CS-230: Digital Logic Design & Computer Architecture

{Engineering + Mathematics

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Lecture 1 (04 January 2022)

CADSL

What is Engineering?

- ✓ the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practices are applied with judgments to develop ways to utilize economically the materials and forces of nature for the benefit of living being. (Accreditation Board for Engineering and Technology (ABET, 2002)

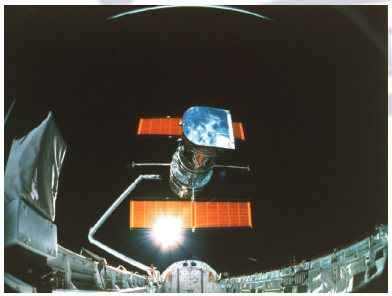
Why Study Digital Design?

- It's exciting!; It has never been more exciting!
- It impacts every other aspect of electrical engineering and computer science

Bionics:
Sensors in latex fingers instantly register hot and cold, and an electronic interface in his artificial limb stimulates the nerve endings in his upper arm, which then pass the information to his brain. The $3,000 system allows his hand to feel pressure and weight, so for the first time since losing his arms in a 1986 accident, he can pick up a can of soda without crushing it or having it slip through his fingers. *One Digital Day*

Some Basic Definitions

What is Science, Technology, Engineering, and Mathematics???



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Science seeks to understand the natural world.

National Science Education Standards, National Research Council, 1996

What is Technology?

the world: to cut, shape, from one place to anoth voices, and senses. (*Benchmarks for Science*

- Technology is the process by which humans modify nature to meet their needs and wants. (*Technically Speaking: Why All Americans Need to Know More About Technology*,2002)

What is Engineering

experience, and practices are applied with judgments to develop ways to utilize economically the materials and forces of nature for the benefit of mankind. (Accreditation Board for Engineering and Technology (ABET, 2002)

What is Mathematics

- ✓ The study of any patterns or relationships (AAAS, 1993)

- ✓ The science of numbers and their operations, interrelations, combinations, generalizations, and abstractions and of space configurations and their structure, measurement, transformations, and generalizations (Webster's Ninth New Collegiate Dictionary)

Science vs. Technology

- Deals with the natural world.
- Is very concerned with what is (exists) in the natural world. (i.e.: Biology, Chemistry, Physics, Astronomy, Geology, etc.)

- Deals with how humans modify, change, alter, or control the natural world.
- Is very concerned with what can or should be designed, made, or developed from natural world materials and substances to satisfy human needs and wants

Science vs. Technology

- Is concerned with processes that seek out the meaning of the natural world by "inquiry", "discovering what is", "exploring", and using "the Scientific Method".

- Is concerned with such processes that we use to alter/change the natural world such as "Invention", Innovation", Practical Problem Solving, and Design.

While technology and science have a common denominator being the natural world, they are similar yet very different.

Technology is not any more "applied science" than science is "applied technology".

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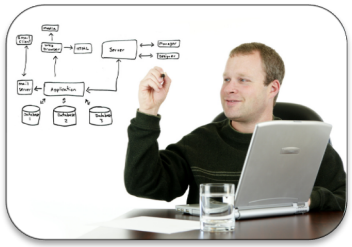
Engineers Apply Math and Science for the Betterment of Society



Design

Manufacturing

Research & Development

Management

Continual Improvement

Logistics

Above all, Engineers are problem solvers who make things work better, more efficiently, quicker and cheaper

Engineering Functions

The focus of an engineer's work typically falls into one or more of the following areas:

- Research - explore, discover and apply new principles
- Development - transform ideas or concepts into production processes
- Design - link the generation of ideas and the production

