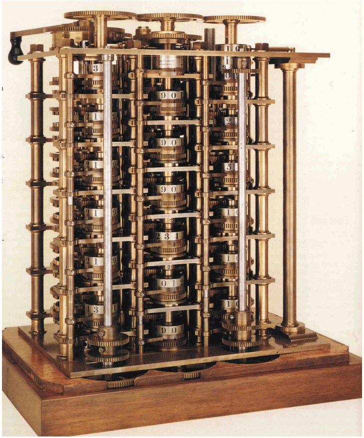
History of Electronic Computers: Machines for Mass Calculation

Waseda University, SILS,
Science, Technology and Society (LE202)

The control revolution

- We often think of computers as increasing individual freedoms and liberties. The first computers, however, were associated with the needs of administrators to calculate and control.
- The massive technological systems of the modern world led to a *crisis of control* and tabulating machines and then electronic computers were used to handle this situation.
- The early drive for computing was largely funded and motivated by military, statebuilding and corporate needs.
- The early images of computers in popular culture and science fiction are always of large machines associated with power and control. (There were no personal computers in science fiction novels or movies before the 1970s.)

Before electronic computers



Babbage's Difference Engine

- There were counting boards of various kinds in most ancient and medieval cultures (abacus, soroban, etc.).
- In the early modern period, Pascal, Leibniz and others developed analog calculators.
- Advanced digital (mechanical) calculators were designed by Charles Babbage (1791–1871), but never built.
- In the early 20^{th} century, a "computer" meant a person (often a woman) who carried out calculations.

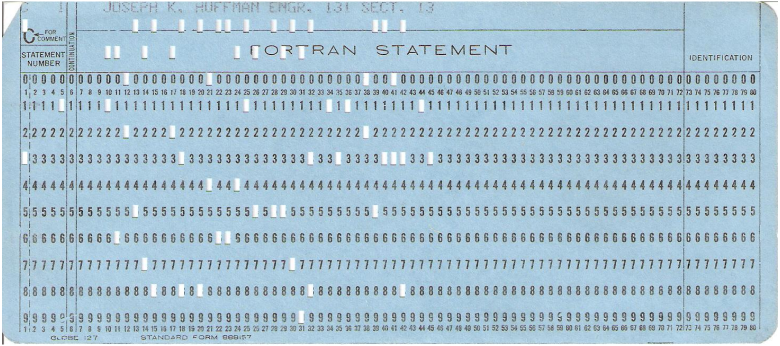
The "computers" of the Paris Observatory, late 19th century.

Punch cards

- The rise of mass production and mass distribution around the turn of the 20th cenury gave rise to a crisis of control.
- This lead to new techniques of data processing and bureaucratic management.
- There were a number of different types of machines that were used to deal with this crisis but the most common was the punch card machine.
  - These consisted of analog computers and electric tabulators that could process around *10,000 punch cards per month*.
- Herman Hollerith (1860–1929), was given the contract to automate the 1890 US census.
  - The census produced over 60 million cards. Using the machines, it took *only* two and a half years to count them and the project came in $5 million under budget.
  - Hollerith went on to found Tabulating Machine Company (later called International Business Machines, IBM).

A Hollerith punch card machine, US census, 1890

A punched card for FORTRAN input, 1960s



The Differential Analyzer, an analog calculator

Kay McNulty, Alyse Snyder, and Sis Stump, Moore School, during WWII

Generations of electronic computers

	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}
Period	1940s–1955	1956–1963	1964–1967	1971–2005	2007–?
Technology	vacuum tubes	transistors	integrated circuits	micro-processors	RISC chips
Size	full room (huge)	large machine	desk sized	desk-top,	hand-held
Software	machine language	assembly language	operating systems	GUI interface	fully networked

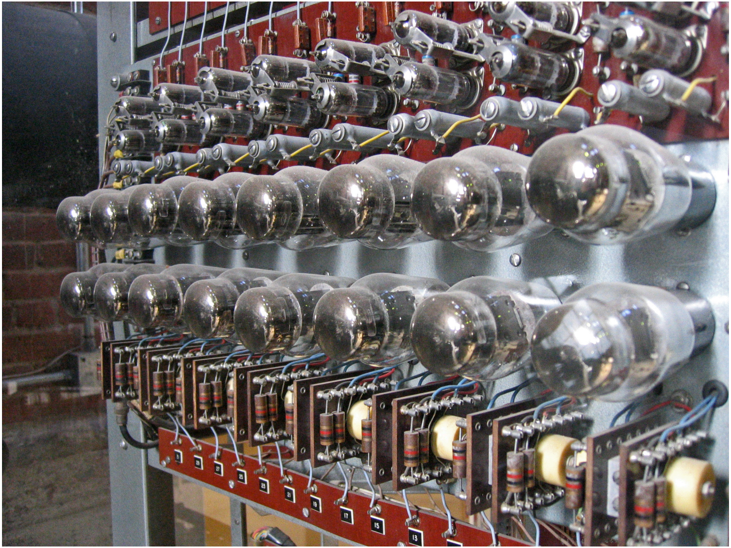
RISC: Reduced instruction set computer. An open-source protocol for the chip instruction set.

GUI: Graphic user interface.

Vacuum tubes

- Vacuum tubes developed slowly from work in cathode ray tubes in the 19th century.
- In the beginning of the 20th century, technoscientists realized that vacuum tubes could create and process electrical current in a number of ways.
  - Transformation between AC and DC, amplification, switching, etc.
- A number of conservative inventions in vacuum tubes lead to the development of radio, sound reproduction, telephone networks, and eventually digital computers.

