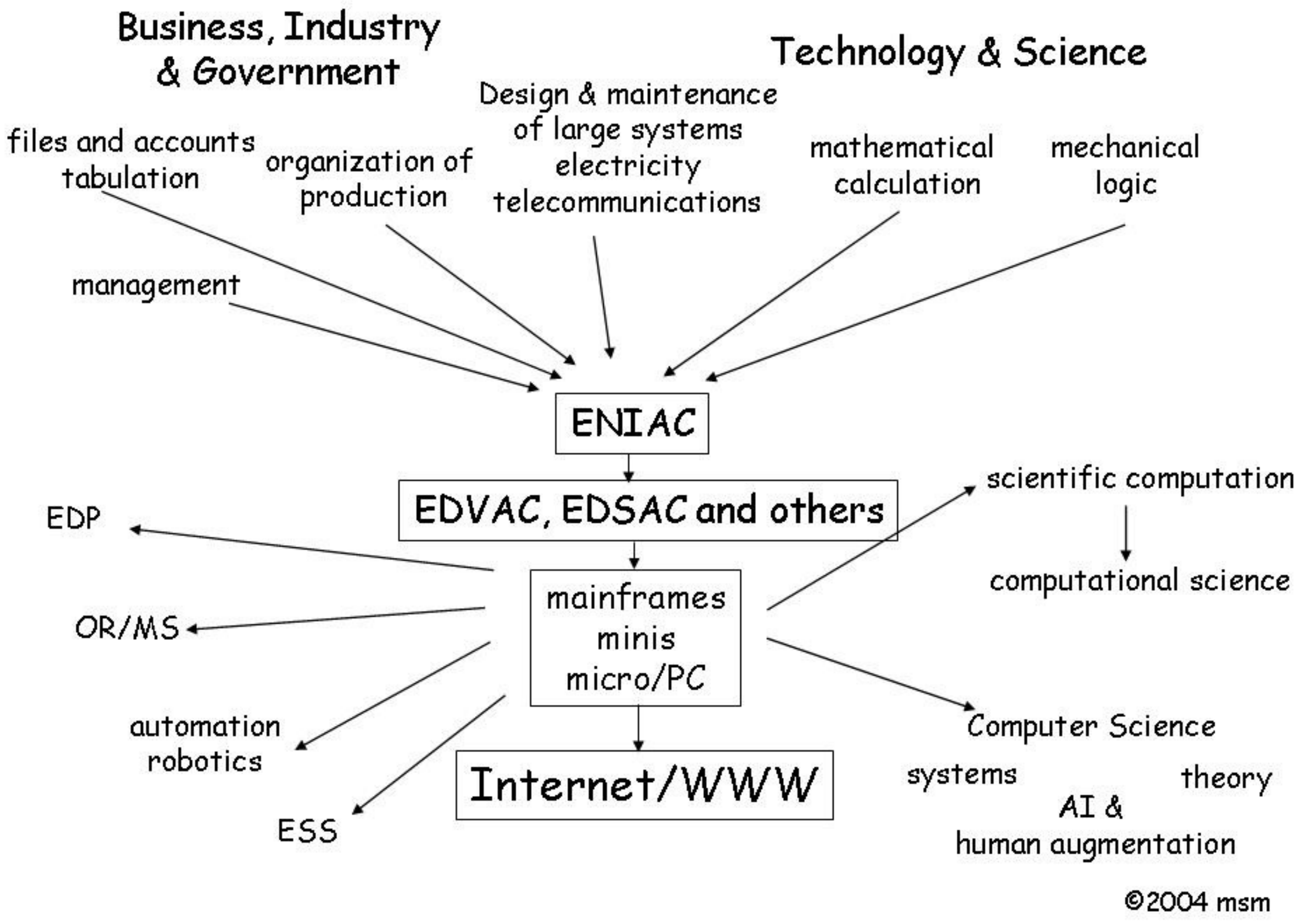

1996




1998

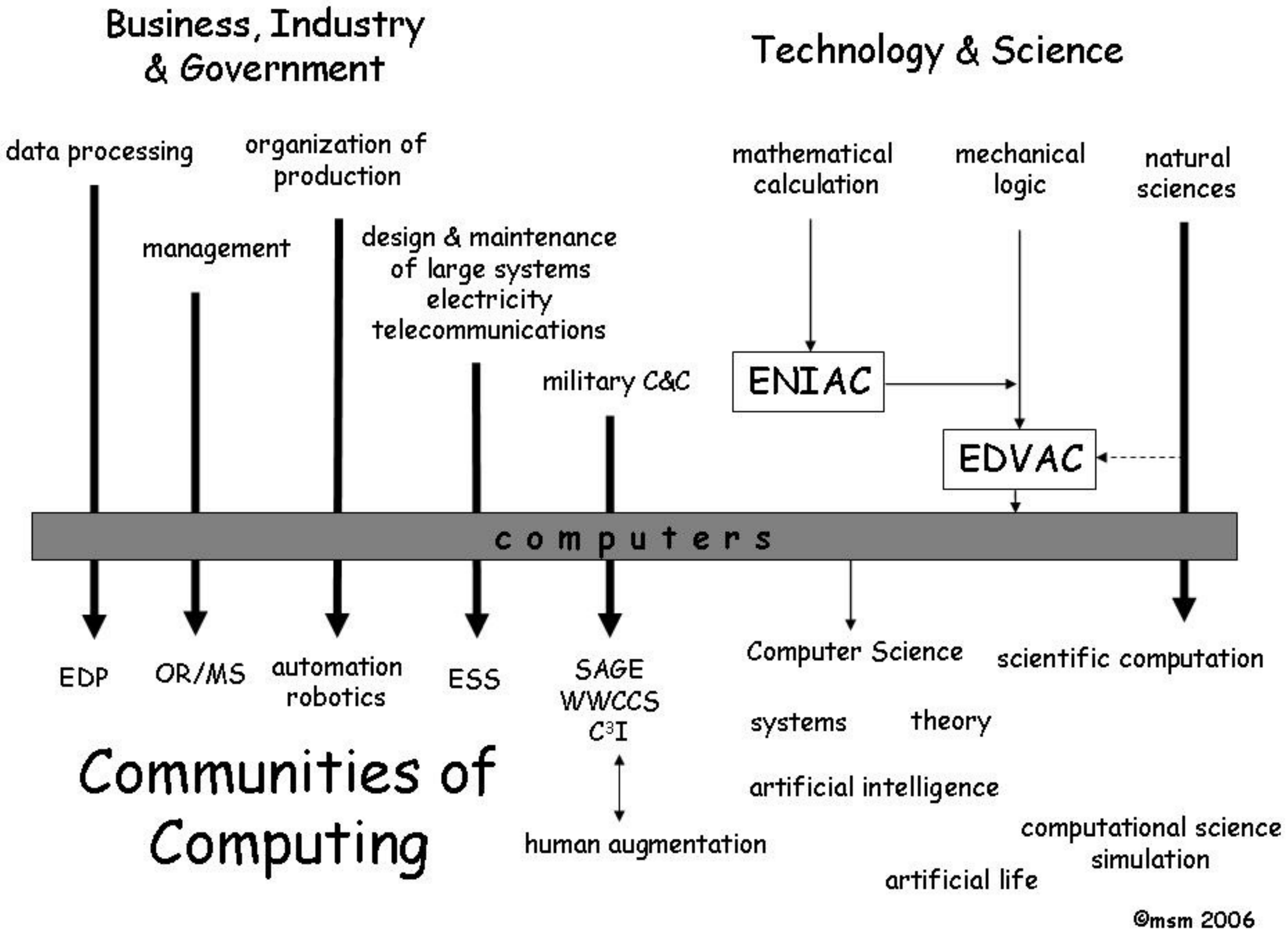
# “Histories of Computing(s)” – Michael S. Mahoney

Traditional master narrative



# Mahoney's suggested alternative

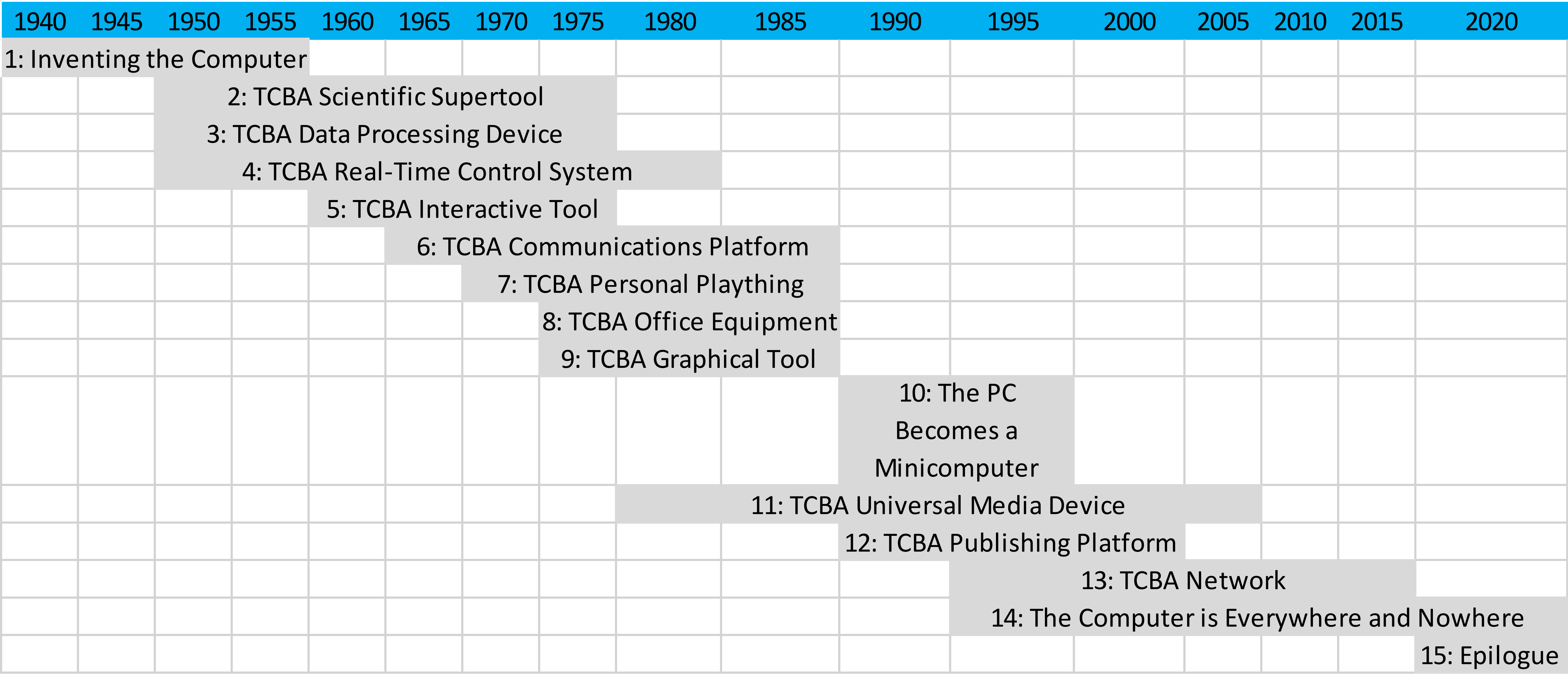
"the histories and continuing experience of the various communities show that they wanted and expected different things from the computer. They encountered different problems and levels of difficulty in fitting their practice to it. As a result, they created different computers or (if we may make the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



