HIS 2129

Technology, Society and Environment since 1800

(Winter 2014)

Remote Control: The Information Revolution

- Communication technologies make it possible to collect information about faraway places, often to the point of permitting either a “sense of presence” in remote locations for the user or a “virtual presence” of another user in the user’s own location
- While such information has political and strategic uses, it can also be used to better control local and remote events
- However, processing the information received is a challenge that must not be underestimated
- The roots of information processing can be traced to calendrical and scientific concerns, but the creation of data-processing capacity has proven to have wide-ranging consequences

Who invented video games?

- This Atari computer game (Galaxian, from Konami) dates back to 1981
- Computer, electronic games, and the Internet have all become significant industries
- But where did they get their start?

The development of computers

- The story of calculators
- Punched cards and tabulating machines
- Programming machines in the 19th century
- Programming machines in the 20th century, with the help of electronics
- From the mainframe back to the calculator, thanks to the calculator
- From hypertext to the internet

Mystery Task of the Week

- Multiply two 8-digit numbers:
- 45624107×98130187
- A pre-1855 calculating machine designed and built by Charles X. Thomas in France could multiply two 8-digit numbers in 18 seconds. By the end of the 19th century, a human computer using a simple mechanical calculator could multiply two 10-digit numbers in 12 seconds, not counting the time required to consult tables or write down results.

2007 Record: 4m40s

Three lines of descent: machines

- Calculators: from the mechanical calculating machines of the 16th c. to the business machines and cash registers of the 20th c.; performed the four basic operations; dependent on manual input
- Tabulating machines: introduced by Hollerith in the late 19th c.; encode data with punched cards; able to perform addition on large quantities of <u>information</u>;
- Programmable machines: introduced by Babbage in the early 19th c.; encode data <u>and</u> instructions with punched cards

Three lines of descent: people

Calculators

Blaise Pascal
Gottfried Leibniz
Charles X. Thomas
William S. Burroughs
(Curt Herzstark)

Tabulating machines

Herman Hollerith
[IBM]

Programmable machines

Charles Babbage
George Scheutz
Vannevar Bush
(John von Neumann)

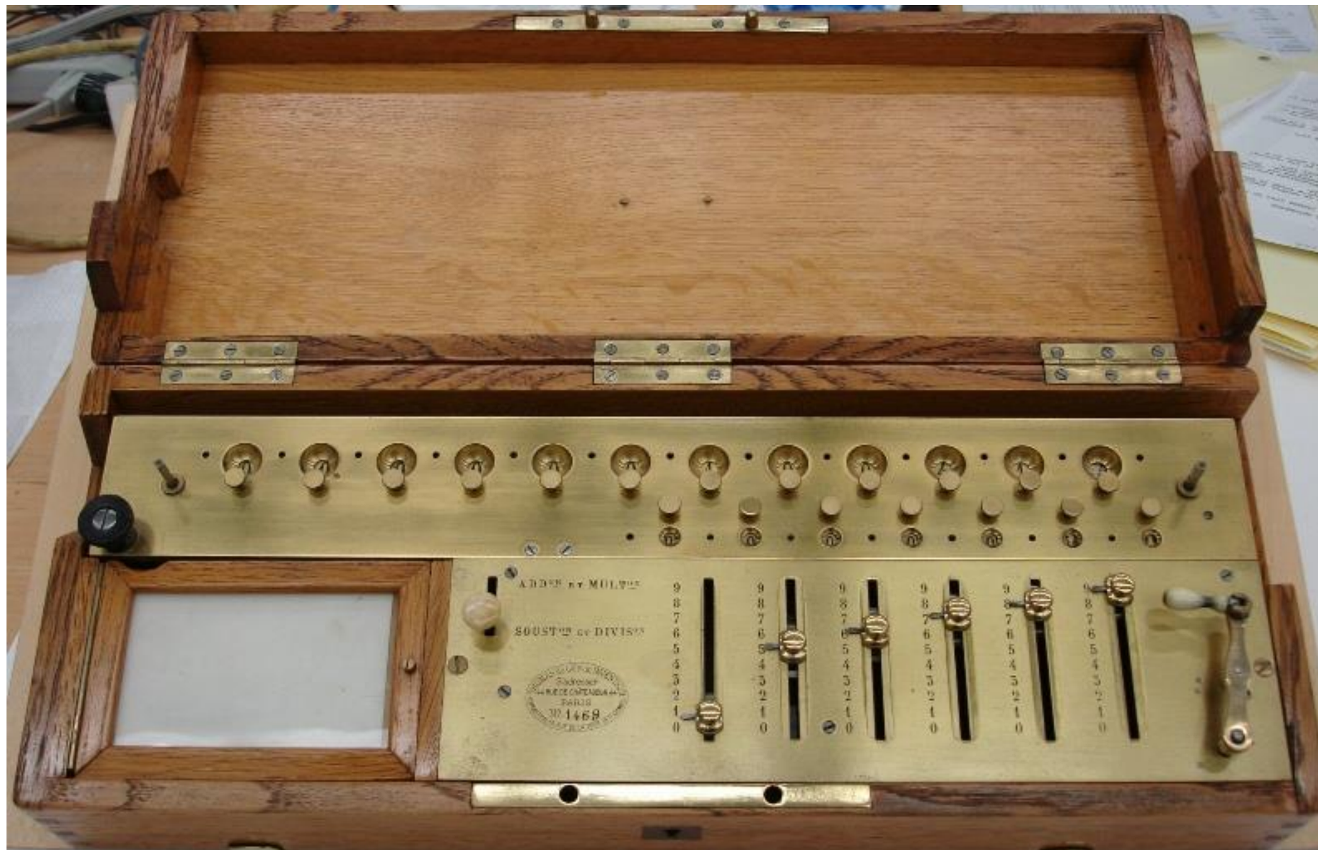
John Mauchly and J. Presper Eckert
(ENIAC, 1945-1946)

From Computers to Machines… (I)

- The first “computers” were people who calculated; they could be clerks and accountants, but early astronomy demanded intricate calculations that were carried out by devoted mathematicians and their assistants
- Therefore, it is not surprising that mathematicians like **Blaise Pascal** and **Gottfried Leibniz** were the first to design calculating machines
- The design conceived by Leibniz in the late 17th century influenced many other inventors, including Charles Thomas who steadily perfected a high-performance calculating machine (known as an *arithmometer*) during the first half of the 19th century

The Thomas Arithmometer

Charles Xavier Thomas (1785-1870) of Colmar (France) patented a belt-driven calculator in 1820 that he then perfected over the course of several more decades. By the last decades of the nineteenth century, they were being made and sold in increasing numbers. (But it would be an exaggeration to speak of "mass production" in their case.)



The First Computer Boom…

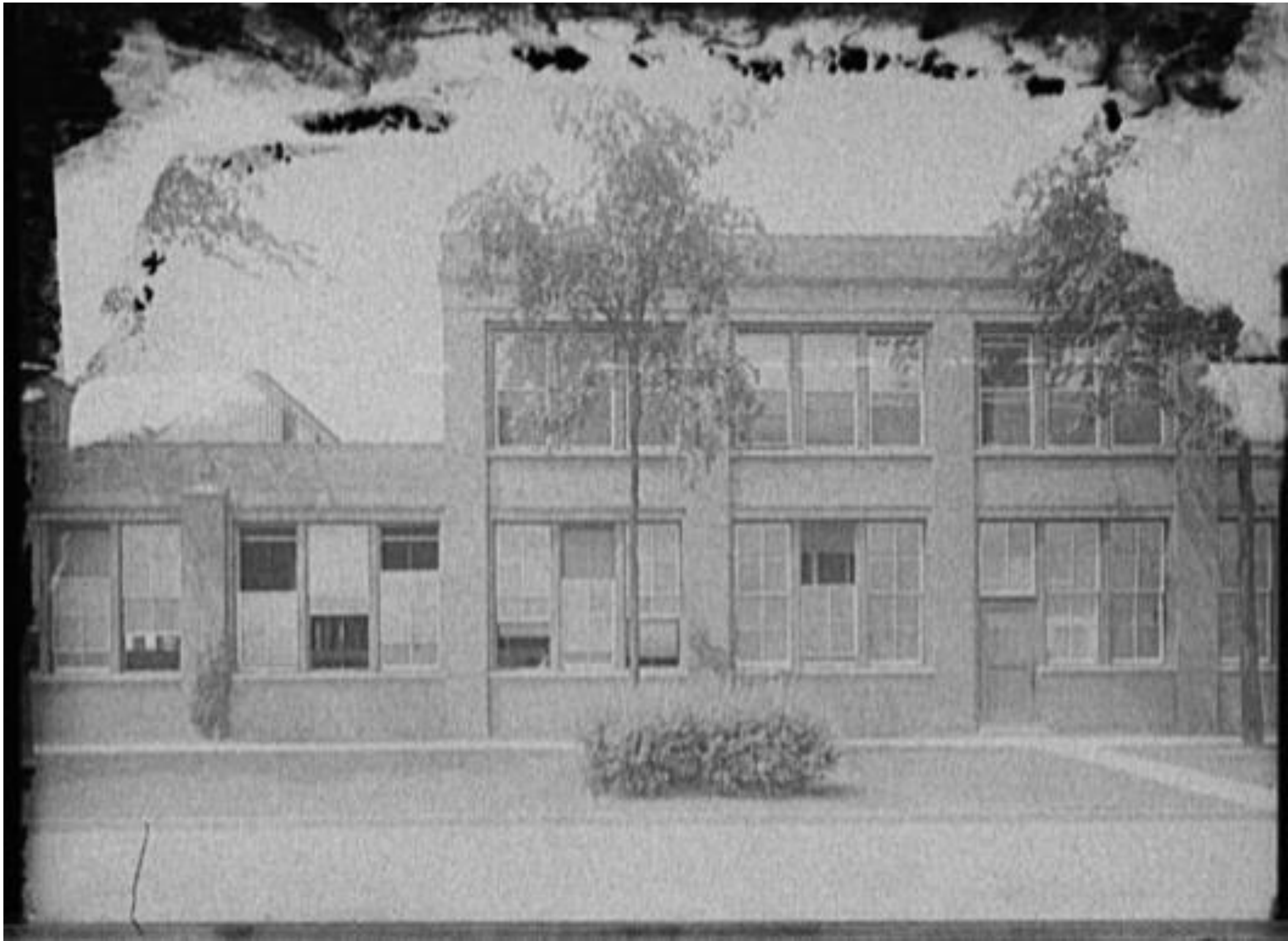
- The Thomas arithmometer showed the way to other inventors in Europe and North America

Poster for a Burroughs "Registering Accountant", *circa* 1891 ➔

🡐 Style No. 4 adding machine, *circa* 1898-1903

- Though the basic mechanical design was different, the Burroughs adding machine was marketed by the "American Arithmometer Company"
- While it was successful, it was only one of many

The American Arithmometer Co. Plant (Detroit, Michigan, *c.* 1905)



Detroit Publishing Company Photograph Collection, Library of Congress

To recapitulate (1)