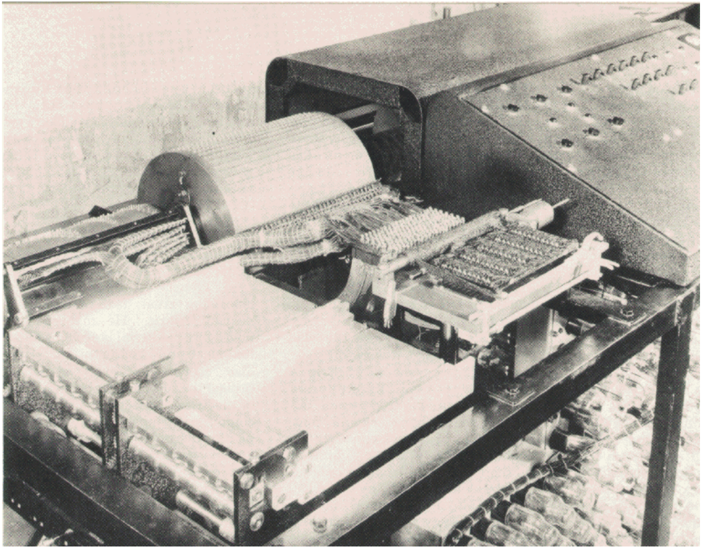
Vacuum tubes used in Project Whirlwind



The Atanasoff Berry Computer (ABC)

- One of the first electronic computers was made by John Atanasoff (1903–1995, PhD Physics, math professor at U of Wisconsin) and his assistant Clifford Berry (1918–1963).
- Atanasoff wanted a mechanism for doing calculations and made a study of the current machines. He called them analog.
- He decided he wanted a digital machine, and set about designing one, in binary (1s and 0s). (He had a long-standing interest in number bases.)
- He came up with the idea of a storage unit and circuit boards to do addition and subtraction.
- With a small grant, he was able to hire Berry and they built the ABC in his basement.
- With the start of WWII, they moved on to war work and abandoned the ABC.

The ABC



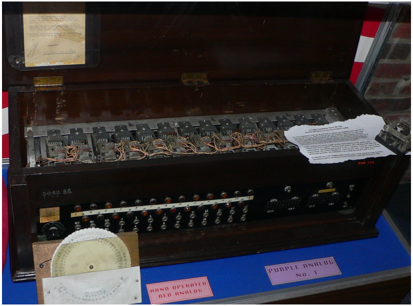
Bombes and the Colossus

- WWII was a war of technoscience as much as military conflict.
- Starting in 1926, the Germans adopted the use of the Enigma encoding machine. The Dutch, Japanese, and Italians followed suit, during the war.
- The Poles bought an Enigma and designed a machine, the Bomba, to decode it. When they realized the Germans were going to attack, they gave the machines to the British.
- The Brits set up a code breaking division at Bletchley Park, where they built 'Bombes' and eventually Colossus computers, to decode the new German Lorenz encoders. (Alan Turing, 1912–1954.)
  - The British also built the first stored-program electronic computer after the war, the EDSAC at Manchester.
- The first Colossus used 1,500 vacuum tubes and read paper tape at 5,000 characters per second. The Colossi decrypted around 63,000,000 German characters of code.

A German Enigma Machine

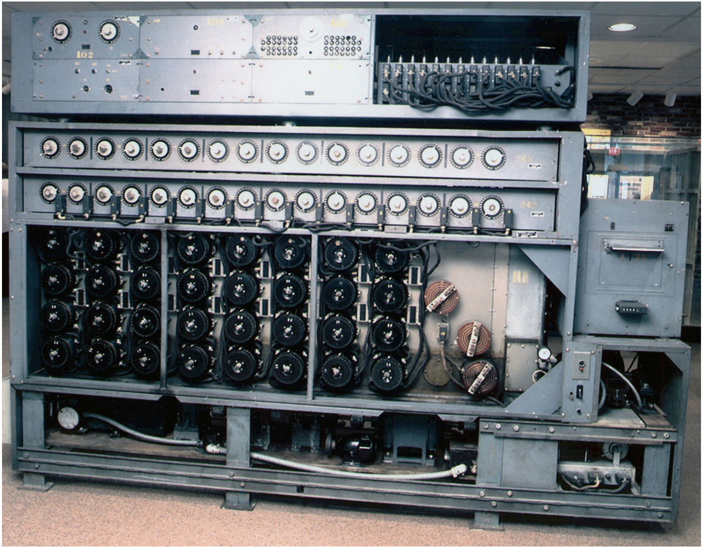
A Japanese “Enigma” – 九七式欧文印字機

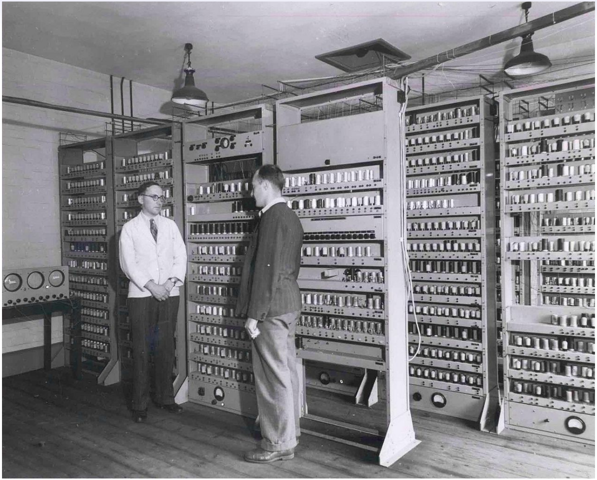
暗号機B型, of which the code was given the codename パープル暗号, by the US.