# Our Structure

- The 15 chapters overlap, rather than dealing with 5 years each
- The story of the computer is a story of constant transformations
  - Each transformation is driven by the needs of a particular community of users
  - Each transformation builds on core affordances developed in earlier transformations

# Structure vs Chronology




TCBA X -> The Computer Becomes A(n) X

# No through-line from earlier technologies

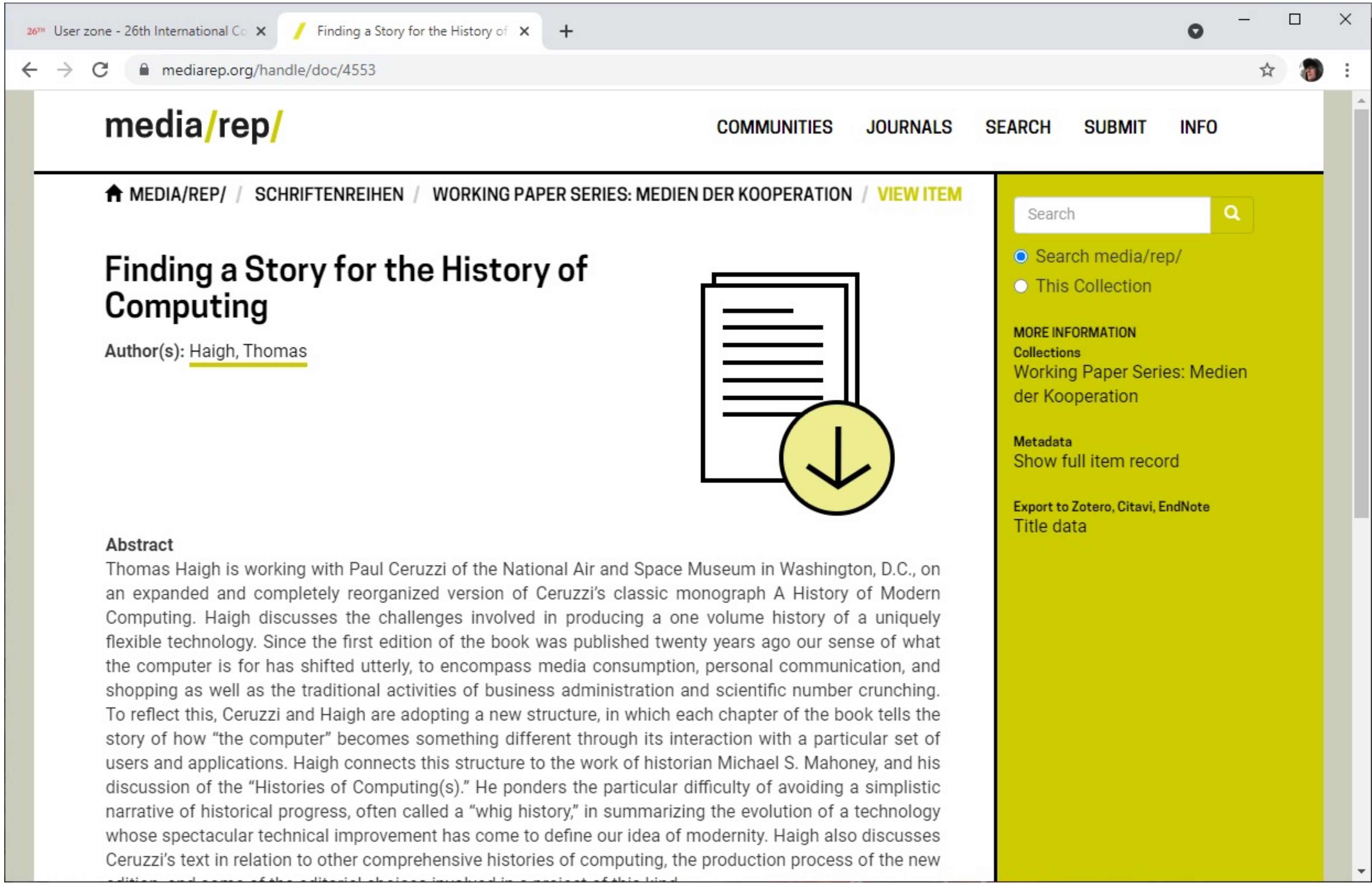
- First chapter sets up ENIAC-EDVAC-UNIVAC as the origin point of the "modern computer" from which change radiates
- User communities and applications enter the story only as they engage with computers on a large scale
  - NASA in the 1960s
  - Domestic users in the 1970s
  - Photographers in the 1990s, etc.
- Prevents a true appreciation of "before and after" continuities between practices built around computers and those shaped by different technologies