MOST EXOTIC NEED OF HUMANS
Mobile Power : Animal Driven Vehicles

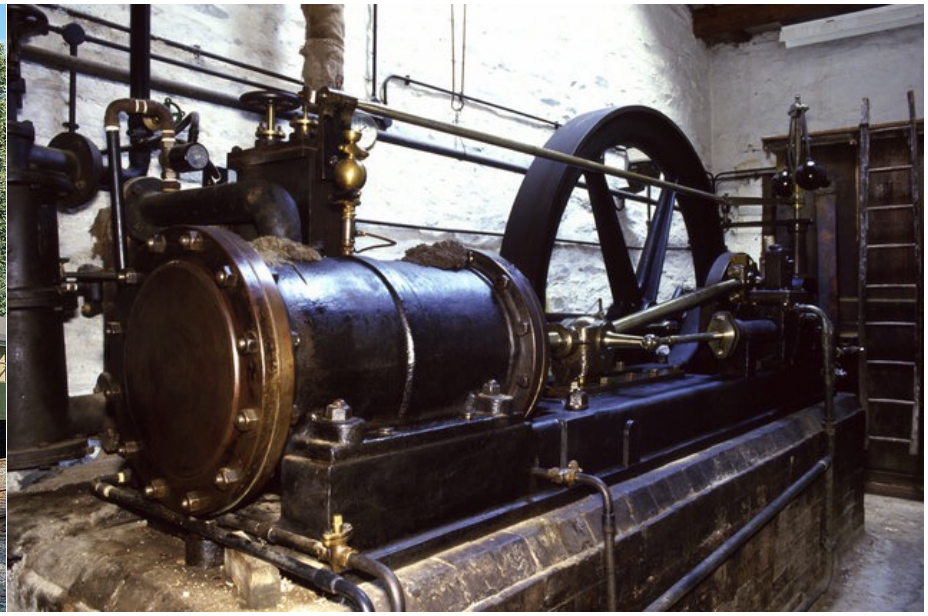
Engineering Challenges: Mobility

- Solve problem for the betterment of society

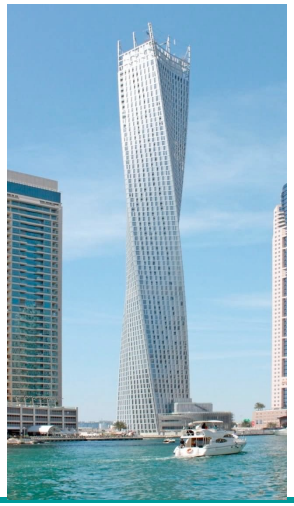
Engineering Challenges: Mobility

- Solve problem for the betterment of society

Engineering Challenges: Mobility



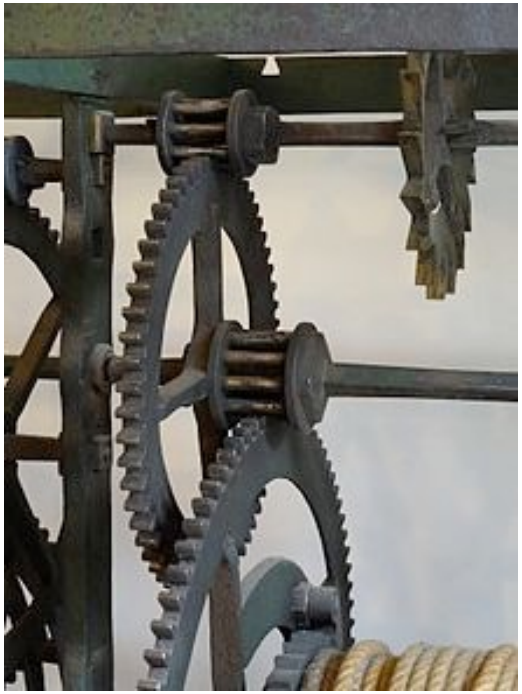
Engineering Challenge - Shelter



At 5:30am on June 27, 2009, an unoccupied building still under construction in Shanghai city toppled over.