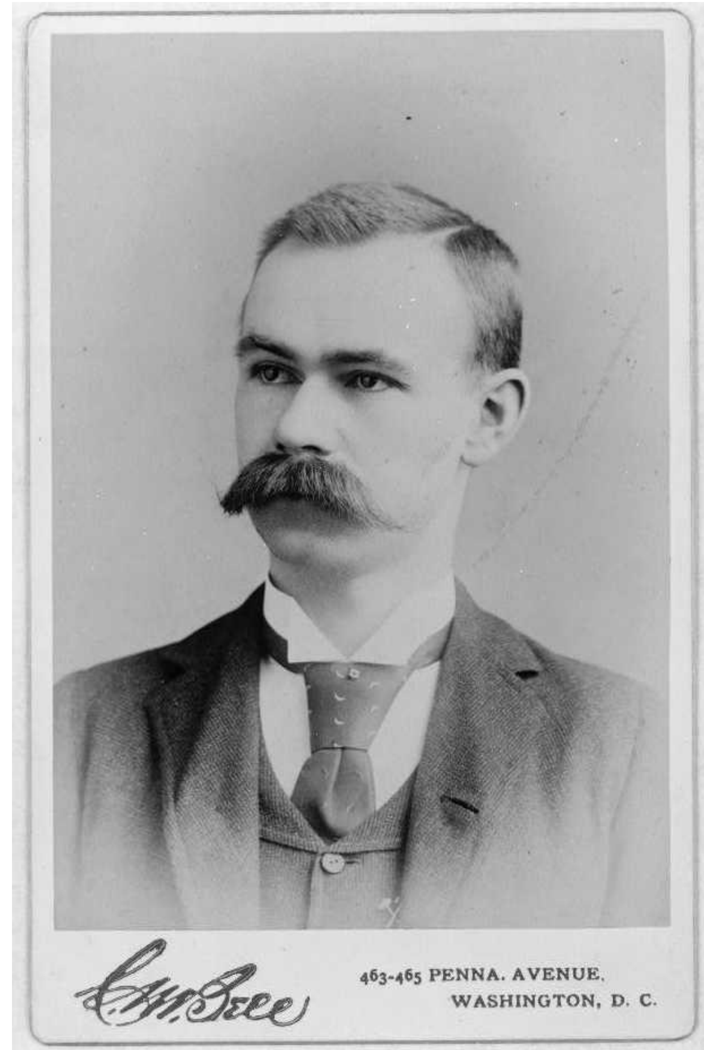
- What European mathematician came up with a key design for mechanical calculators that influenced inventors down to the 19^{th} century?
- What two mechanical ancestors of the modern computer encoded data on punched cards?
- What U.S. company began making commercial calculators in the late 19^{th} century to reproduce the success of the Thomas arithmometer?
- Associate one inventor with each line of descent of mechanical precursors of modern computers.
- What mechanical ancestor of the modern computer relied entirely on manual input?

On the road to modern computing

- Adding machines (especially when they were called “Registering Accountants”!) proved that it was possible to supplement mechanically, perhaps even replace the mental work performed by humans
- Beyond the basic operations of arithmetic, with the results printed out on a slip of paper, other elementary operations beckoned, such as the tabulation of selected data
- This last challenge was taken up by U.S. inventor Herman Hollerith in the hope of selling the resulting device to the U.S. Census Bureau

Tabulating Machines

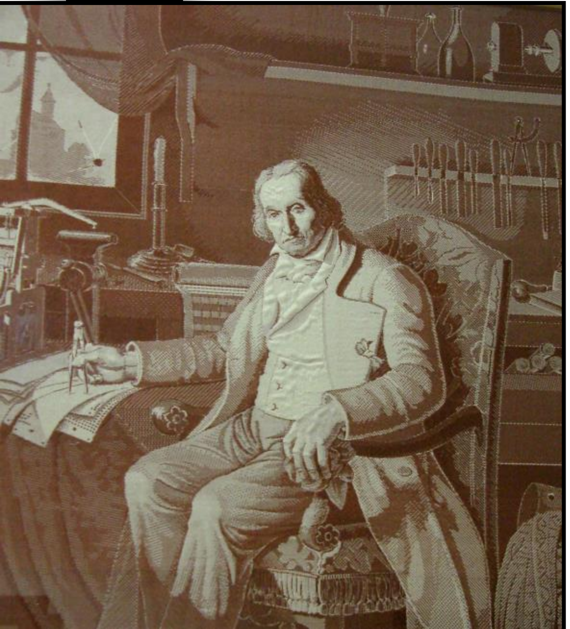
- Herman Hollerith (1860-1929) designed a tabulating machine using punched cards that was first put to work by the New York Board of Health and several other states for tabulating vital statistics
- The machine was then used on a large scale for the 1890 census of the United States
- The company founded by Hollerith was one of the direct forerunners of IBM



Picture of Herman Hollerith by Charles Milton Bell (Library of Congress)

Punched cards before Hollerith

- Building on earlier 18^{th}-c. developments in France, Joseph Marie Charles *dit* Jacquard (1752-1834) perfected the use of punched cards for looms after 1801



Left: A silk portrait of Jacquard produced with a Jacquard loom

Right: A typical Jacquard loom

(Both are at the Maison des Canuts in Lyons, France)

The Use of Punch Cards Before Hollerith

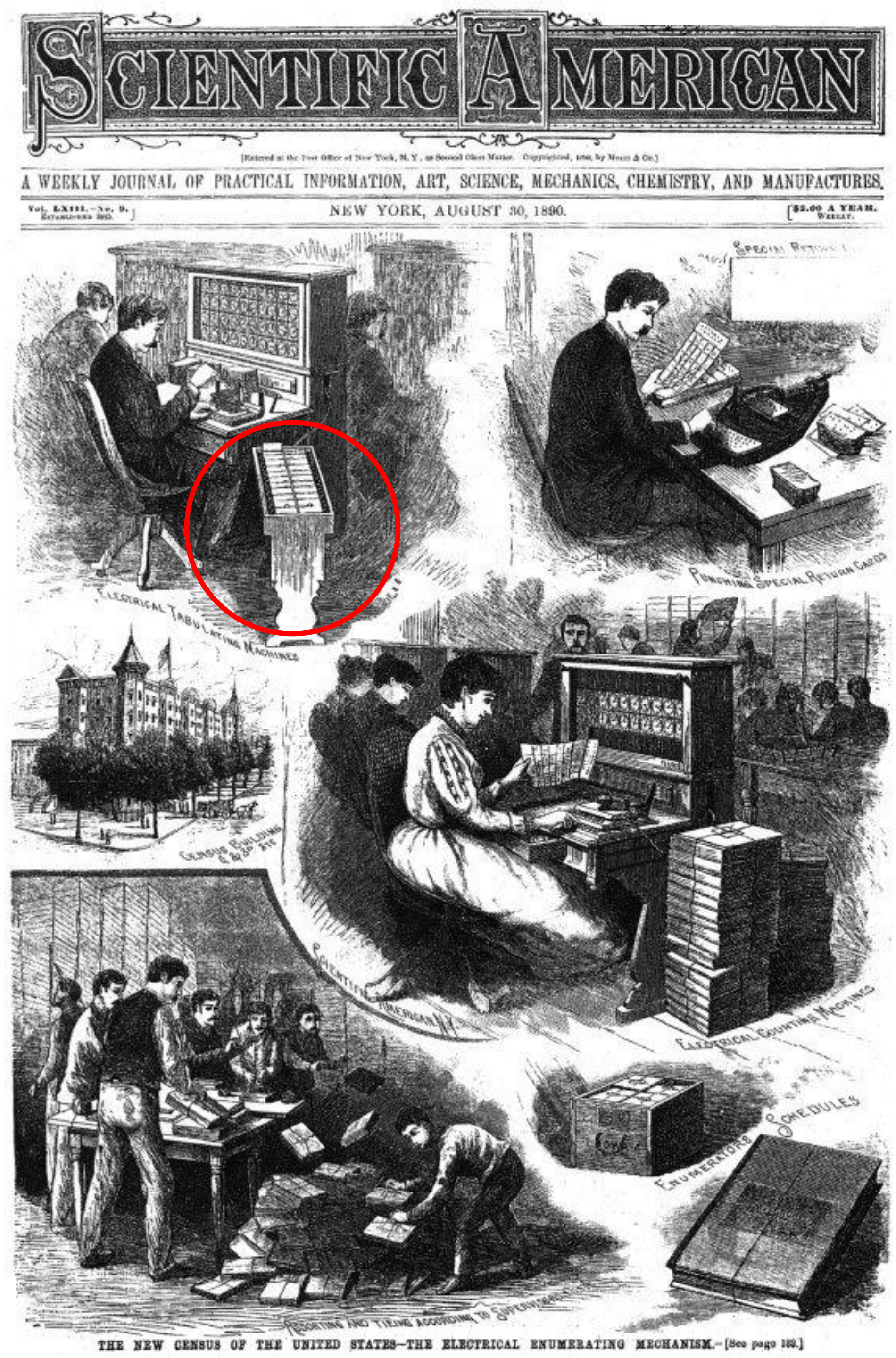
- Jacquard's punched cards were were strung together, made of heavy stock (to resist the mechanical handling), and usually held together by string or cord
- By the 1830s, they inspired inventors such as Charles Babbage, concerned with machine control
- The success of Hollerith inspired many other uses by the early 20th century

Lewis Wickes Hine (1874-1940), Library of Congress

Fifteen-year-old girl punching cards and sheets at the Boston Index Card Co. (31 January 1917, Boston, Mass.)

The 1890 U.S. Census Machines

1) Upper right: the pantograph puncher
2) Upper left: the hand press of the tabulator (with running totals showed by the tabulator dials)
3) Upper left (in red circle): the automatic sorting box with electrically-activated lids opening automatically to the right folder



Scientific American, 30 August 1890

Computing Before World War II

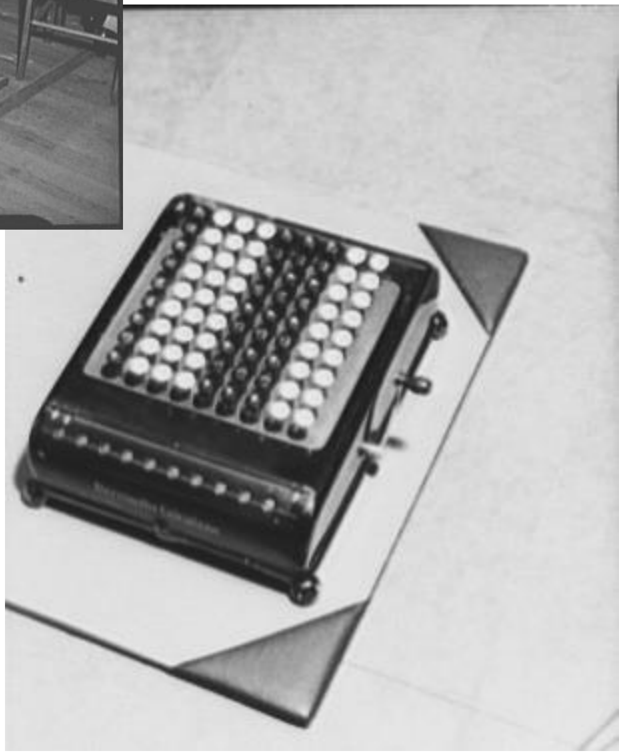
Calculating veteran bonuses in the Treasury (?) Department, U.S.A.