An American machine for decrypting the Japanese code, named PURPLE.

A Bombe machine in the US



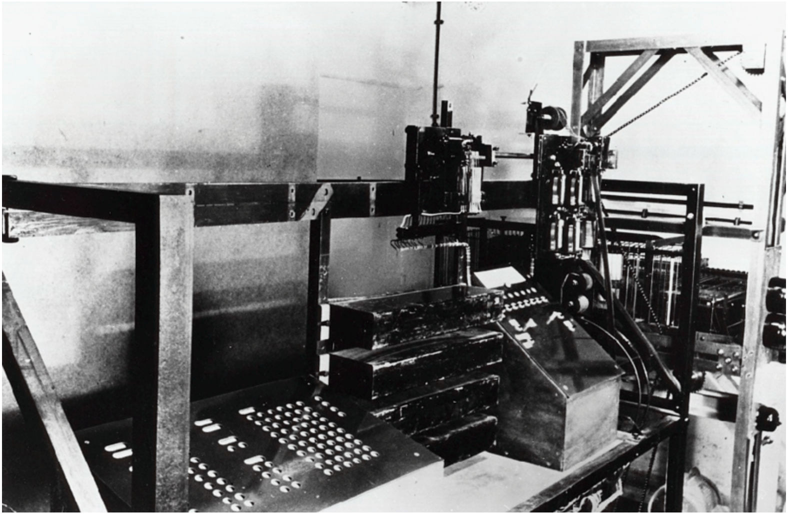


The EDSAC (Electronic Delay Storage Automatic Calculator) was built by a team led by Maurice Wilkes at the University of Cambridge Mathematical Laboratory. It was one of the first stored-program computers.

The Zuse machines

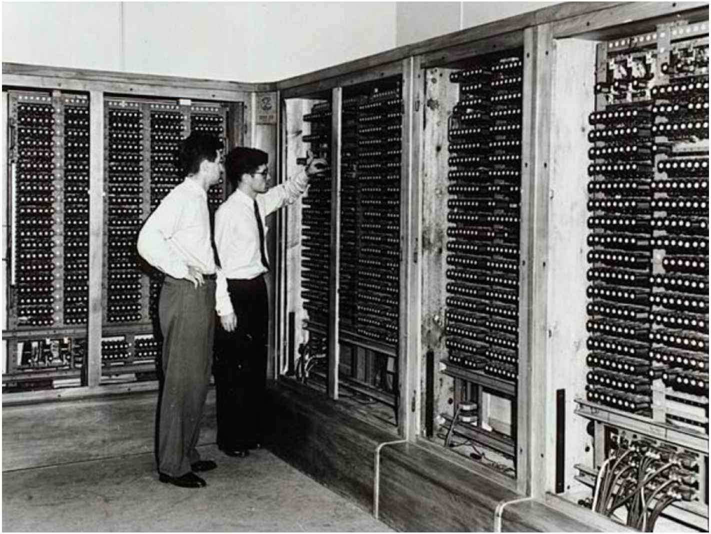
- Konrad Zuse (1910–1995) was originally a German aircraft engineer who began working on computers as a hobby.
- He designed a series of models, Z1–Z31+, throughout his life, all based on his own designs, using binary and eventually his own language, Plankalkül ("formal system for planning").
- He was interrupted by war work during WWII, but he eventually founded a couple of companies and continued to work on his projects.
    - His final company was incorporated into Siemens.
- In his later years, he proposed a cosmology in which the universe itself is considered to be running on a grid of "computers," *Rechnender Raum* (1967). (Calculating space.)

Zuse's Z4



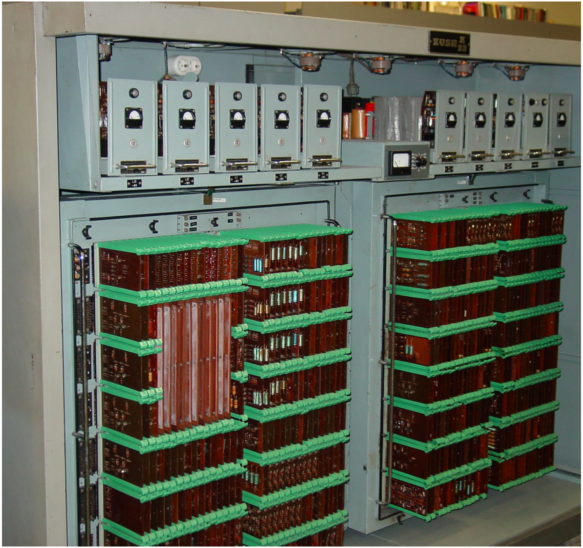
Zuse's Z4, with floating arithmetic, already in poor condition in 1949, Hopferau