Engineering Challenge - Communication

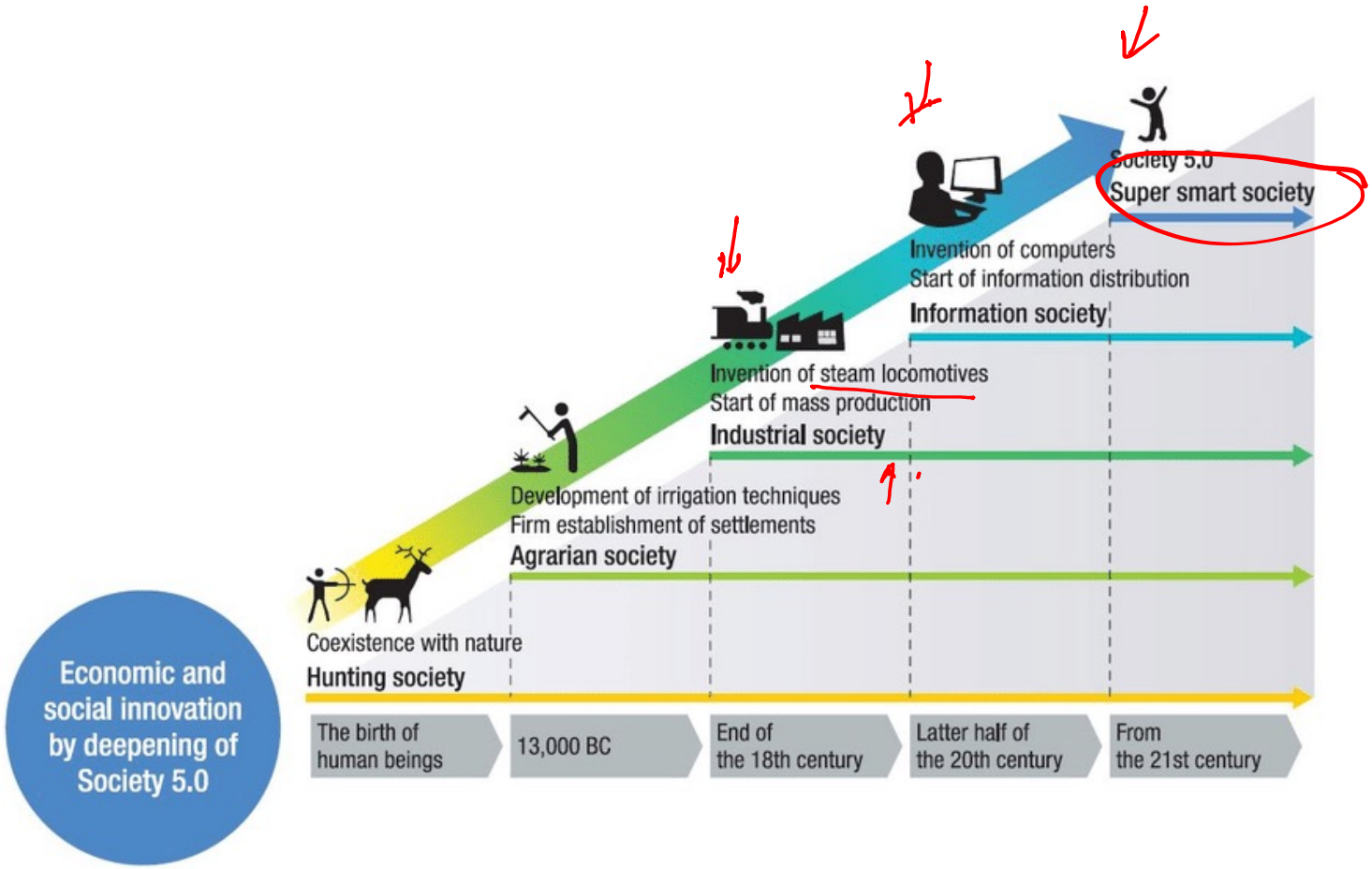
Engineering Challenge- Computing



What is Needed to Become an Engineer?