Before the Electronic Computer: A Stable, Mature Technology

Woman with adding machine by 1935 (Library of Congress)

Office worker adding up checks at the W. Atlee Burpee Co. in Philadelphia (PA) in March 1943
Arthur S. Siegel
(Library of Congress)

Theodor Horydczak (*c*. 1890-1971), Library of Congress



Desktop adding machine
(Electric Institute of Washington)

Even in an American concentration camp… Bookkeeper in Manzanar War Relocation Center (California, *c.* 1943)

Mrs. Teruko Kiyomura

Photographs by Ansel Adams (1902-1984)
Library of Congress

Burroughs Adding Machine (1945)

Left to right: Mildred Crooks and Helen Whipple (ex-RCAF LAWs) with instructor Miss Freyne training them at the Burroughs Adding Machine School (April 1945, Toronto)
John F. Mailer, Library and Archives Canada

Other office machines used before the electronic computer

Mrs. Elsie Maddox, automatic key punch and tabulator operator, feeds the punched tape through the machine that marks the cards in the Office of Defense Transportation
(Albert Freeman, Library of Congress)

Operator Jack Keefe, in the IBM room of the Office of Defense Transportation feeds the coded punched cards into the tabulating machines (June 1942)
(Albert Freeman, Library of Congress)

Wartime Records and Files Office at the Experimental Farm (Ottawa, 1945)

To recapitulate (2)

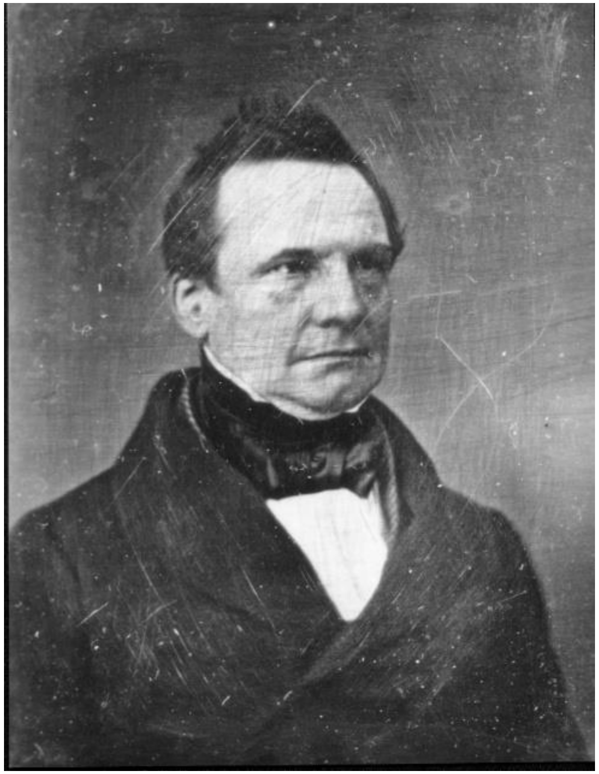
- Before the invention of the electronic computer, were some adding machines electrical?
- What was the oldest mentioned use of punched cards in industry?
- Herman Hollerith's tabulating machine was used
  - **(i)** to calculate veteran bonuses after WWI
  - **(ii)** to run WWII U.S. concentration camps
  - **(iii)** to replace paper records in Canadian offices
  - **(iv)** to process the data from the U.S. census
- The company created by Herman Hollerith became an ancestor of which manufacturer?
  (i) Apple **(ii)** the American Arithmometer Company
  (iii) IBM **(iv)** XEROX

From Computers to Machines… (II)

- In the late 18th century, it occurred to French engineer Gaspard de Prony that the division of labour so enthusiastically described by Adam Smith could be applied to the work of human "computers"
- To reduce the raw data provided by a geographical survey of France, he divided the needed calculations among three groups of variously skilled "computers" (the least able mathematicians being recruited, it is said, among the former apprentices to wigmakers whom the Revolution had deprived of a job by cutting off the heads of aristocrats)
- The speed with which the reductions were completed inspired an English mathematician, Charles Babbage

Charles Babbage (1791-1871)

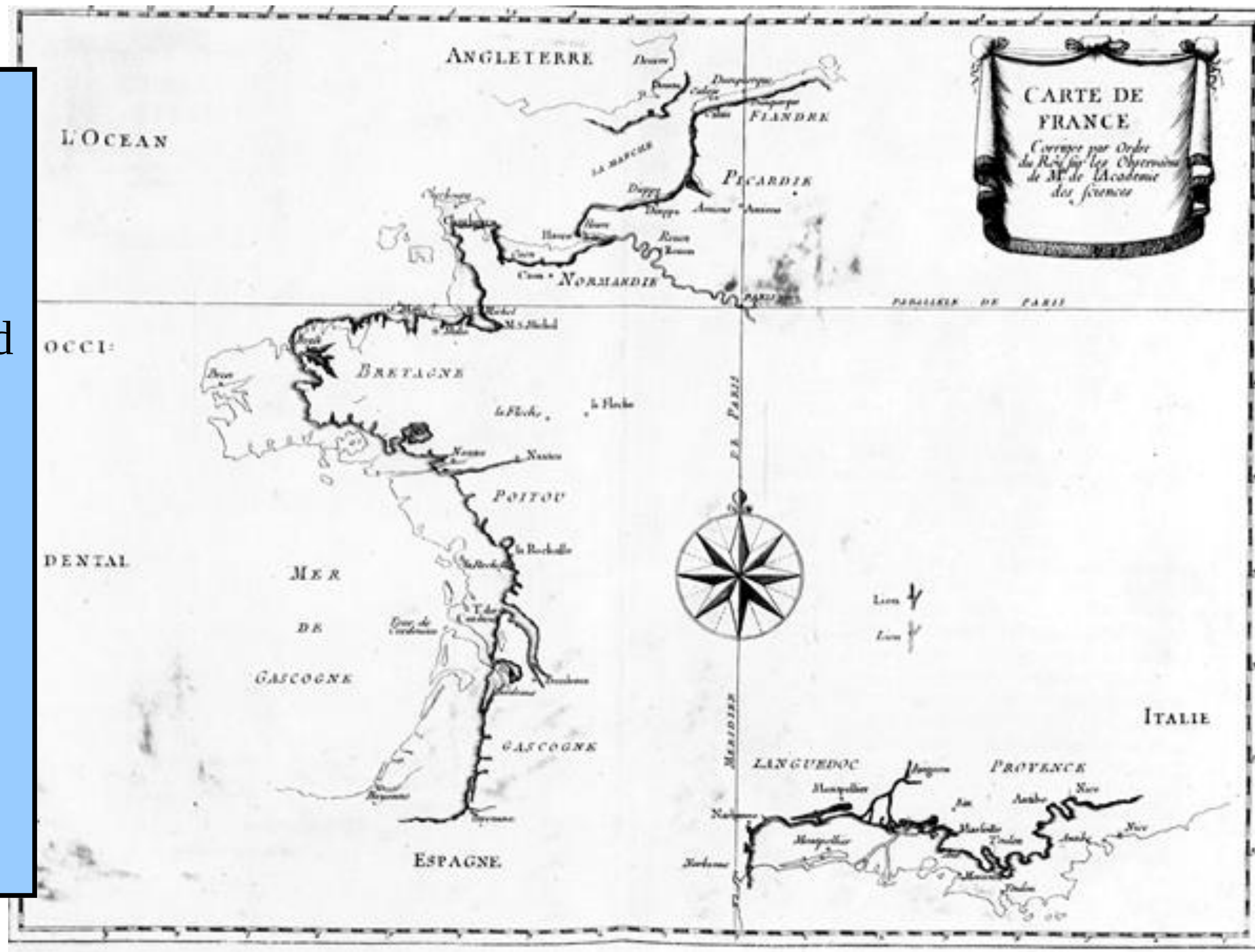
- The son of a banker, he attended Cambridge where he tackled mathematical problems with the younger Herschel
- An inventor and self-proclaimed philosopher, industrialist and friend of the working man, he is remembered as the author of the first universal computing machine
- A keen observer of nature, society, and technology, he also evinced considerable practical talent as a tool and machine designer



Charles Babbage (*c*. 1843)

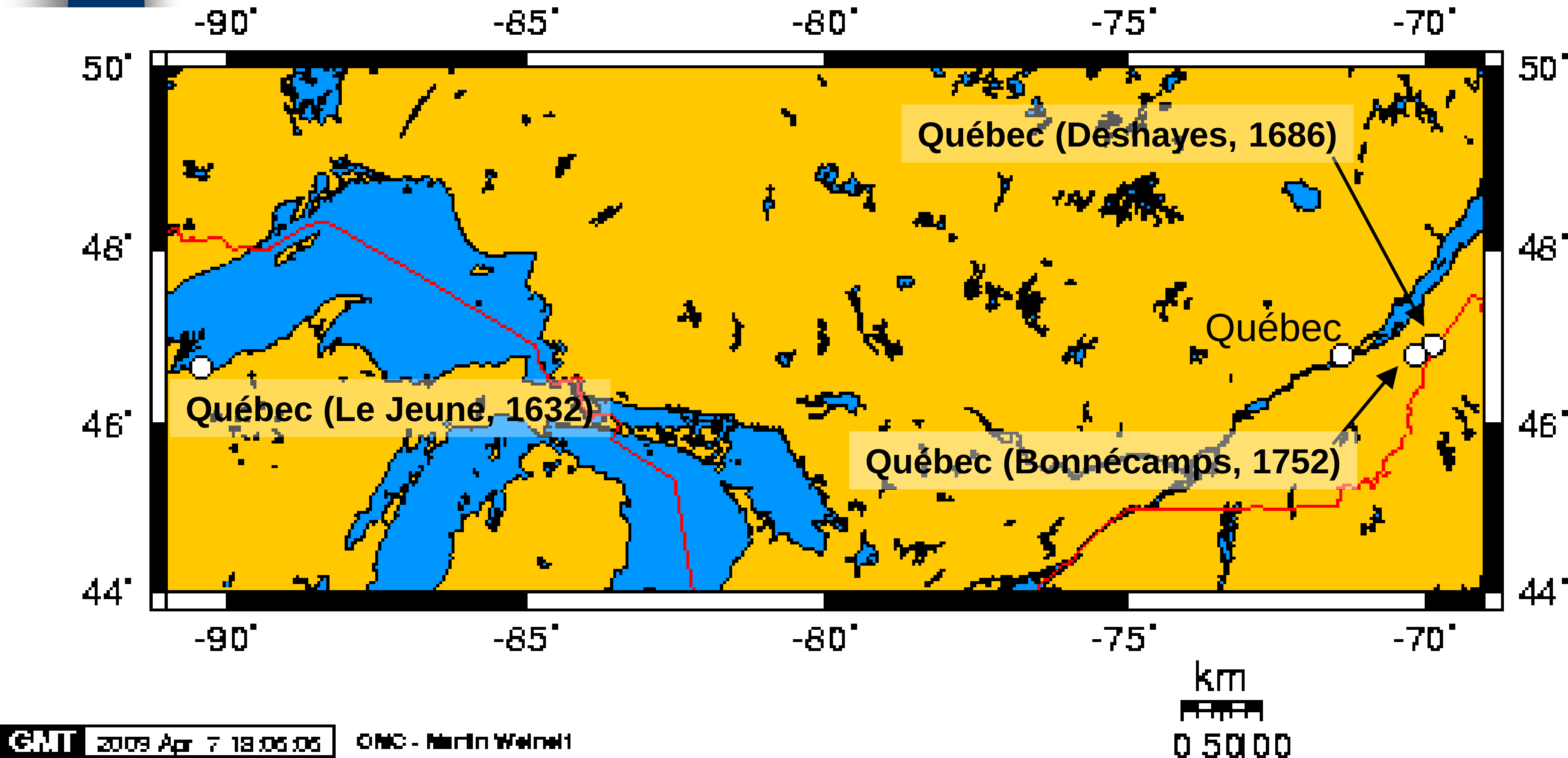
Astronomy and mapmaking in the 17th century

In this 1693 map of France by La Hire based on surveys by royal astronomers, the newly-determined borders (darker ink) are compared with the old ones (pale ink). Accumulated errors between Paris and the far end of Brittany amounted to a difference of over 100 kilometres.