Zuse's Z4



Zuse's Z4, in operation at the ETH Zurich,early 1950s

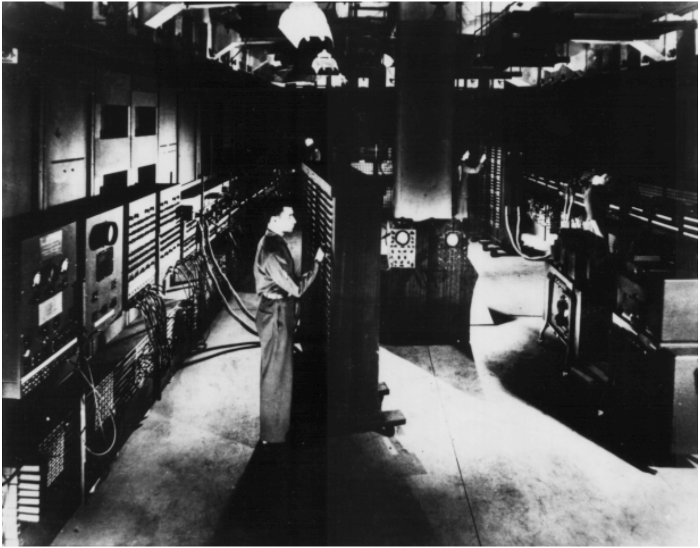
Zuse's Z23



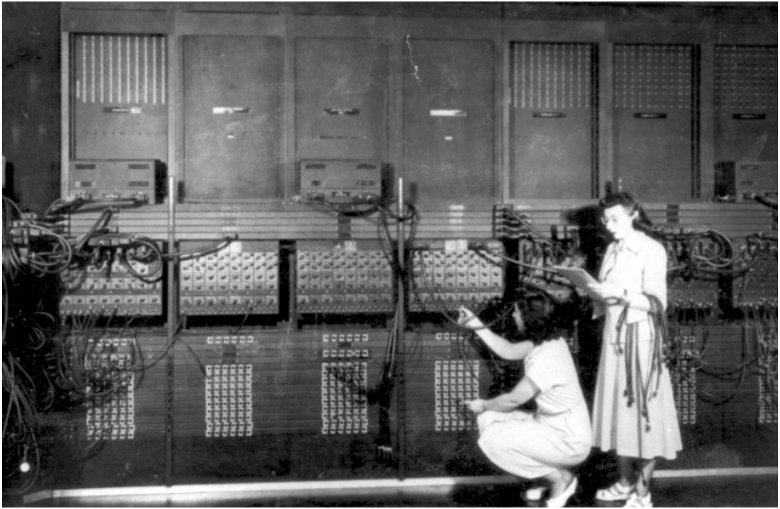
ENIAC, EDVAC and IAS

- The ENIAC (Electronic Numerical Integrator and Computer) was built by a team headed by Mauchly (who had seen the ABC) and Eckert at the Moore School of Electrical Engineering for the US Ballistics Research Lab, to help in war work.
  - It consisted of 49 cabinets, 18,000 vacuum tubes and weighed 30 tons.
- The EDVAC (Electric Discrete Variable Arithmetic Computer) was designed at the Moore School to be one of the first binary, stored-program computers, but the construction was delayed.
- The IAS was built by von Neumann, based on his experiences working with the ENIAC group. It incorporated von Neumann's concept of storing programs in the computer's memory after they had been input by tape or cards.