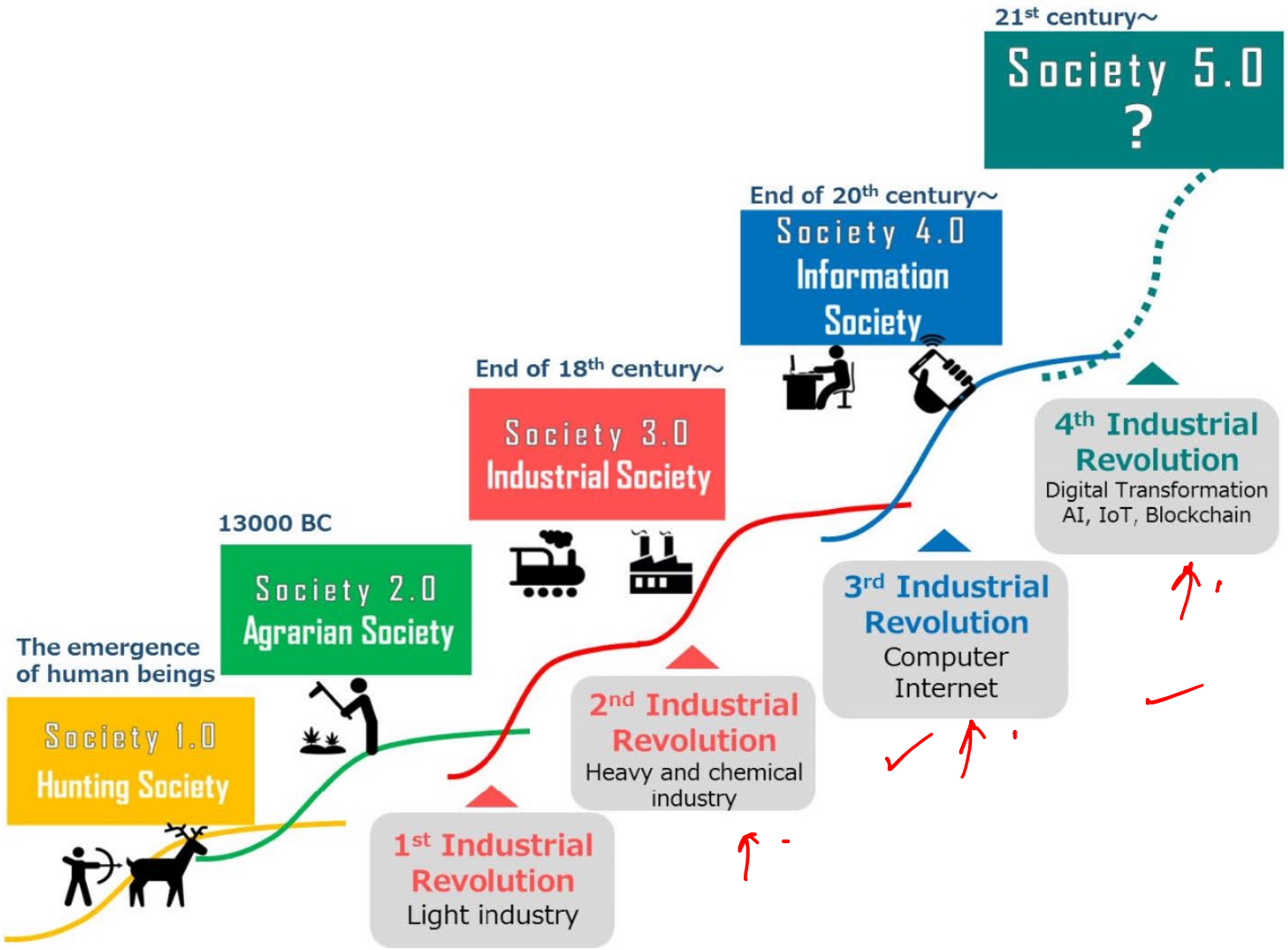
- Solid background of Science and Mathematics
- Analytical ability
- Engineering design principles
- Rigour