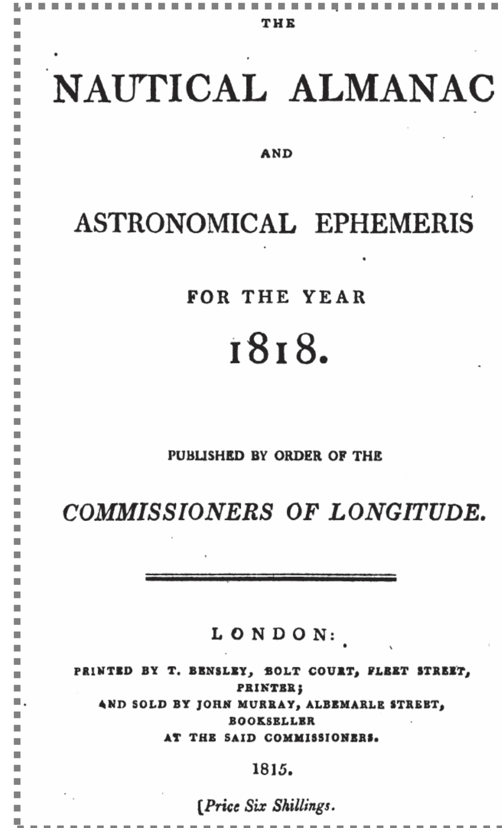
Knowing where you are…

- French explorers and astronomers found it difficult to pinpoint the exact location of Quebec City and the determination of longitude was especially imprecise



A Government Project… alas!

- In 1822, Babbage proposes to mechanize the production and printing of numerical tables
- By July 1823, he is at work on his full Difference Engine (capable of generating six decimal places), using funds from the British government
- A prototype is near completion in 1830 when a disagreement with the contractor leads to the end of its construction
- By then, he is planning better calculating machines, including his Analytical Engine, but he will be unable to get the required funding


THE

NAUTICAL ALMANAC

AND

ASTRONOMICAL EPHEMERIS

FOR THE YEAR

1818.

PUBLISHED BY ORDER OF THE

COMMISSIONERS OF LONGITUDE.

LONDON:

PRINTED BY T. BENSLEY, BOLT COURT, FLEET STREET, PRINTER;
AND SOLD BY JOHN MURRAY, ALBEMARLE STREET, BOOKSELLER
AT THE SAID COMMISSIONERS.

1815.

[*Price Six Shillings.*

Concrete Results

- The simplest Difference Engine was described and built in 1820-23
- The second Difference Engine was never built, but its designs were completed by 1848
- Babbage envisioned the use of punched cards for his grand Analytical Engine, but he couldn't build more than a few parts for it

III. FEBRUARY 1818. 15

Days	Time of ☉'s Semidiam. Pass. Merid.	The SUN'S Semi-diameter.	The SUN'S Hourly Motion.	The SUN'S Logar. Distance.	Place of the ☽'s Node.
	M. S.	M. S.	M. S.		S. M. D.
1	1. 8,1	16. 15,3	2.32,1	9.99366	1.13.26
7	1. 7,4	16. 14,3	2.31,8	9.99410	1.13. 7
13	1. 6,7	16. 13,2	2.31,5	9.99460	1.12.48
19	1. 6,1	16. 11,9	2.31,1	9.99517	1.12.29
25	1. 5,5	16. 10,5	2.30,7	9.99578	1.12.10

ECLIPSES of the SATELLITES of JUPITER.

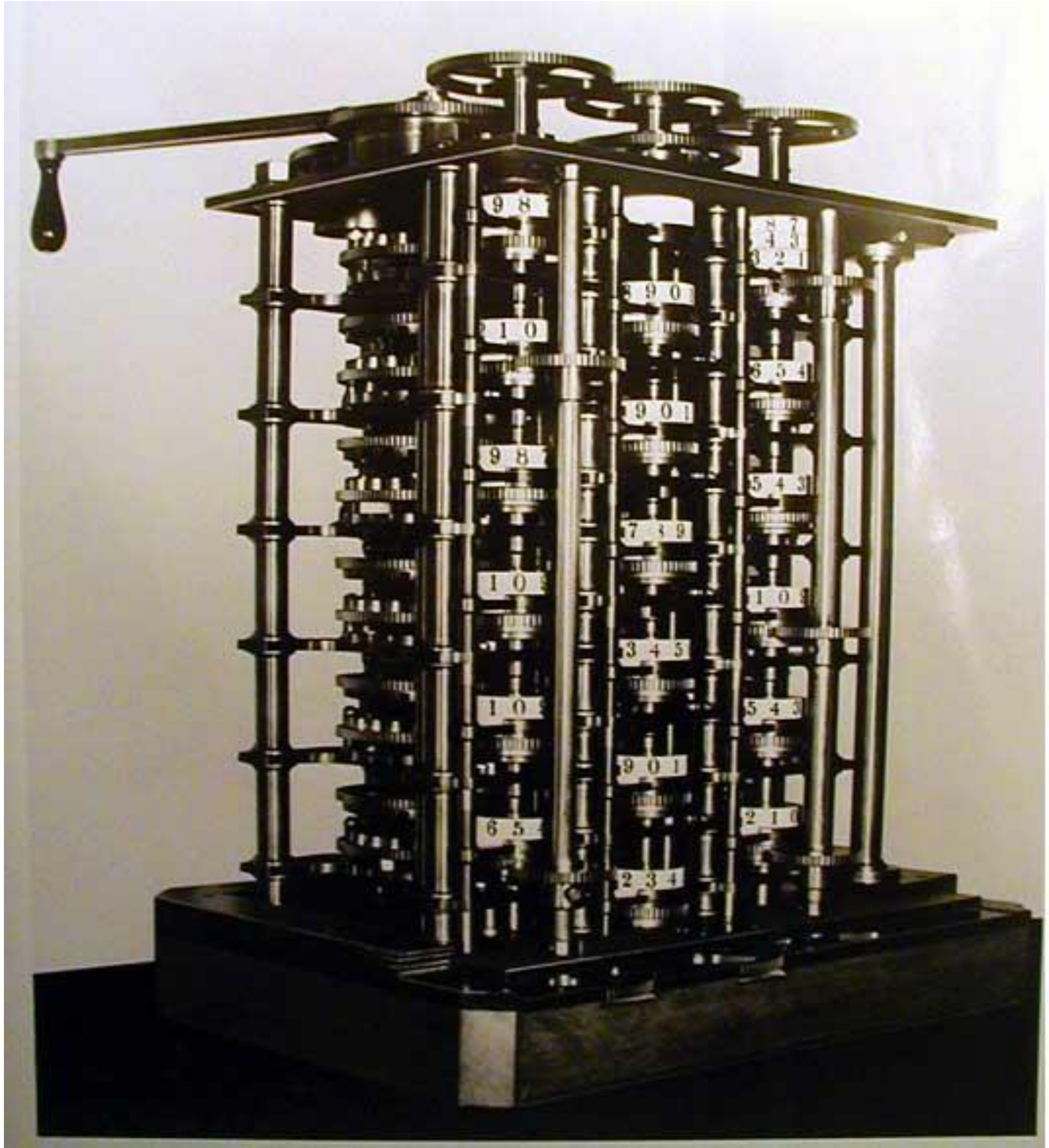
MEAN TIME.

I. Satellite. Emersions.		II. Satellite. Immersions.		III. Satellite.	
Days.	H. M. S.	Days.	H. M. S.	Days.	H M. S.
*1	17. 2.16	1	22.29.40	* 7	18.16.51 Im.
3	11.30.34	5	11.48. 3	7	21. 8. 4 E.
5	5 58.58	9	1. 5.32	14	22.14.35 Im.
7	0.27.16	*12	14.23.46	15	1. 6.38 E.
8	18.55.39	16	3.41.13	22	2.12. 6 Im.
10	13.23.57	*19	16.59.18	22	5. 5. 5 E.
12	7.52.20	23	6.16.41		
14	2.20.37	26	19.34.39		
15	20.48.59				
*17	15.17.17				
19	9.45.40				
21	4.13.57				
22	22.42.20				
*24	17.10.37				
26	11.38.58				
28	6. 7.17				