The Electronic Numerical Integrator and Computer



ENIAC, programming with switches

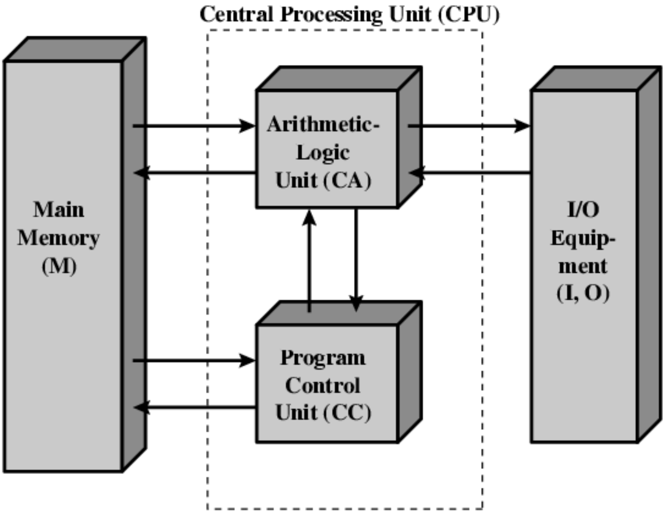


Gloria Gordon Bolotsky and Ester Gerston programming the ENIAC

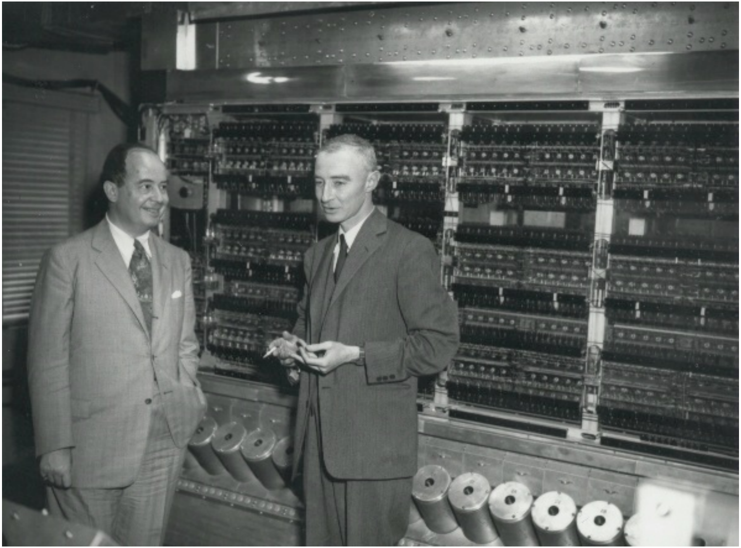
The von Neumann architecture

- John von Neumann (1903–1957) was a brilliant Jewish-Hungarian mathematician who emmigrated to the US, developed economic game theory, worked on the theory of the stored program computer, and did important war work.
- He first became involved with the ENIAC project after a random encounter with an officer at a railroad station.
- The von Neumann architecture, which is the basis of all modern computers, was described in his report on the EDVAC system. It was based on the theoretical ideas of Alan Turing.
- This model is based on (1) a memory which holds both the data and the program and (2) a fetch-decode-execute repeating cycle, in which instructions are fetched from the memory and then decoded and executed in a central processing unit (CPU).

The von Neumann architecture, simplified

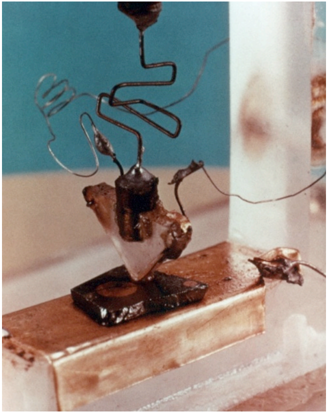


von Neumann and Oppenheimer, the IAS

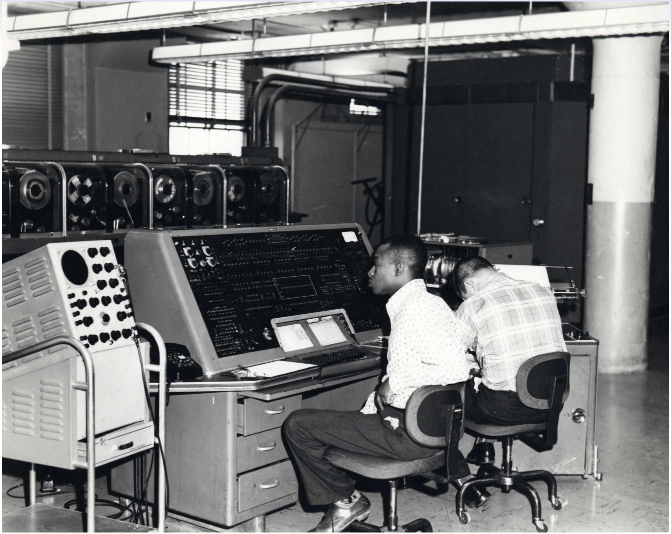


Transistors, 1947

- Early computers were limited by the use of vacuum tubes: they were large, overheated and often failed.
- The transistor was developed in Bell Labs by Bardeen, Brattain, Shockley. (Nobel Prize, 1956.) They used, germanium, a semiconductor material.
- Transistors can do various things, such as act as switches and amplifiers.
- The US military immediately saw the potential for transistors and invested in developing the invention.



The first transistor, Bell Labs



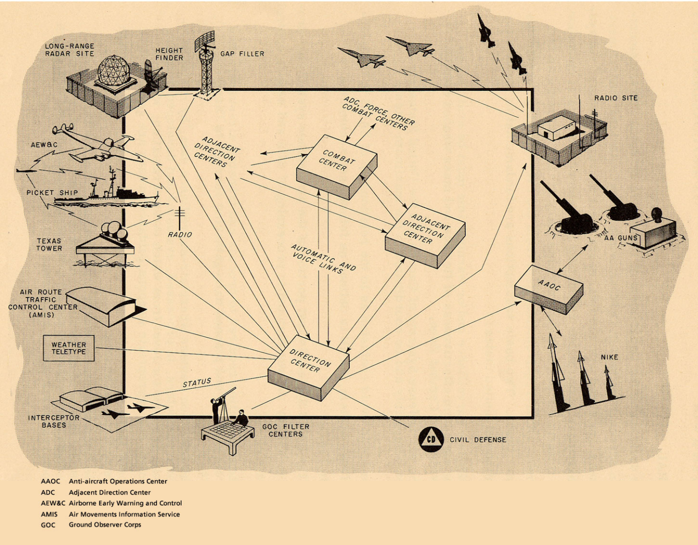
One of the early transistor-based computers was the UNIVAC (Universal Automatic Computer). Here we see one of the UNIVAC systems at the US Census Bureau.

Project Whirlwind and SAGE

- Project Whirlwind was a US Navy project to build a flight simulator. The project was begun at MIT, by Jay Wright Forrester, an early cyberneticist.
- In the late 1940s, the US Air Force asked MIT to build the Semi-Automatic Ground Environment (SAGE) system. This was a military command and control system.
- IBM built the computers, which were the largest ever built at that time.
- The SAGE software was around 1,000,000 lines of code and at one time over half of the programmers in the US worked on the project.
- The SAGE network was a great success in terms of human-machine interfacing, and networking as systems engineering, combining social and technological factors into a functioning whole. It was less successful as a military system.