# Centering “the computer”

- Builds on technological engagement in the original book
- Hardware and software features like
  - Timesharing
  - Packet switching
  - Multitasking
  - Virtual memory
  - GUIs
  - Object oriented programming
- Originate in specific contexts, but become part of the core bundle of layered technologies that define “the computer”
  - Even when hidden inside televisions, phones, or media players

# For more details on our work methods

- See Siegen University working paper “Finding a Story for the History of Computing”



# 3: New Coverage

# One long 4* Amazon review of the 2nd edition of A History of Modern Computing:

Living, computing, and reading in 2016, Ceruzzi's history's "closing date" of 2003 seems to be a long time ago. … "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. The important, almost dominating, role of software houses and their effects upon hardware architecture are not touched. Use of files accessible by internet as the world's online library is not touched. Communicating is as much a part of using computers today as what happens within arm's reach at one's desk…. Digital photography came into being in the time period covered by this history and its effects upon "computer use" and communication content has been real. Ceruzzi does not include this facet of the new century's use of computing technology. We learn almost nothing about Apple, Dell, Compaq, Hewlett Packard, AMD, Lenovo, Samsung, and the like.

# Lack of attention to UK developments also noted

Ben Attenborough

★★★★☆ **Strong academic history, lacking in certain areas**

Reviewed in the United Kingdom on June 6, 2015

**Verified Purchase**

An interesting read. This book starts it's history in post war America, so it misses a lot of the pioneering work at Bletchley Park. Also the focus is firmly on the US and misses out on developments like the Commodore, Atari, Amiga, spectrum, Acorn computers. Also this book is pretty dated now so for stuff later than 2000 you'll need to look elsewhere. As such it is a bit weak on the Internet. But for a history of IBM and development of technologies for the later part of the 20th century it's strong and academically rigorous.

# Other New Expectations

- Pay attention to users (long established in STS), not just technologies and producers
- New economic, cultural and political centrality of big-tech firms
  - The first trillion-dollar companies were Apple, Microsoft, Amazon, Alphabet and Tesla
  - They shape our lives and communities in profound ways
- Engage with current political concerns
  - Issues of gender, race and sexual identity central to the "culture wars" engulfing the US
  - Class, race and gender established as the central trinity in US historical storytelling since the 1980s

# Draws heavily on recent secondary literature

- New emphasis on topics such as
  - Timesharing
  - Video games
  - Networking
  - Graphical user interface
  - Software technologies such as DBMS
  - Embedded media technologies
- New sections based on work of Paul Edwards, Joy Rankin, Matthew Kirschenbaum, Tom Lean, Michael Z. Newman, David Brock, Con Diaz, Valerie Schafer, Nick Montfort, Ian Bogost, Jonathan Sterne, and many others
- Just as earlier overviews drew on 1980s histories of IBM, ENIAC, ERMA, etc.

# Home Computing

- Ch. 7 “The Computer Becomes a Personal Plaything” takes material on microprocessors, calculators and early personal computers from original book
- But adds new coverage of
  - Arcade video games
  - Early games consoles
  - Home computers from the US (Atari, Commodore, Texas Instruments) and UK (Sinclair, Acorn).


**Figure 7.11**
The ZX81 sold very well in the United Kingdom, where its extraordinarily low price more than offset limitations such as a memory capacity of just one kilobyte. W.H. Smith, a nationwide British chain, was advertising not just the computer but also programs, magazines, and blank tapes to use with it. *Computer & Video Games* 1, November 1981, p. 38, used courtesy of W. H. Smith.

197 *The Computer Becomes a Personal Plaything*


**Figure 7.13**
Eventually priced at less than $200, the Commodore 64 became the bestselling computer model in history. Commodore stressed the savings its computers offered against better built rivals with similar memory capacities. Notice the family members crowded around a television set.

200 *Chapter 7*

# Graphics and Games

- Sketchpad and Spacewar in ch. 5
- 3D graphics for workstations, PCs and Consoles in chapters 10, 11 and 13.
- Shift of AI and supercomputing to GPUs in ch. 13


**Figure 7.12**
The programmers of home computers displayed great creativity. The ZX81 had a text-based display with special characters to represent block shapes and shading. *3D Monster Maze*, programmed by Malcolm Evans in
ate a 3D maze, home to a rampaging Tyrannosaurus rex.

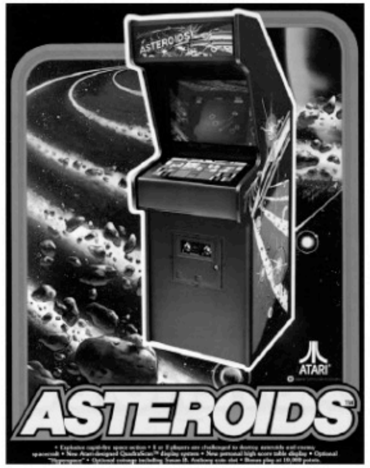



**Figure 7.7**
This *Asteroids* arcade cabinet sold three lives for a quarter. Early cabinets relied on bold, colorful gr
on the cabinet and around the edge of the screen to supplement their limited graphics. *Asteroids* of
crisp, but monochrome, vector display inspired by *Spacewar*.