Evolution of Society



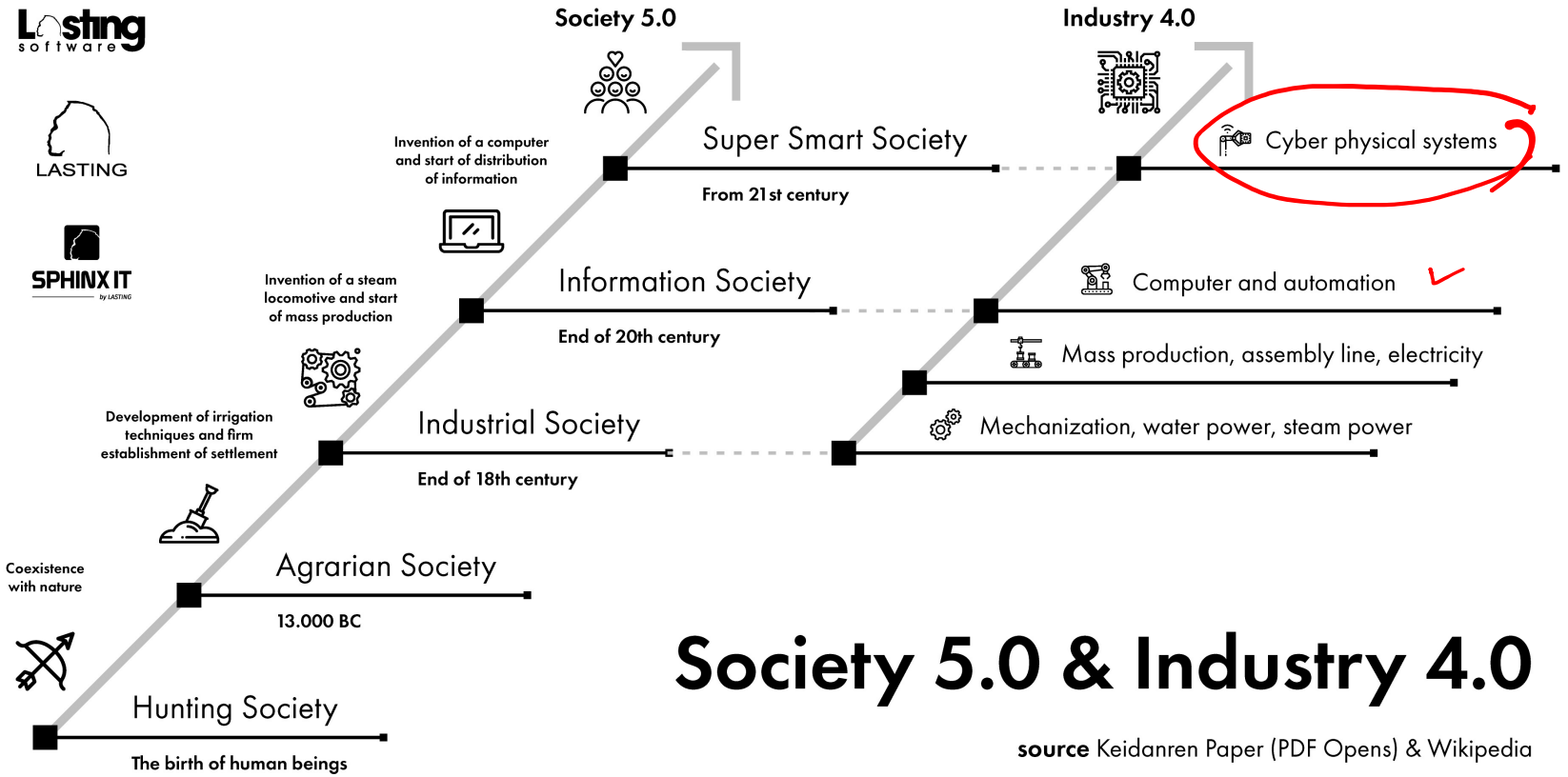
Source: Prepared by the author based on material from the Japan Business Federation (Keidanren) "Japan's initiatives — Society 5.0"; Y. Harayama, "Society 5.0: Aiming for a New Human-centered Society", Hitachi Review, vol. 66, no. 6, 2017, pp. 556–557