Project Whirlwind, 1947 (Robert Everett)

SAGE, network



SAGE, information flow and control

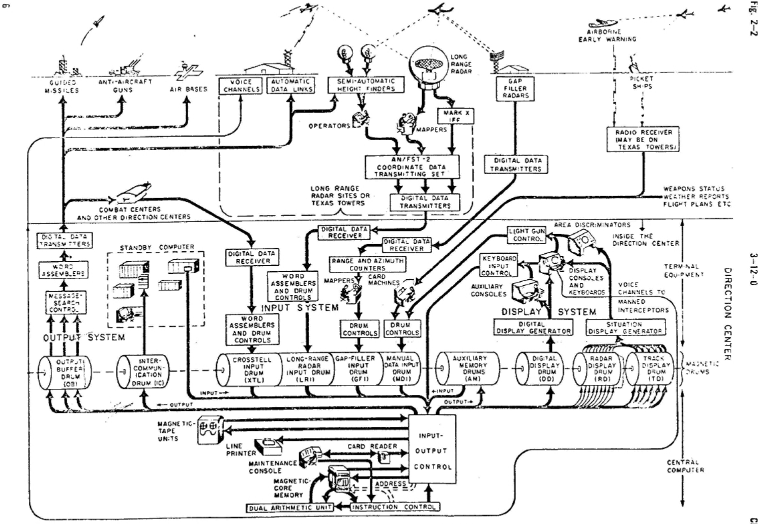
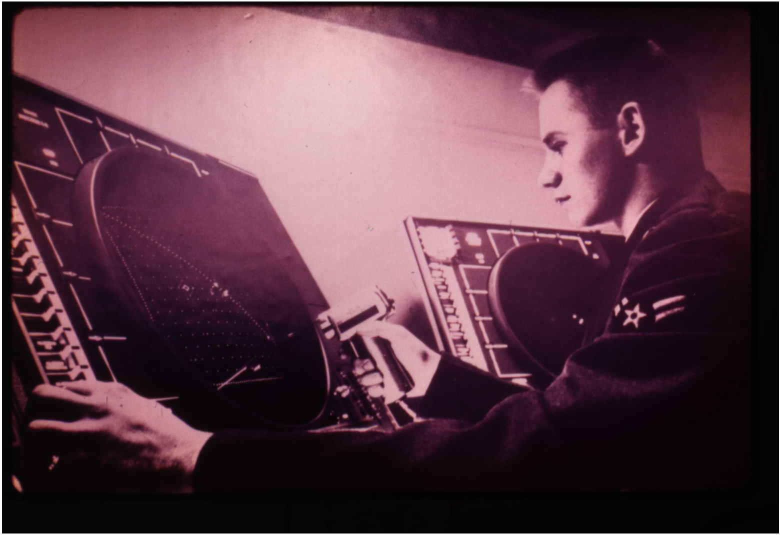
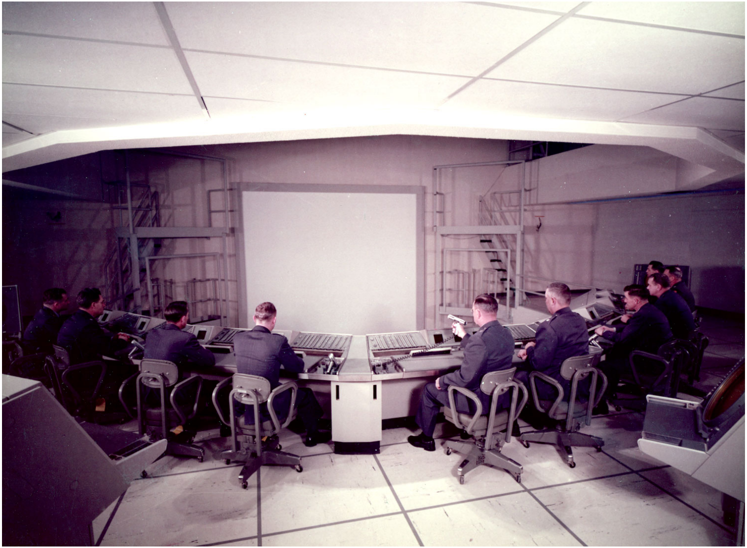


Figure 2–2. Information Flow in the Sector

SAGE, terminal



SAGE, command center

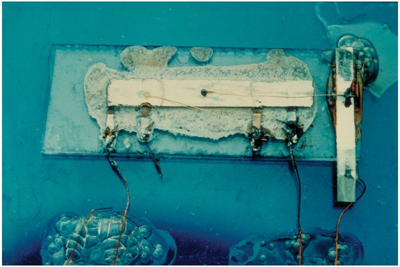


The NORAD command center

Pres. Eisenhower and others, North American Aerospace Defense Command

The integrated circuit, 1958

- Jack Kilby (1923–2005), at Texas Instruments, and Robert Noyce (1927–1990), at Fairchild, independently developed the integrated circuit (Nobel Prize, 2000).
- Kilby invented the circuit while everyone else was away for summer vacation.
- He started with germanium and then switched to silicon.
- Again, it was the US military that invested in the development process.

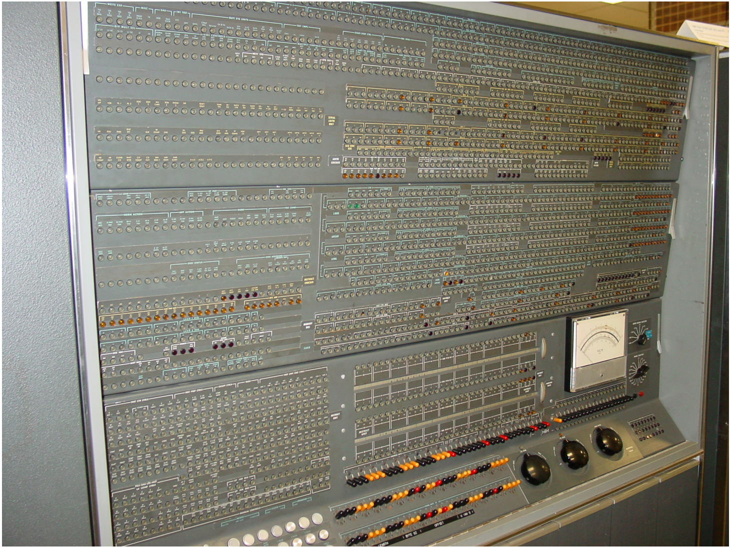


The first integrated circuit designed by Jack S. Kilby using germanium and gold wire.