That tiny RAM couldn't come close to holding a full screen of graphics inform
even at the VCS's chunky 160 by 192 pixel resolution. The VCS hardware was des
with simple games in mind. It had special facilities to display two relatively de
*sprites*, one controlled by each player. In the *Combat* game supplied with the sy
(figure 7.8), sprites were things like tanks or airplanes. The hardware also tracke
position of "ball" and "missile" sprites and drew these on the appropriate points. E
thing else on the screen was background graphics drawn at a lower resolution, repr
ing things like clouds or maze walls in the early games. As there wasn't enough me
to store the whole background at once, programmers had to time their code wi
awareness of the progress of the television's electron beam across the screen. For exa



never appealed to the mass market. The discs stored analog video, not digital, though later versions coupled it with digital audio.

The group also experimented with producing a digital model of the town and using it to create realistic 3D views, but this could not yet be done in real time. Relatively realistic computer graphics sequences, with solid objects, lighting, and shadows, first appeared in movies like *Tron* (1982) (see figure 11.2), *Star Trek II: The Wrath of Khan* (1982), and *The Last Starfighter* (1984). This required massive amounts of computer power. The specialist company Digital Productions needed ten seconds of time on its Cray X-MP supercomputer to render each frame and output it to film. The twenty-seven minutes of digital footage for *The Last Starfighter* took months of preparatory work and tied up the Cray for so long that Digital Productions had to temporarily abandon its lucrative trade in animated commercials.[5]

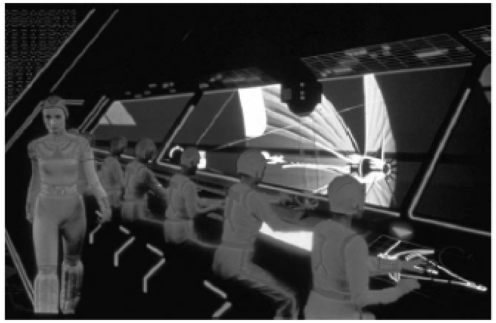


**Figure 11.2**
An image from the 1982 Disney movie *Tron*, which broke new ground by including more than fifteen minutes of purely computer-generated animation and, as here, by mixing filmed and generated elements in the same shots. Computer scientists Alan Kay advised Disney on the film, which required cutting-edge computer power and expertise. (Kay later married writer Bonnie MacBird, who edited her original script for *Tron* on an Alto at Xerox PARC.) The Solar Sailer visible through the window was animated by Information International, Inc., founded in 1962 by Ed Fredkin, an early adopter of DEC computers and later the director of MIT's Laboratory for Computer Science. Information International had the most advanced capabilities of the four companies hired to produce graphics for the movie. It relied on the unique Foonly F1, the most powerful PDP-10 compatible computer, custom built in the mid-1970s by former members of the Stanford AI Lab. Photo: Moviestore Collection Ltd / Alamy Stock Photo.



ition to a postindustrial "information society."
the nation's public service broadcaster, created
pulation get to grips with the new technology.
models for these shows, it sponsored Acorn
ll the required features. The BBC Micro had a
tions, with connections for printers, modems,
ves, analog instruments, and ROM chips hold-
ming languages. One optional hardware kit
lcasts, which included downloadable software.
a Sinclair (although far less than an Apple II),
made it the choice of hackers and tinkerers.[74]
ess Spartan than Sinclair's offerings, were like-
npete with the Atari VCS for space in front of
e VIC-20 had color, sound, joystick ports, and
anted to program, they offered real keyboards
quipped for applications such as word process-
characters across its screen (ensuring visibility
5 KB of memory.[75] Nevertheless, Commodore
mething that would be better for their video
onsole. One advertisement featured an intimi-
applicant why his resume mentioned having
planet Mondo." "You are good at computer
u know about computers?" The tagline was "A

price of $525 for its computer, but aggressive
lown the price of both machines. By 1982 they
he next year retail prices dipped below $100.[77]

# Computer Science

- This is Not a history of computer science (Knuth)
- BUT we did look for ways to intertwine work by computer scientists that shaped widely used computing technologies
- Examples:
  - New treatment of Algol and the “Software Crisis” in ch. 5 (“The Computer Becomes and Interactive Tool”)
  - Discussion of Quicksort and complexity analysis in ch. 3 (“The Computer Becomes a Data Processing Device”)
  - Discussion of RISC in ch. 10 (“The PC Becomes a Minicomputer”)
  - VLSI and Meade Conway in ch. 7 (“The Computer Becomes a Personal Plaything”) & ch. 8 (“The Computer Becomes an Office Tool”).

# The PC standard

- Existing histories focus on the 1981 launch of the original IBM PC
- We have two chapters primarily on the volution of the PC as an template for an entire industry
- 1980s: ch. 8 “The Computer Becomes an Office Tool”
- 1990s: ch 10 “The PC Becomes a Minicomputer”


Figure 10.1
Windows 3 could multitask DOS applications such as Lotus 1-2-3 and Word Perfect, but the bundled Solitaire game was a threat to office productivity. Its interface split the capabilities of the Macintosh desktop between the Program Manager (used to launch programs) and the File Manager (to manipulate files via directory structures). Minimized windows appeared as icons on the desktop. Unlike the Macintosh, Windows placed the pull-down menus for each application at the top of its window, not at the top of the screen. In 1990, the 1024 × 768 resolution shown here was usable only with an expensive monitor connected to a recent graphics card.

benefits of graphical computing: mixing text and graphics in documents, cutting and pasting between applications, and seeing screen previews that matched printed output.