Evolution of Society



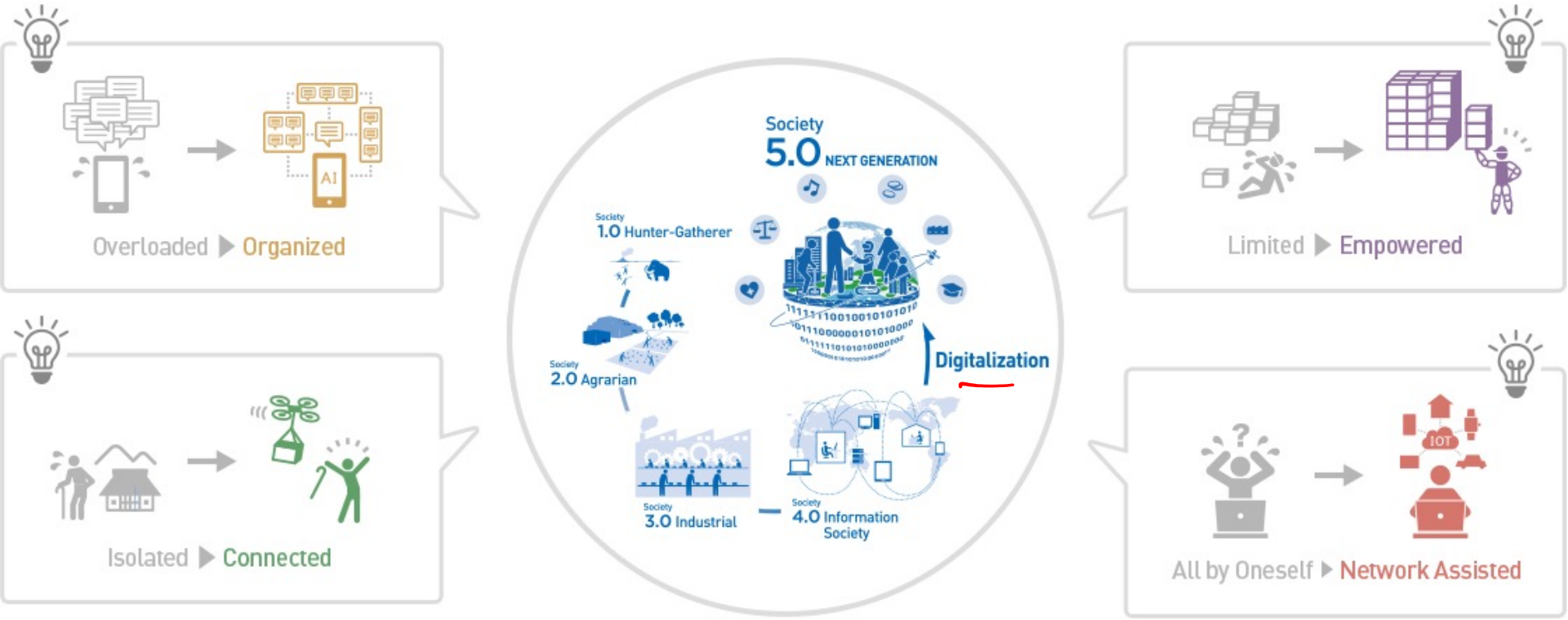
Super Smart Society

Technology Evolution with Society

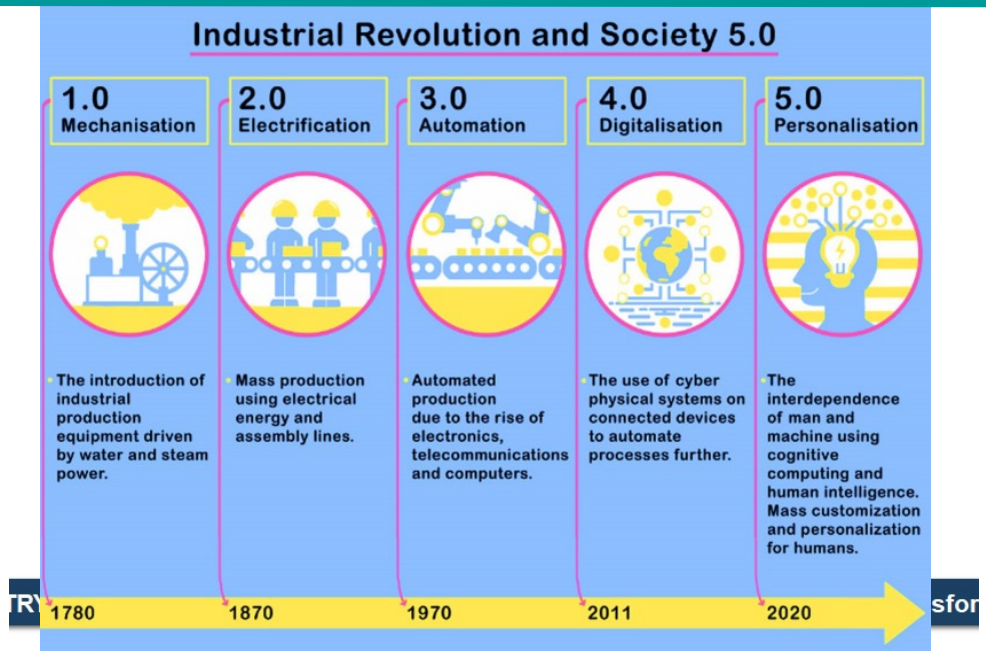