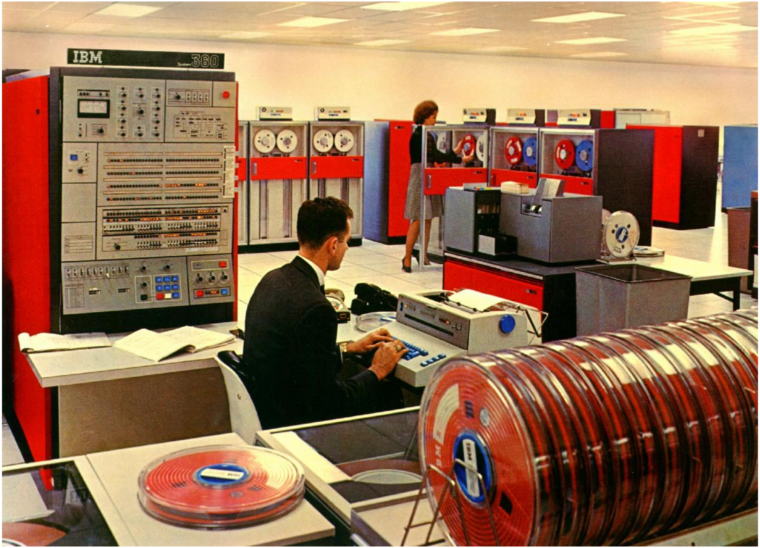
Commercial computing and IBM ("Big Blue")

- Most of the early computers were *military projects* and most of the early computer companies were *financial failures*.
- In the 30s–40s, IBM dominated the world market for punch card equipment. In 1951, they decided to move into electronic computers. Although there were competitors, IBM dominated the market until the rise of personal computing.
- In 1955, Los Alamos Lab commissioned IBM to build a computer 100 times faster than anything on the market. IBM's answer, the 7030, was the first computer to be based completely on transistors.
- In the 1960s, IBM came out with System 360, which standardized the operating system and programs for all the models, and by 1970 had 70% of the world's computer market. It was a technological failure, but a commercial success.

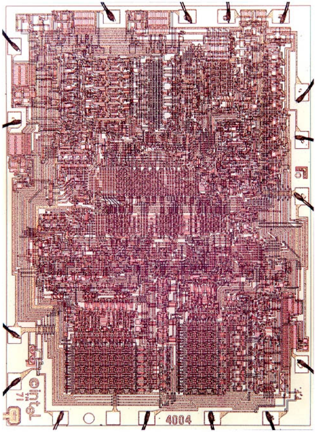
The IBM Stretch 7030, built for Los Alamos Lab



The IBM System 360, 1960s



The microprocessor



Schematic: The Intel 4004

- In 1968, the "traitorous seven" left Fairchild Semiconductor to found Intel.
- In 1969, Busicom, a Japanese firm, commissioned Intel to make a microprocessor for a handheld calculator.
- This lead to the Intel 4004. Intel bought the rights to sell the chip to other companies.
- Intel immediately began the process of designing more and more powerful microchips.
- This has lead to computers small enough to fit in our hands.

Consumer electronics

Sony Walkman, 1979

- The microprocessor made it possible to create more affordable *consumer electronics*.
- The Walkman came out in 1979. Through the 1980s video players, recorders and stereos were marketed.
- In the 1980s-1990s, data storage moved more completely from analog (paper tape, records) format to digital (cassette tape and 8-track from 60s, VCR, CD, DVD).
- We now use watches, TVs, automobiles, mobile phones, microwave ovens, etc., all of which contain microprocessors.

The Altair 8800

- In 1975, the Altair was marketed as a "computer kit" and advertised in *Popular Electronics*. (Over 4,000 orders in the first month.)
- No keyboard, monitor, etc.
- The operating system was based on BASIC and written by Microsoft.
- It had an *open architecture*, which encouraged users and start-ups to make their own peripherals.
- (The first microcomputer was actually marketed in France, but did not catch on. Only 500 machines were made.)


Popular Electronics
JANUARY, 1975

PE TESTED

EXCLUSIVE!

ALTAIR 8800
The most powerful minicomputer project ever presented—can be built for under $400

BY H. EDWARD ROBERTS AND WILLIAM YATES

THE era of the computer in every home—a favorite topic among science-fiction writers—has arrived! It's made possible by the POPULAR ELECTRONICS/MITS Altair 8800, a full-blown computer that can hold its own against sophisticated minicomputers now on the market. And it doesn't cost several thousand dollars. In fact, it's in a color TV-receiver's price class—under $400 for a complete kit.

The Altair 8800 is not a "demonstrator" or souped-up calculator. It is the most powerful computer ever presented as a construction project in any electronics magazine. In many ways, it represents a revolutionary development in electronic design and thinking.