More importantly, a PC running Windows was still a PC. Thousands of DOS programs handled every possible need, including hobbyist packages such as astrological table generators, niches such as IBM terminal emulation, and untold numbers of applications written or customized for particular organizations. It would be years until Windows alternatives would be available for most of these, but the existing DOS code would usually run fine under Windows and could sometimes be smoothly multitasked to exploit the new capabilities of 386 processors. Aggressively coded MS-DOS programs that wouldn't run at all inside Windows could still be used, by exiting Windows to reach the standard DOS command line. Many users continued to spend most of

267 *The PC Becomes a Minicomputer*

Figure 8.6


Figure 8.9
By the end of the 1980s, most PC companies purchased standard parts and screwed them together. This Dell advertisement from *Byte*, December 1989, consisted almost entirely of technical specifications and prices in small print. Potential customers would compare the components and pricing offered by Dell with those of its many rivals.

241 *The Computer Becomes Office Equipment*

# Gender and Work

- We mention the contributions of women throughout the book, but also
- Issues gender and labor are threated through the book, for example
  - ENAIC in ch. 1 (“Inventing the Computer”)
  - Data processing work in ch. 3 (“The Computer Becomes and Data Processing Device”)
  - Masculinity and home computing in ch. 7 (“The Computer Becomes a Personal Plaything”)

**Figure 7.9**
Advertisements like this one, for the Texas Instruments home computer, attempted to showcase the new machine as a new gathering place for the nuclear family. The applications areas highlighted were programming, personal finance, education, and entertainment. Courtesy Texas Instruments, scan by Bryan Roppolo.

# Communications

- Not just a chapter about the Internet at the end
- chapter 4 (“The Computer Becomes a Real Time Control System”)): transmission of data for military and aerospace applications in the 1950s and 60s
- 5 (“The Computer Becomes an Interactive Tool”): timesharing and its use, together with remote terminals, to make on-line interactive access to computers commo.
- 6 (“The Computer Becomes a Communications Medium”) we look at how applications such as email, the Plato educational environment, videotext systems like Minitel, and the packet-switched ARPANET were constructed around timesharing systems.
- 7 (“The Computer Becomes a Personal Plaything”) includes discussion of bulletin board systems
- 8 (“The Computer Becomes and Office Tool”) integrates Ethernet into the story of electronic office work.


Figure 6.6
In 1983, CompuServe was promoting it
to home computer users across North A

night, we exchanged letters wit
ferent states and only had to wa
“CompuServe Electronic Mail
mark application for *Email* dro
standard contraction of *electron*
While individuals and sma
big companies were increasing

156 *Chapter 6*

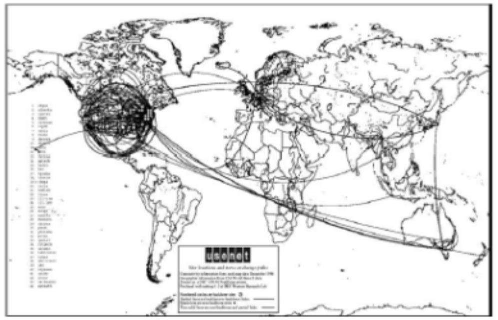



Figure 6.5
Although little remembered today, by 1986 Usenet had built dense connections in North America and Western Europe, with tendrils extending to Australasia and Japan. Reproduced courtesy of Brian Reid.

153 *The Computer Becomes a Communications Platform*

# Web, Cloud & Smartphones

- Hypertext and the classic Web in ch. 12 (“The Computer Becomes a Publishing Platform”
- The cloud and brower-based applications in ch 13. (“The Computer Becomes a Network”)
- Smartphones, mobile devices and apps in ch. 14 (“The Computer is Everywhere and Nowhere”)

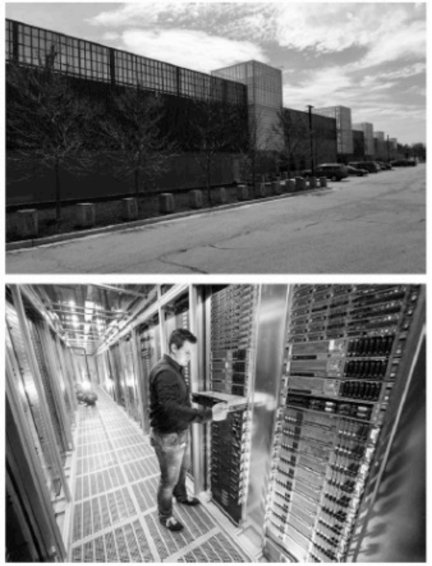


Figure 13.2
Top: Data center, Ashburn Virginia. Cloud servers are located around the world. The data centers in Ashburn, just north of Dulles Airport in Loudoun County, Virginia, may be the epicenter of cloud storage but their exteriors give little away. Photo by Paul Ceruzzi. Bottom: inside a T-Systems (Deutsche Telecom) data center in Biere, Germany, in 2014. A technician removes a standard-sized rack mount unit from a chassis into which servers, network switches, backup power supplies, and storage arrays all fit. These rack-mounted servers placed a PC motherboard, drives, and expansion cards into a compact, easily swappable case. Photo: Thomas Trutschel via Getty Images.