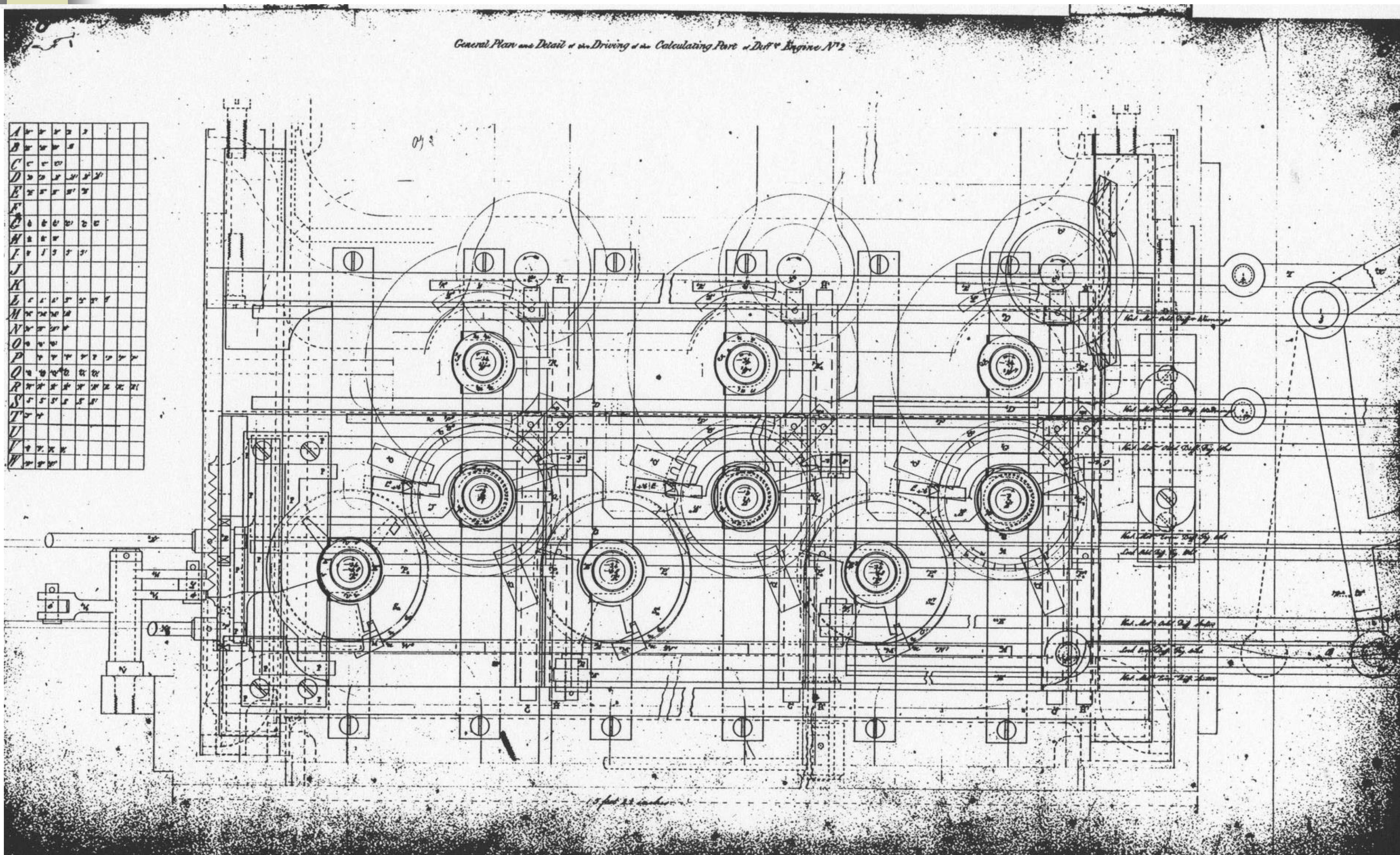
IV. Satellite.

- Babbage's design of lathes and tool-shapers for the required die-cast pewter gear wheels stimulated the British machine tool industry; a foreman of his, Joseph Whitworth, played a prominent role in that industry and introduced the first standard screw threads

Difference Engine No. 1



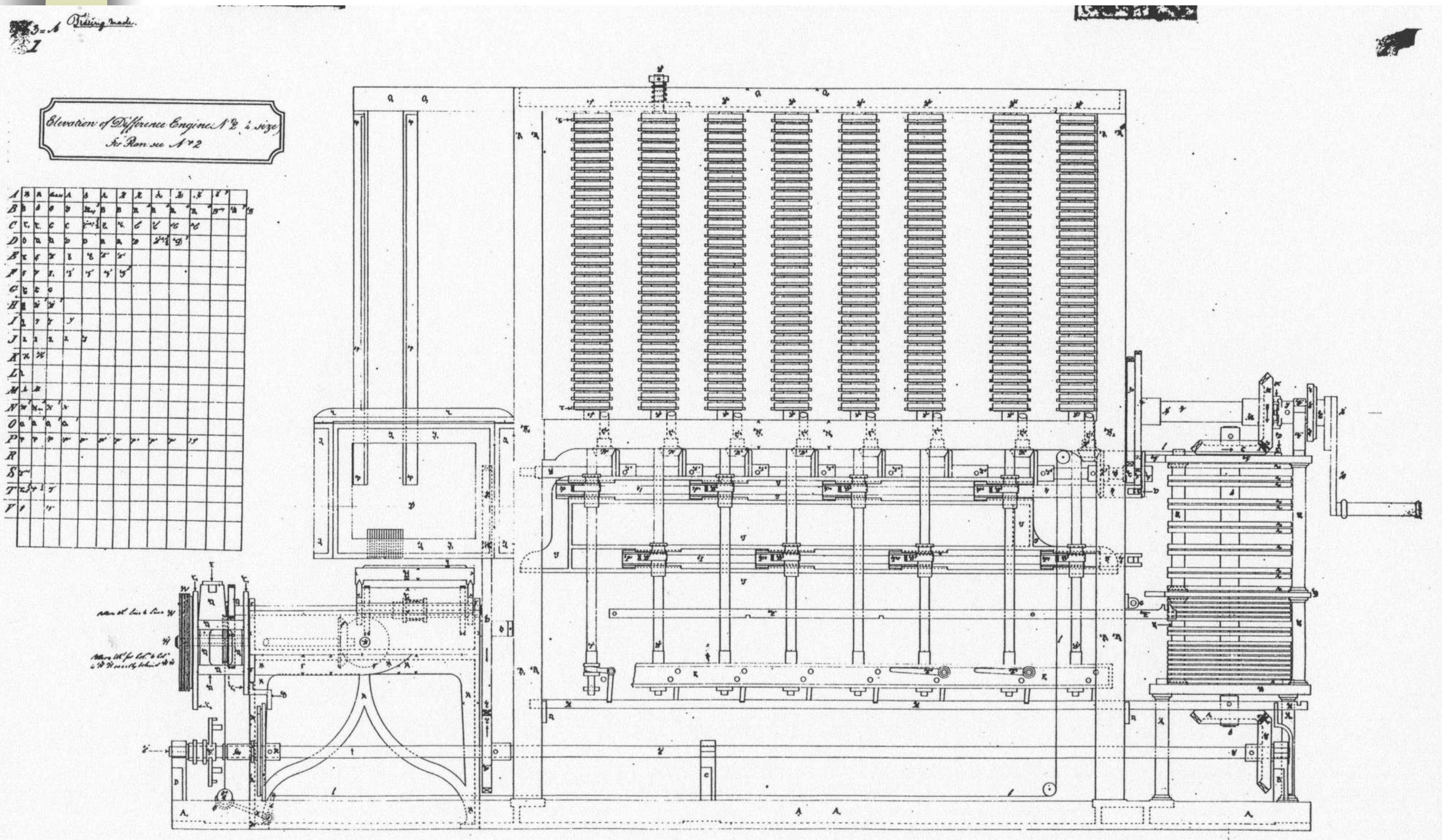
The Driving of the Calculating Part of Difference Engine No. 2



Doron Swade, *Charles Babbage's Difference Engine No. 2: Technical Description*, British National Museum of Science and Industry, Papers in the History of Technology No. 5., 1996

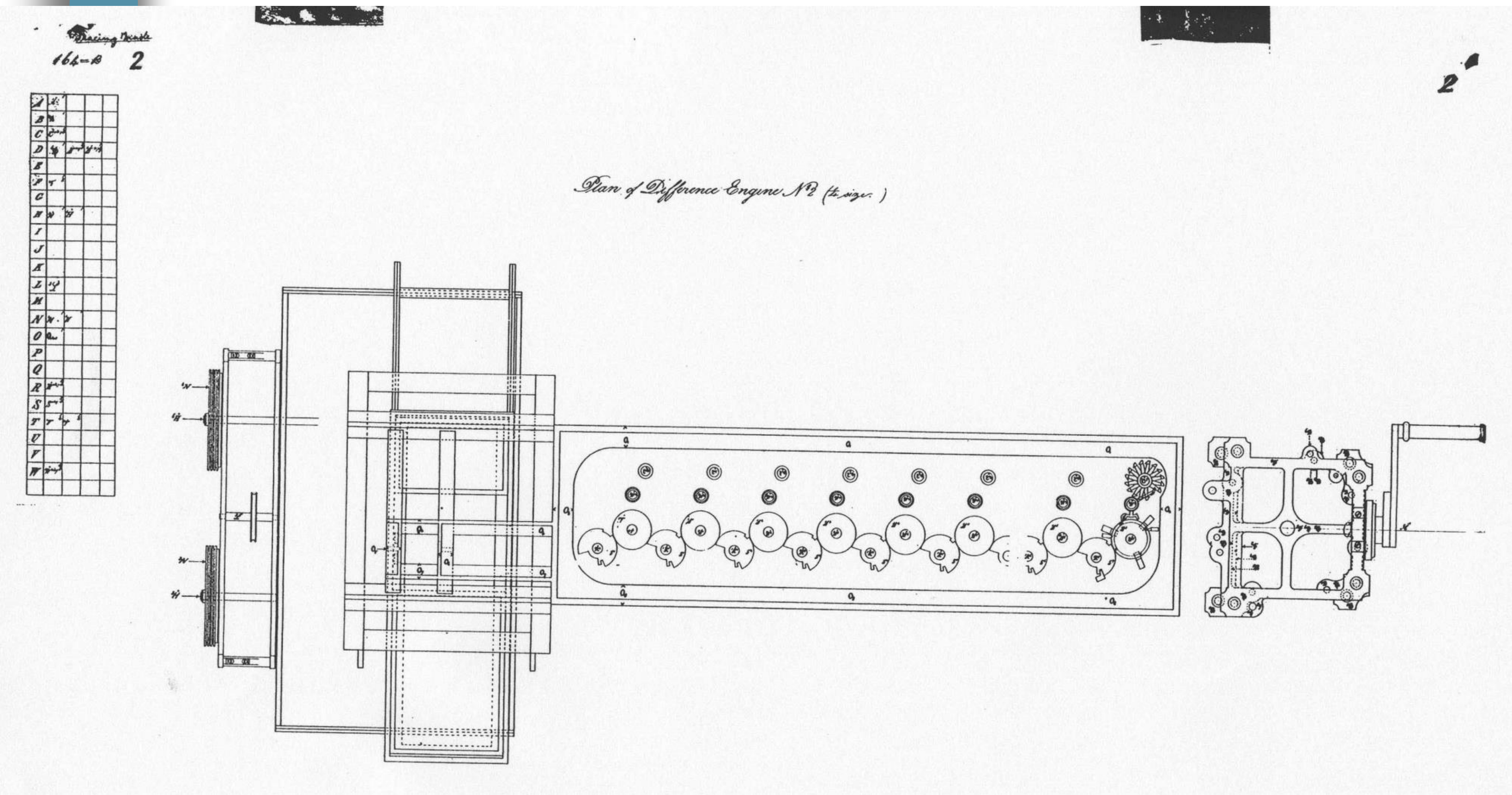
Elevation
of Difference Engine No. 2

Doron Swade, *Charles Babbage's Difference Engine No. 2: Technical Description*, British National Museum of Science and Industry, Papers in the History of Technology No. 5., 1996