The Altair 8800 is a parallel 8-bit word/16-bit address computer with an instruction cycle time of 2 µs. Its central processing unit is a new LSI chip that is many times more powerful than previous IC processors. It can accommodate 256 inputs and 256 outputs, all directly addressable, and has 78 basic machine instructions (as compared with 40 in the usual minicomputer). This means that you can write an extensive and detailed program. The basic computer has 256 words of memory, but it can be economically expanded for 65,000 words. Thus, with full expansion, up to 65,000 subroutines can all be going at the same time.

The basic computer is a complete system. The program can be entered via switches located on the front panel, providing a LED readout in binary format. The very-low-cost terminal presented in POPULAR ELECTRONICS last month can also be used.

PROCESSOR DESCRIPTION

Processor: 8 bit parallel
Max. memory: 65,000 words (all directly addressable)
Instruction cycle time: 2 µs (min.)
Inputs and outputs: 256 (all directly addressable)
Number of basic machine instructions: 78 (181 with variants)
Add/substract time: 2 µs
Number of subroutine levels: 65,000
Interrupt structure: 8 hardwire vectored levels plus software levels
Number of auxiliary registers: 8 plus stack pointer, program counter and accumulator
Memory type: semiconductor (dynamic or static RAM, ROM, PROM)
Memory access time: 850 ns static RAM; 420 or 150 ns dynamic Ram

JANUARY 1975 33

The Apple II

- The Apple I was built by Steve Wozniak, with the help of his friend Steve Jobs, in 1976.
- Jobs secured $300,000 in capital and they founded a company and brought out the Apple II.
- The Apple II came with a keyboard and could connect to a color TV. It was the first personal computer for the "general" market.
- In 1979, two Harvard MBA students wrote a spreadsheet program, VisiCalc, which became the first "killer app," driving up sales.

The Apple I, 1976

The IBM PC

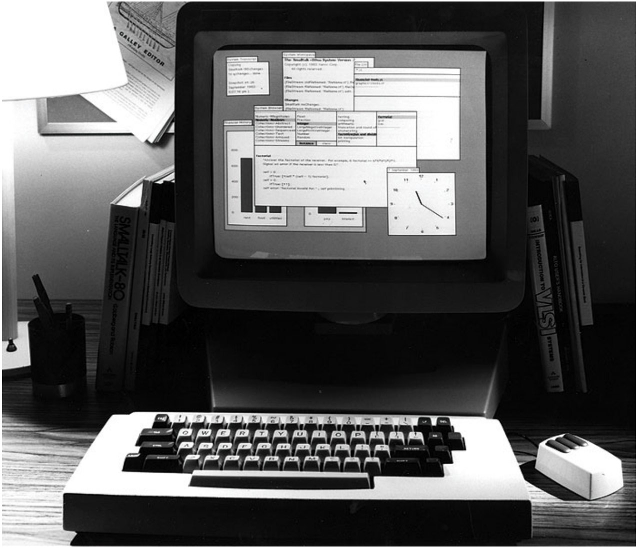
IBM PC Advertisement, 1981

- In 1981, "Big Blue" came out with its first personal computer (PC).
- In order to get into the market quickly, IBM decided not to do everything in-house: they used existing chipsets, an *open architecture*, and wrote complete documentation.
- They contracted with Microsoft to write the operating system (PC-DOS, MS-DOS).
- This made it acceptable for businesses to buy a PC.
  - "No one ever got fired for buying IBM."

The NEC PC-98 Series, and MSX

- In the 1980s, Japanese hardware firms made their own PCs that ran MS-Basic or MS-Dos.
- The NEC PC-98 series of PC clones, which started shipping in 1982, were popular in Japan.
- MSX began shipping a PC clone that ran MS-Basic in 1983. They were probably the best selling PC in Japan.

The Xerox Alto, with mouse and windowing GUI



The Macintosh

- In 1979, Steve Jobs and some other Apple employees visited Xerox PARC and came away with a new vision of the future of computers.
- Apple's first attempt at a GUI machine, the Lisa, was a commercial failure. (Too expensive and incompatible with anything else.)
- In 1984, the Mac was announced with a US Superbowl commercial, directed by Ridley Scott. (It won many top commercial awards.)
- Aldus Pagemaker, 1985, became the "killer app" that drove Mac sales.
- Jobs was forced out of Apple in 1985. He came back in 1996, on the condition that they buy NeXT Computer.

The Macintosh, 1984

The Next, early 1990s

PC clones and the rise of Microsoft

- It was possible to clone PCs for three reasons:
  1) Intel could sell their microchips to anyone.
  2) Microsoft could sell their operating system to anyone.
  3) The read-only memory basic input/output system (ROM BIOS) chips could be reverse engineered, using "clean room design."
- This lead to a host of knock-off companies like Compaq, Dell, Gateway, NEC, MSX, Toshiba, etc.
- Since Microsoft, and eventually, Windows was shipping on all of these machines, this contributed to the rise of Microsoft.
- This lead to IBM losing its market dominance and the new standard became "Wintel" (Windows OS running on an Intel chipset).

Final remarks

- We have looked at the history of electronic computers.
- We have seen how much of this development was driven by *military* investments and the needs of *large corporations*.
- We see that development process of computers and electronics from invention to product is quite lengthy and involves considerable innovation.
- We have seen how systems-builders used a wide array of different resources to create systems of computers and electronic equipment.
- The development of even a simple computer, which is itself a kind of socio-technological system, requires the work of hundreds, sometimes thousands, of people.