364 *Chapter 13*

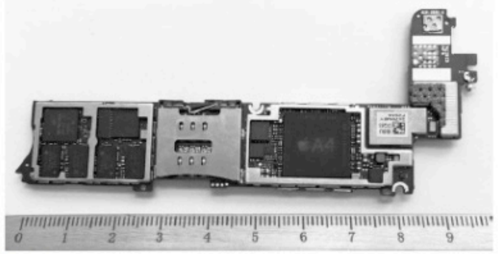



Figure 14.3
An iPhone 4 circuit board from 2010. The large A4 system on chip (SOC), also used in the first iPad, integrates an ARM-based microprocessor with a graphics processor and, sandwiched into a second layer above the processor, 512 MB of RAM. Other chips integrate up to 32 GB of flash memory, radio receivers and transmitters, a GPS receiver, an accelerometer, and a magnetic compass. The entire board is less than 10 cm long. Photo: Paul Ceruzzi.

small screen. Others offered social media and communication services already popular with personal computer users, such as Facebook, YouTube, Netflix, and Skype.

Apple's affluent customer base and thriving App Store made it the leading target of smartphone developers even after rival platforms with the same capabilities became available. The growing complexity of professional applications, plus the investment needed to get a new product distributed and advertised, had consolidated the PC software industry around a handful of large publishers. In the 1990s, entrepreneurs and investors had shifted their focus from software packages to websites. In contrast, iPhone apps were relatively simple programs, and modern development tools made it easier for small groups to produce polished software.

The App Store gave those groups a shot at distributing that software to a large market. By 2016, the App Store had more than two million apps available for download, with about 100,000 new or updated titles arriving every week.[9] Using the App Store was safer than downloading a conventional program from the Internet and offered something the Web lacked: a built-in payment system. The vast majority of apps sank without trace, but there were enough stories of authors earning huge payouts from self-published programs to inspire many others to try their luck.

Many of the most popular apps were accessible titles that exploited the iPhone's novel interface capabilities, like tilting the phone or flicking a finger. The *Angry Birds*

396 *Chapter 14*

# Digital Media Devices

- The vast majority of the computers in the world do not look like computers
- Ch 11: "The Computer Becomes a Universal Media Device"
    - Fax machines
    - DVD players
    - Music players
    - 1990s game consoles
    - Digital cameras
    - Music synthesizers
    - HD televisions, etc.

computers), or regular computers to automate the control of electronic instruments. The Atari ST, one of the few computers to include MIDI sockets as standard, was a common sight on stage during the late 1980s. Synthesizers defined much of the popular music of the era, particular in Britain where their possibilities were variously explored by the perky Human League, mopey Depeche Mode, camp Soft Cell, orientalist Japan, and wonderfully arch Pet Shop Boys. Not everyone liked the new sound—one disgruntled writer coined the term "Casio effect," after a leading producer of cheap keyboards, to describe the displacement of a technology by a convenient but inferior rival.[9]

Keyboard synthesizers were coupled with electronic drum machines, grinding out robotic rhythms that no human could hope to replicate. The iconic drum machine, the Roland TR-808, was labeled "Rhythm Composer. Computer Controlled." It combined analog drum synthesis with digital sequencing, driven by an embedded microcontroller (the computer doing the controlling), running a program burned into ROM. Microcontrollers account for most of computer technology's power as a universal technological solvent. As of this writing, they cost just a few cents each when ordered in bulk, making them cheaper and more flexible than the huge range of control mechanisms they've dissolved, from rotating cylinders in the mechanical programmers of washing machines to hardwired digital logic in burglar alarms.

The noises produced by the TR-808, particularly the bass effects, were nothing like real drums, but that ultimately made them more interesting—and more immediately recognizable—than expensive rivals better able to pass for human drummers. On


**Figure 11.7**
Apple's original iPod was controlled by four buttons, and a mechanical control wheel turned to move though menus and song lists. It held up to three thousand songs on a miniature hard disk drive with more than a thousand times the capacity of IBM's original RAMAC unit. Image created by Wikimedia user Miguelon756–5303, used under the Creative Commons Attribution-Share Alike 4.0 International license.

thousand songs in your pocket." They fit because Apple had built it around a new, miniaturized, 1.8-inch hard drive able to store 5 GB. The user interface was stripped down to its essentials, centered on a spinning wheel. Four buttons let users start/stop playback, jump forward or backward with songs, and return to the previous screen. As with the original Macintosh, back in 1984, the interface broke new ground. Unlike the original Macintosh, the iPod was ideally suited to its intended task.

Other companies had already built players around hard drives. What Apple did have was first rate industrial design and an aesthetic of elegant simplicity. Reviewing the device, Walter Mossberg of the *Wall Street Journal* called it a "terrific music player that solves all [the] problems" with rival hard drive based players like Creative's Nomad Jukebox, launched the previous year, which looked like a bloated, budget priced CD player.[37] Steven Levy devoted an entire book, *The Perfect Thing*, to the iPod, calling it "the most familiar, and certainly the most desirable, new object of the twenty-first century."[38] It felt

317 *The Computer Becomes a Universal Media Device*


**re 11.3**
Roland TR-808 drum machine flaunted its digital sequencing ability in the label "Rhythm Composer. puter Controlled." (Image by Wikimedia user Brandon Daniel used under Creative Commons Attribution- e Alike 2.0 Generic.)