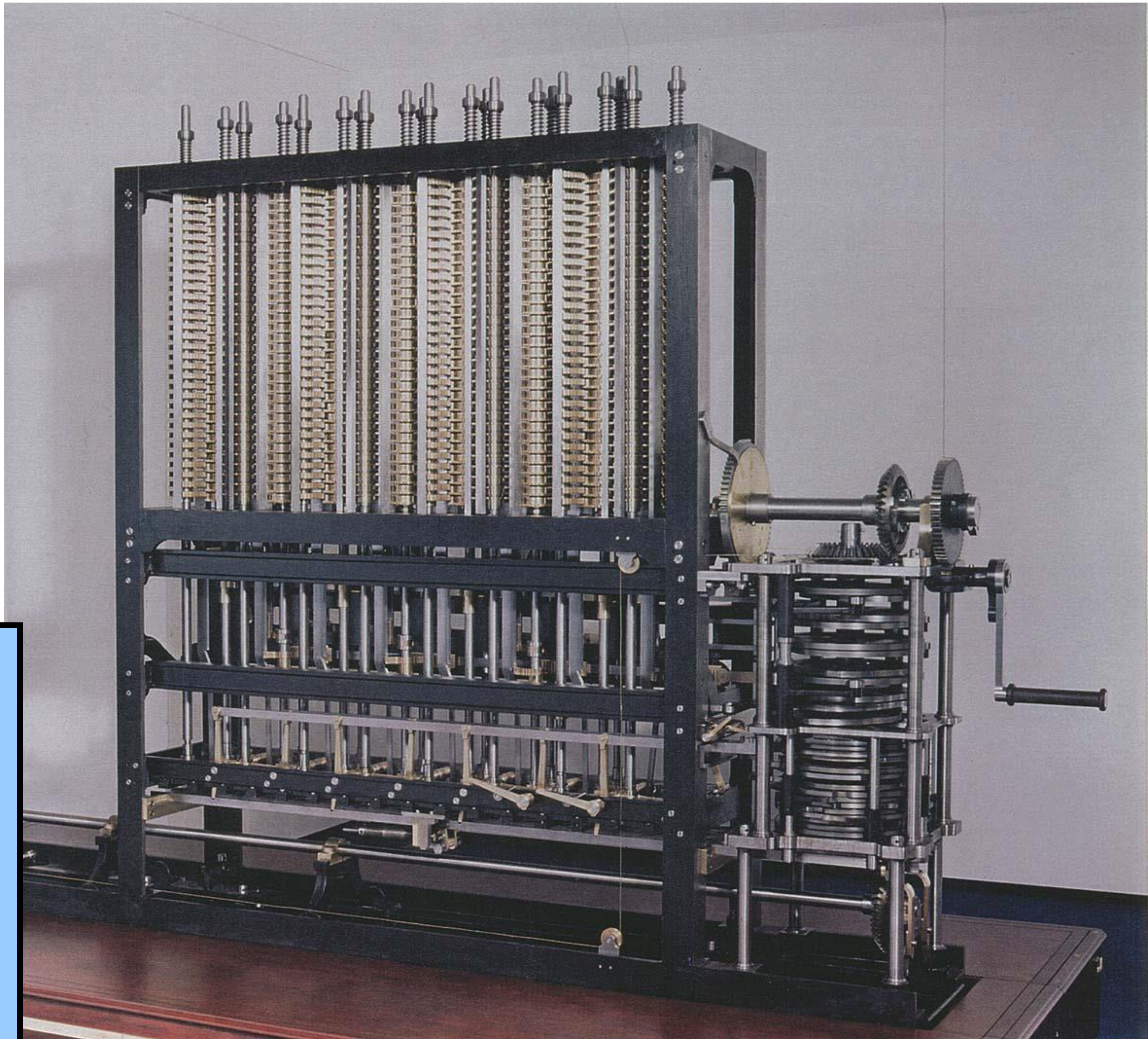


Plan of Difference Engine No. 2

Doron Swade, *Charles Babbage's Difference Engine No. 2: Technical Description*, British National Museum of Science and Industry, Papers in the History of Technology No. 5., 1996



Difference Engine No. 2



This Difference Engine (Babbage's second version) was built at the British National Museum of Science and Industry in 1991. The printing extension is missing, but it was finally built and added to the replica in 2000.

To recapitulate (3)

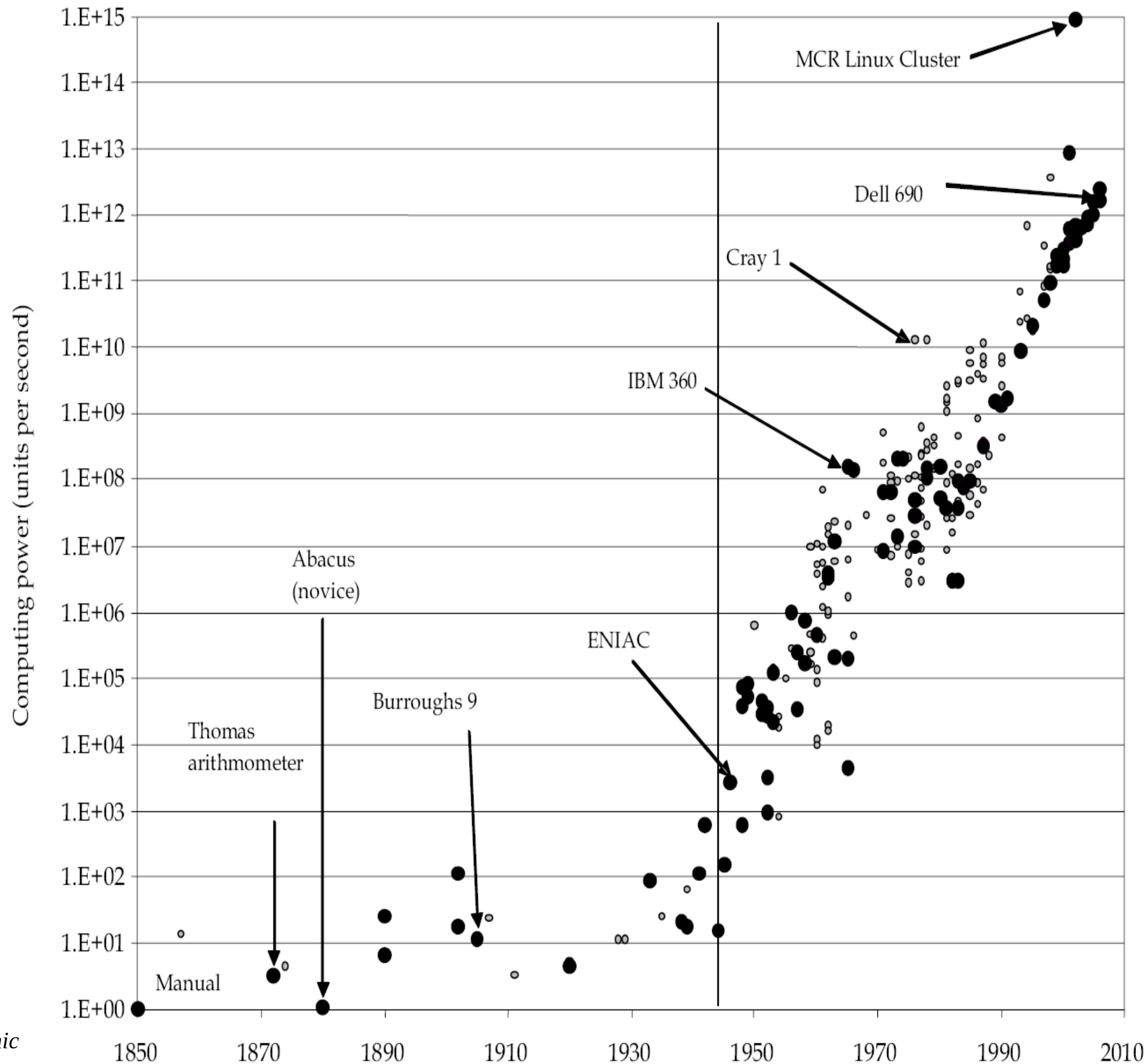
- The conception of Babbage’s high-precision mechanical calculating machine was inspired by
  - (i) the astronomical discoveries of John Herschel
  - (ii) the division of labour observed by Adam Smith
  - (iii) the new survey of France by Gaspard de Prony
- In terms of error reduction, what was one key advantage of Babbage’s second Difference Engine?
- Name two (2) concrete consequences of Babbage’s efforts to build a Difference Engine
- Was Babbage’s Difference Engine No. 2 ever built in his lifetime? Why?

From Machines to… Computers

- The third stage in the evolution of modern computers began during the interwar period
- Starting in 1925, Dr. Vannevar Bush at M.I.T. developed with his collaborators a mechanical differential analyzer to solve differential equations
- While he experimented with electrical integrators, mechanical wheels and discs were used in the first effective models; during World War II, versions of the Bush Differential Analyzer were used to compute firing tables, processing a 60-second trajectory in 15 minutes whereas a human operator of a desk calculator would need 20 hours to do the same
- The next step was the Mark I Relay Computer created by Howard Aiken in 1944 with assistance from IBM and Harvard

The Rise of Computing Power

(in computations per second)
Filled circles designate the more reliable estimates, while the empty ones are less reliable values. The break in the trend happens in 1944. Here, manual computing is set as the reference at 1.



From: William D. Nordhaus, "Two Centuries of Productivity Growth in Computing", *The Journal of Economic History*, **67** (March 2007), 143.

The Electronic Computer (1)