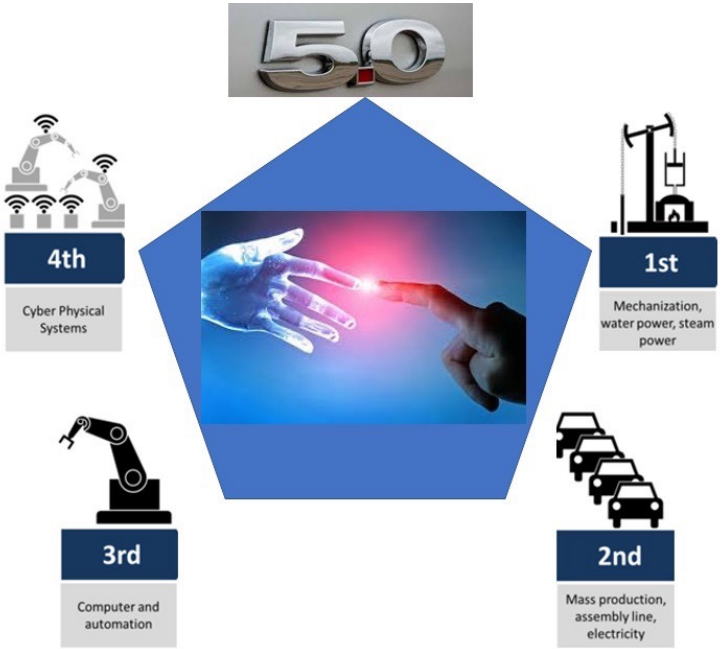
Source: https://www.sphinx-it.eu/from-the-agenda-of-the-world-economic-forum-2019-society-5-0/