**298** *Chapter 11*

# End Point: A Tesla in the Valley

- I always had a Tesla car, rather than a smartphone, in mind as the end of the story arc
  - Hundreds of embedded computers within the car recapitulate everything the computer became during the narrative
  - In terms of processing power and cost, a modern car is a typical middle class family's biggest investment in computer technology (c.f. impact of recent chip shortages)
- We had the car make its drive through Silicon Valley, to twist the perspective to acknowledge the new centrality of firms clustered there
- Revisions post-review added discussion of computing's essential roles during the current pandemic

# Does the story of "the computer" now have an end as well as a beginning?

Our final page →

the combined size of those of the US and Europe. Despite China's increasingly overt regulation of personal freedom and economic activity it appears poised to emerge from the pandemic on course to overtake the US as the world's largest economy more rapidly than previously expected. We can at the very least, no longer assert that Internet technology has an inherent tendency to boost freedom and undercut autocracy. Nor is it clear that democratic systems of government will shape its continued development.

And so on, and so on. By the time you read this, many more things will have happened in the world and a good proportion of them will have been made possible by computer technology. Yet, this may be a good place to end our story. At the start of the 2020s, the story of modern computing has reached the beginning of an end, as the last great story of modernist technological progress fractures belatedly into postmodern chaos. Computing is deeply intertwined with vital structural developments in global relations, economics, society, and culture. Barring apocalypse, those connections will only deepen. As the computer has become a truly universal machine, the history of computing has become a part of the history of everything. Computer technology does not dictate the direction of history, but its affordances do create new possibilities, advantage some choices over others, and rearrange economic and political incentives. We began the story of the modern computer with the debut of a single machine on the front page of the *New York Times* in 1946 and have followed its legacy to the point of asking whether liberal democracy can survive the Internet. There is little prospect of squeezing an answer into this book. Once computers became part of every infrastructure, the idea of *the computer* as a machine in the tradition of ENIAC, a self-contained device whose users tackled different jobs by creating new programs, has become less relevant. The conceptual problem with the idea of a universal solvent was always that, if any such substance was ever concocted, no flask could contain it. Our protagonist, which dissolved so much in the world that once seemed permanent, has finally dissolved itself.

# 4: Limitations and Challenges

# Limitations of our new book

- Retains US bias
  - Default is to tell story from US viewpoint, other countries enter the story mostly when they push technology in unique directions
  - E.g. France for Minitel, UK for 1980s home computers and ARM, etc.
- Little on race, largely mirroring the secondary literature
- Political engagement comes primarily in the epilogue, in a kind of twist ending
- Treatment of recent developments shallower, based on news reports rather than secondary historical literature
  - Last few chapters will go out of date much faster than the first ten

# A question:

- Can a comprehensive overview history of computing be coherently structured around anything OTHER than the story of “the computer”?
- Maybe,
  - Otherwise it just becomes the history of everything, as the scope of computing has become so big
  - Each chapter could (and should) be told in its own book, focused on a different community over time
- We attempt to tell human stories within the individual chapters of a book whose overall protagonist is a cluster of technologies.

# A necessary evil? An unnecessary one?

- One might see the need for a one-volume history, but only for teaching or non-specialists
- One might take a stand against broad, comprehensive narratives as inherently favoring the interests of dominant groups
  - Should white men get to tell big stories anymore?
  - Is “problematization” of myths of progress an end in itself?
  - Should we be content just to push back at the (now ended) veneration by politicians and customers of Silicon Valley and big tech firms?
- Or, one might align the story closely with the history of US or global capitalism, looking always for racism, sexism, heteronormativity
  - So that computing doesn’t need its own story, as it just reflects broader developments

# Disjunction between the history of computing and general (US) history

- My most general self-definition is as a US historian
- Main teaching areas
  - History of Race and Health in the US
  - History of Capitalism in the US
- Both go from the colonial era to Covid-19 over the course of a semester, focused on
  - National expansion and domestic conflict
  - Racial struggle and oppression
  - Clashing interests and experiences of different social groups

# Do we need a master narrative of computing?

- Term itself was of course always pejorative (Lyotard, 1979)
  - And “master/slave” language is being replaced even in technical usage
- For generations ambitious historians have been acclaimed for undermining received narratives
  - Stress on discovering agency, specificity, complexity
- Which is a problem in areas like computer science
  - Where the boring, plodding internal, technical and institution histories were never written in the first place
  - So there is nothing to become famous by undermining

# My own hope

# My own hope

- Is that we as a community can work towards broad, coherent and ambitious narratives of computing that don’t just echo and reenact those long told in social and cultural history
  - Because there is something unique about the trajectory of computer technology since 1945
  - And its distinctive affordances underpin the dominance of big tech firms, the rise of fake news, replacement of devices with code, etc.
  - So maybe we can create the narratives and frameworks that other historians and tech scholars will find useful to understand crucial aspects of our world

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- Ties into my current project to derive a historically grounded understanding of digital materiality
  - In collaboration with others associated with Siegen University’s Media of Cooperation SFB