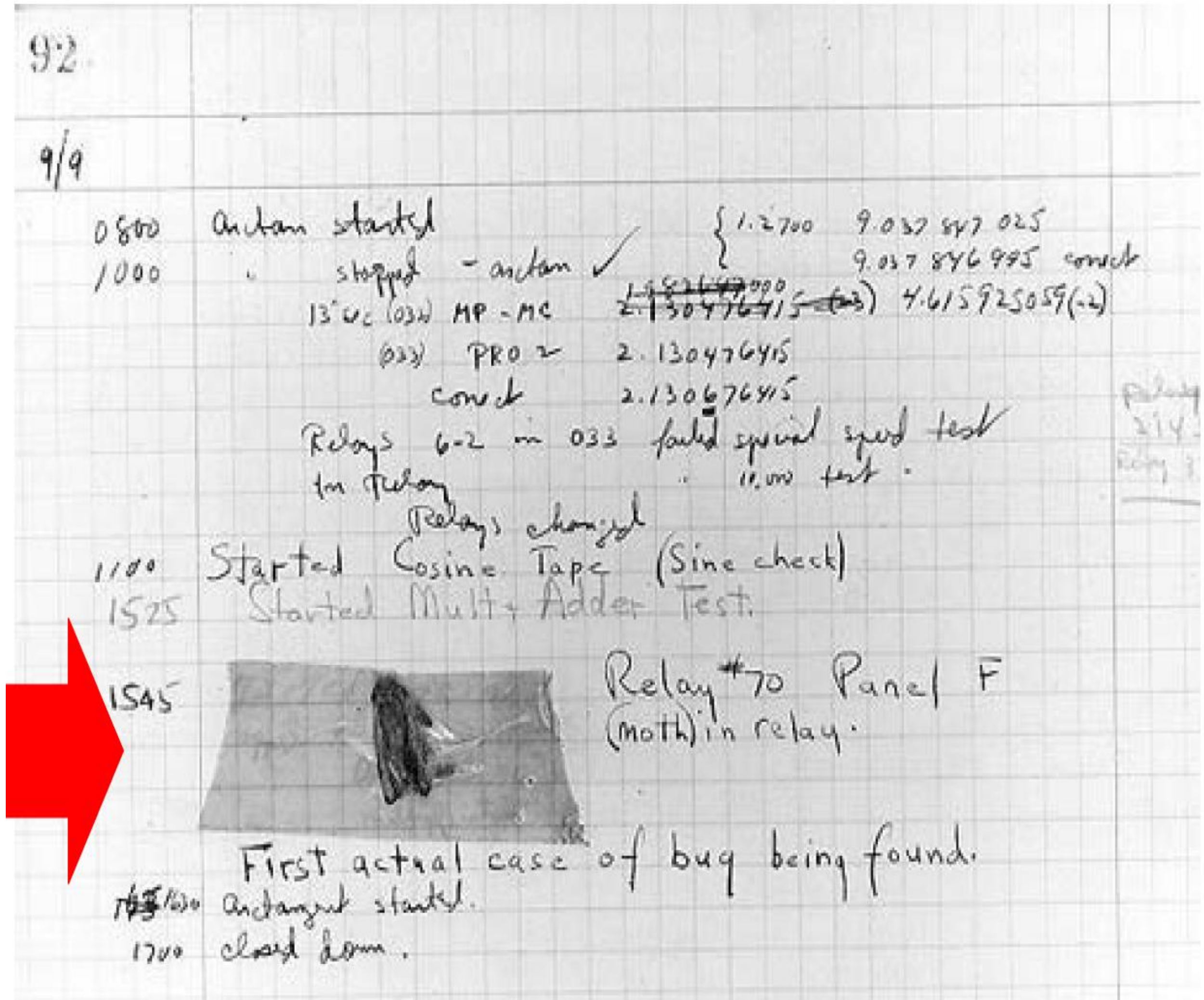
- Technologically, the electronic computer was an outgrowth of the radio (vacuum tubes), but the first generation also incorporated punched cards, electricity, and the basic architecture of Babbage
- The first effective programmable electronic computer is generally admitted to be the ENIAC (Electronic Numerical Integrator And Computer) built at the Moore School of Engineering of the University of Pennsylvania by **John Presper Eckert** and **John Mauchly** in 1944-1946
- However, electronic technology was also applied to information processing in England and the U.S. by inventors such as John V. Atanasoff (1941) and Alan M. Turing (Colossus, 1943)

The Electronic Computer (2)

- The breakthroughs of the war years did not lead to immediate developments
- Not until 1949 were users able to access functional electronic, digital, stored-program computers such as the EDSAC (Cambridge University, UK), quickly followed by the Manchester Mark I (UK), the EDVAC (Moore School, USA), and the computer at John von Neumann’s Institute for Advanced Studies (IAS)
- Commercial versions of these machines then entered the market: the **UNIVAC** (1951) and the **IBM 701** (1952) were the most powerful, but the British firm **Ferranti** also put out its Mark I in 1951 (the second one made was Canada’s first modern machine at the University of Toronto in 1952)

Bugs and Vacuum Tubes

- Vacuum tubes were famously hard to work with; given the huge numbers in early machines, tubes failed constantly
- Edison had talked of bugs, but some were real insects in early machines



Paul E. Ceruzzi, *A History of Modern Computing* (MIT Press, 2003)

Who bought the first computers?

- A complete UNIVAC sold for about a million dollars at first
- Its central processor used 5,000 vacuum tubes, but its main novelty was the use of magnetic tape to store and retrieve data
- Customers were governmental or large corporations

UNIVAC	**Customers**
Summer 1951	U.S. Census Bureau
late 1952	U.S. Air Force (Pentagon)
late 1952	U.S. Army Map Service
Fall 1953	U.S. AEC (N.Y.U., NY)
Fall 1953	U.S. AEC (Livermore, CA)
Fall 1953	David Taylor Model Basin (Carderock, MD)
1954	Remington Rand, NY
1954	General Electric, KY
1954	Metropolitan Life, NY

Ferranti Mark I	**Customers**
February 1951	Manchester University
April 1952	University of Toronto

Mainframes and Organization Men

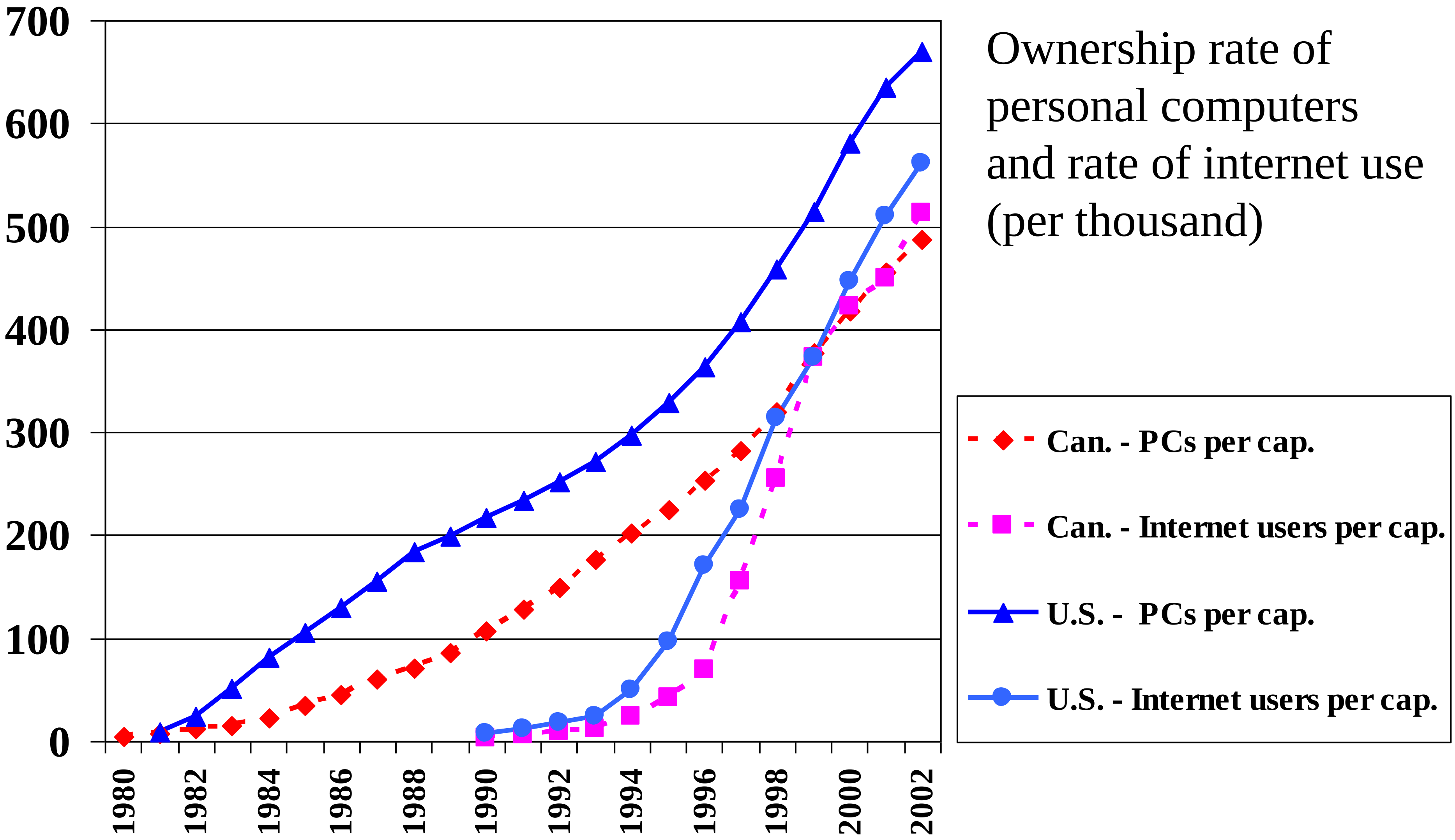
Collins C-8500 computer (Toronto, October 1968)

From Mainframe to Calculator

- The UNIVAC generation, 1951-1960s (vacuum tubes)
- Second-generation computers, 1956-1963 (solid-state transistors)
- Third-generation computers, 1964-1971 (integrated circuits)
- Modern computers and handheld calculators were made possible by the microprocessor (1969)

In 1977, the TI-30 was the first cheap scientific calculator, using one chip for most functions, one 9V battery, and a LED display

From personal computers to internet access (1980-2002)



To recapitulate (4)

- By the year 2000, was the number of Internet users per capita higher in Canada than the U.S.?
- Identify four (4) generations of modern electronic computers and the key, associated technologies.
- Were the first half-dozen customers of UNIVAC from the private or public sector?
- Did the Thomas arithmometer offer more computing power than the ENIAC?
- In the U.S., firing tables were calculated faster than ever before during WWII by
  - (i) the Bush differential analyzer
  - (ii) the ENIAC
  - (iii) human computers using abaci

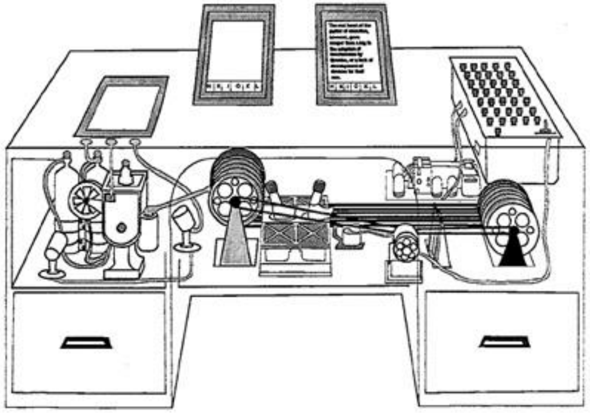
The *memex* of Vannevar Bush in "As We May Think" (1945)

- In an essay for the *Atlantic Monthly*, Bush arguably describes in conceptual form the notion of the modern internet *hyperlink* for an information-processing device he called the <u>*memex*</u>
- "When the user is building a trail, he names it, inserts the name in his code book, and taps it out on his keyboard. Before him are the two items to be joined, projected onto adjacent viewing positions. At the bottom of each there are a number of blank code spaces, and a pointer is set to indicate one of these on each item. The user taps a single key, and the items are permanently joined [...]"

The "trail" as hyperlink

- "Thereafter, at any time, when one of these items is in view, the other can be instantly recalled merely by tapping a button below the corresponding code space. Moreover, when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book. It is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book."

Conceptual schematics for the Vannevar Bush *memex* (1945) ➔



Inventing the Internet

- In 1959, U.S. engineer **Paul Baran** begins working at the Rand Corporation on a communications system that could survive a nuclear ballistic missile strike; by 1964, he has released a plan for a "distributed adaptive message-block network"
  (for "message-block", read *packet* in modern parlance)
- However, the U.S. Air Force decides not to build it
- In 1965-1966, U.K. computer scientist **Donald Davies** (re)invented "packet-switching" to make it easier for programmers to communicate by telephone with a large remote computer running several *time-shared* programs by sending commands split into discrete **packets** of equal length

The first networks

- In the U.K., Davies spearheaded the creation of the Mark I network in 1969, with packet-switching but only a single node connecting the terminals, remote computers, and peripherals at the National Physical Laboratory; an upgraded Mark II system operated from 1973 to 1986
- In the U.S., ARPA did not have its own labs, but its staff was able to fund and manage projects carried out by academic and industry contractors
- Mandated by the government to create “centers of excellence”, ARPA was funding by 1970 computing centres scattered across the U.S.
- **ARPANET** was intended to connect them

From ARPANET to internet (1)

- ARPANET was being planned in 1967 when ARPA computer scientist **Lawrence Roberts** heard of the British work at a conference and, through the British, of Baran’s earlier work
- ARPA’s contractors at BBN (Bolt, Beranek and Newman) drew upon both to design the network nodes, the adaptive routing, and packet-switching using a new generation of computers as switches
- In September 1969, the first node was installed at UCLA

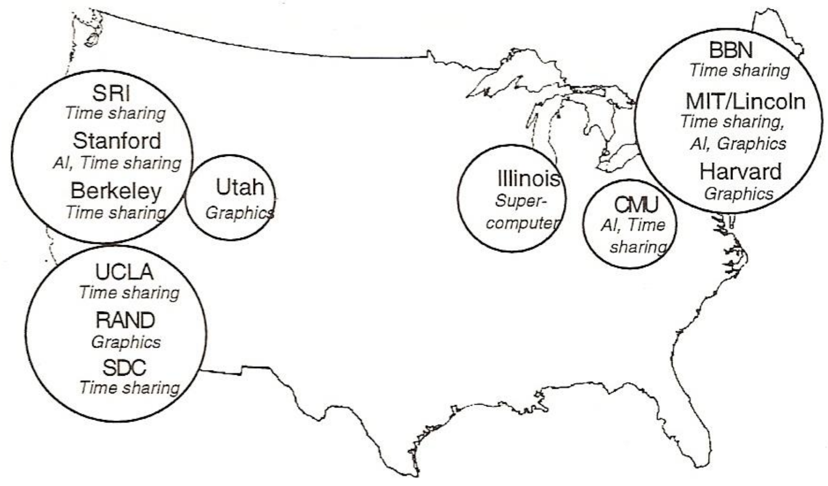


Figure 2.1
The main IPTO research centers at the time of the ARPANET’s creation.

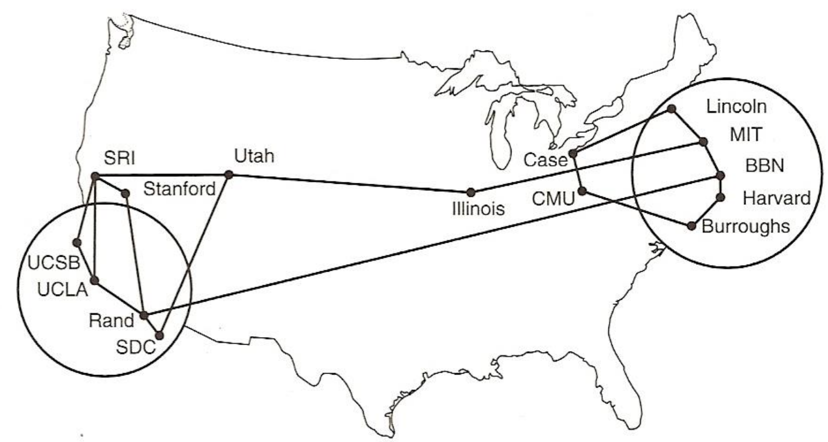


Figure 2.2
A map of the fifteen-node ARPANET in 1971, redrawn from Bolt, Beranek and Newman’s original. (SDC: Systems Development Corporation. CMU: Carnegie Mellon University.)

Source: Janet Abbate, *Inventing the Internet* (1999), p. 45.

From ARPANET to internet (2)

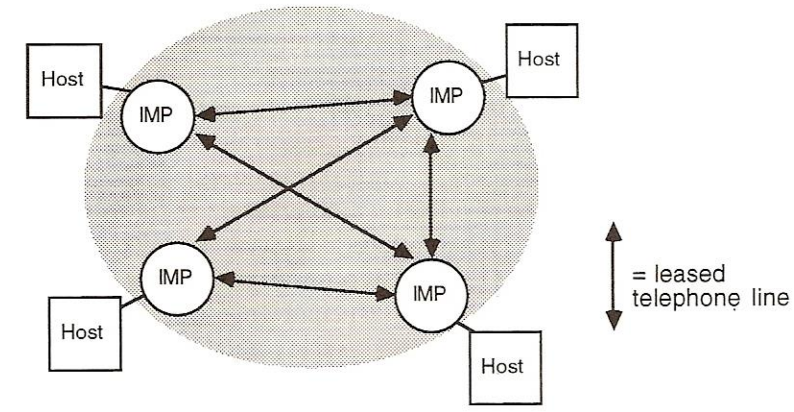


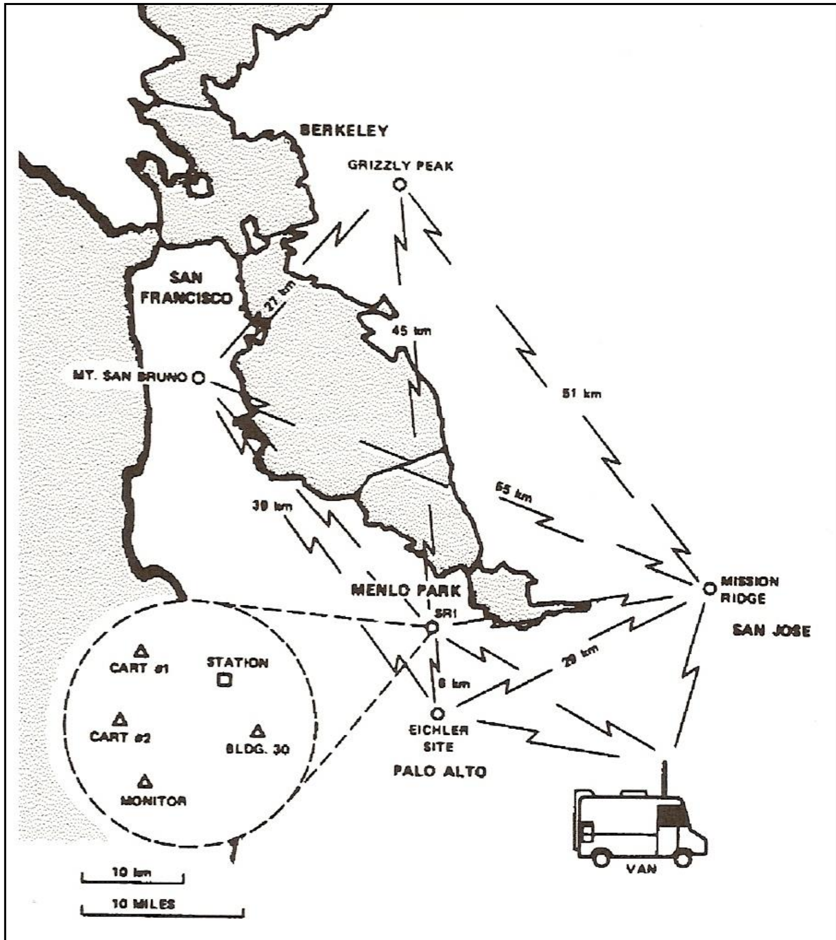
Figure 2.3
Network model with communications subnet.

- ARPANET was up to 4 nodes by the end of 1969; it numbered 15 nodes in 1971 and was connecting to sites outside the ARPA network of computing centres
- After the display of ARPANET capabilities at the October 1972 First International Conference on Computer Communications, ARPANET traffic went up by 67%
- By 1975, the first commercial packet switching network using ARPANET-derived technology was serving seven U.S. cities

Source: Janet Abbate, *Inventing the Internet* (1999), p. 52.

Birth of the Internet (1)

- The ARPANET was one network; by 1975, ARPA operated ARPANET and two packet-switching networks using land-based radio (PRNET, inspired by Hawaii's similar Alohanet from 1970) and satellite radio (SATNET)
- The University of Hawaii's Alohanet also inspired work that led to the development of Ethernet technology at the Xerox Palo Alto Research Center by the mid-1970s



o = repeater

Figure 4.2
A map of the PRNET in 1977. The repeaters were located in elevated areas to increase their unobstructed transmission range. A radio-equipped van was used to test mobile communications. Source: Kahn et al. 1978.

Source: Janet Abbate, *Inventing the Internet* (1999), p. 119.

Birth of the Internet (2)

- To tie together the ARPA networks, Robert Kahn (ARPA) collaborated with Vinton Cerf (Stanford University) in 1973 on the basic design of the modern Internet, using ideas from Louis Pouzin and Hubert Zimmerman of the French Cyclades network project, and from Robert Metcalfe and others at the Xerox Palo Alto Research Center who had designed the Ethernet to connect PARC workstations

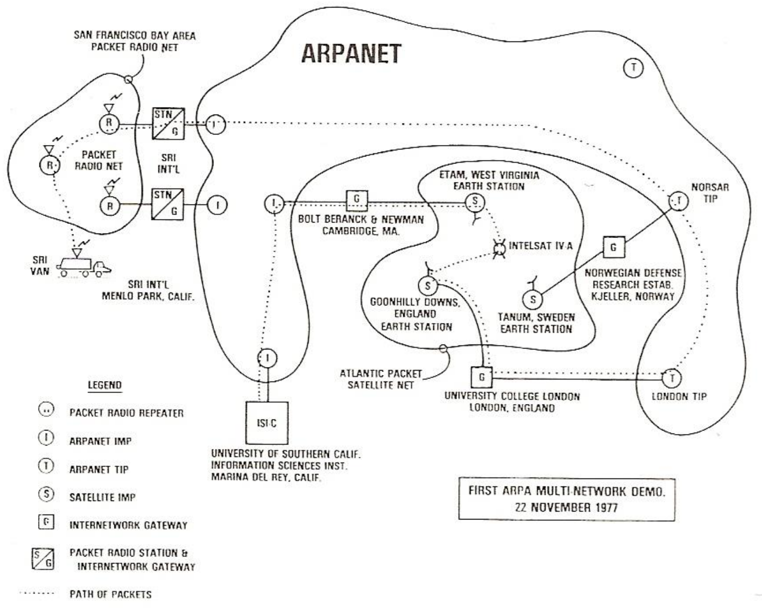


Figure 4.3
Diagram of 1977 Internet demonstration.

- Thus, the original Internet was understood as a network of networks using a single host protocol (TCP), later split into the dual TCP/IP protocol in 1978

Source: Janet Abbate, *Inventing the Internet* (1999), p. 132.

To recapitulate (5)

- The basic designers of the original Internet were
  - (i) Louis Pouzin and Hubert Zimmerman
  - (ii) Donald Davies and Lawrence Roberts
  - (iii) Robert Kahn and Vinton Cerf
- The first node of the ARPANET was set up in **(i)** 1964 **(ii)** 1967 **(iii)** 1969 **(iv)** 1971
- Was the original Internet designed as a network able to survive a nuclear strike so that the president of the U.S. could order a second strike?
- Name three (3) communication technologies used by the ARPANET and its sister networks.
- Explain Bush’s concept of a *trail* in his “memex”.