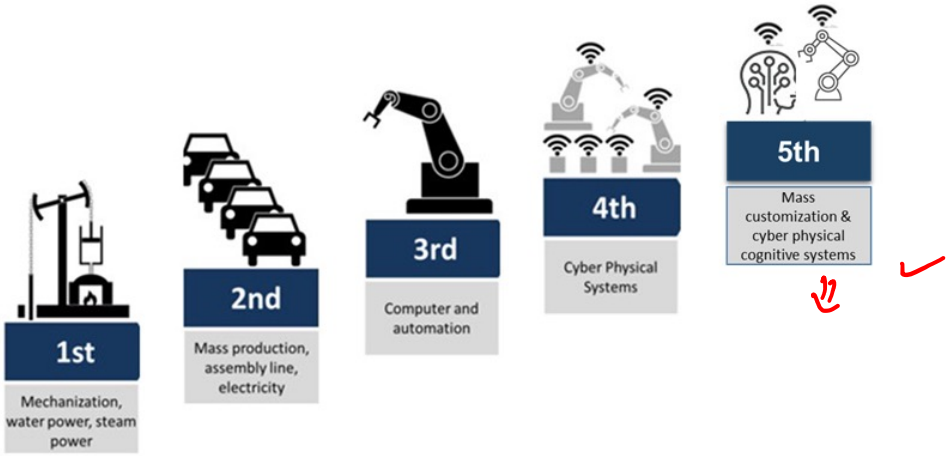
Society 5.0


Overloaded ▶ Organized
AI
Isolated ▶ Connected
Limited ▶ Empowered
IOT
All by Oneself ▶ Network Assisted
Society 5.0 NEXT GENERATION
Society 1.0 Hunter-Gatherer
Society 2.0 Agrarian
Society 3.0 Industrial
Society 4.0 Information Society
Digitalization

Industry 5.0







Source: https://michael-rada.medium.com/industry-5-0-definition-6a2f9922dc48

Source: https://blog.capabilitydevelopment.org/the-next-industrial-revolution-industry-5-0/

Industry 5.0

- Industry 5.0 priority is to utilize efficiently machine and human synergistically.
- This makes significant changes in Industry 4.0 and create smart factory
- Within the modular structured smart factories
  - Cyber physical systems monitor physical processes
  - Create a copy of the physical world and make decentralized decisions
  - Over the Internet-of-Things, Cyber Physical systems communicate and cooperate
  - Via Internet of services, both internal and cross-organizational services are offered and used by the participants of the value chain

Internet of Things

What are Things

- Not computers
- Phones, Watches, Rings, TVs, Cars, etc..

- IoT = Sensing + Communication + Computation + Actuation

- Smart World

Smart World: Smart City

Smart World: Smart City

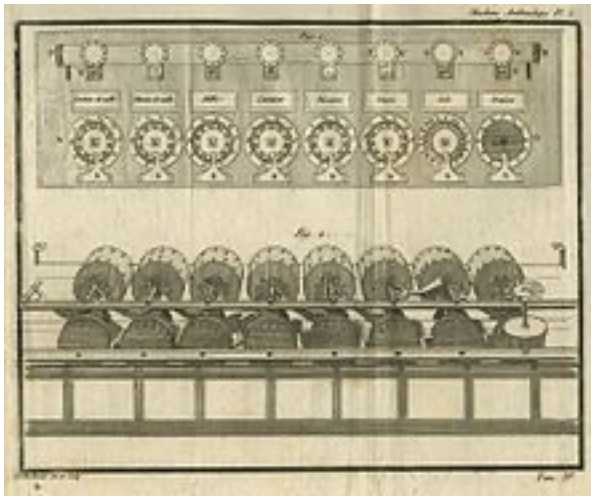
Smart World: Smart Home

Smart World: Smart Transport

Evolution of Computers

Historic Events

- 1623, 1642: Wilhelm Strickland/Blaise Pascal built a mechanical counter with carry.



- 1823-34: Charles Babbage designed difference engine. http://www.youtube.com/watch v=0anIyVGeWOI&feature=related

Babbage's Difference Engine

- Babbage Difference Engine
  - Hand-cranked mechanical computer.
  - Computed polynomial functions.
  - Designed by Charles Babbage in the early to mid 1800s.
    - Arguably the world's first computer scientist, lived 1791-1871.
  - He wasn't able to build it because he lost his funding.

- His plans survived and this working model was built.
  - Includes a working printer!

http://www.computerhistory.org/babbage/

Babbage's Computer

Ada Lovelace

- English Mathematician and Writer
- Recognized that machine can do more than calculation
- Published first algorithm to be carried out by these machines
- Regarded as the first programmer

History of Computers

- 1930s has seen unprecedented interest and proposals
  - Automatic calculation challenges

Mechanical
⇓
Electromechanical
⇓
Electronic

- Atanasoff's exceptional invention and development of electronic digital computing marked the beginning of information revolution

- In 1937, Atanasoff came up with basic design principles of electronic digital computing

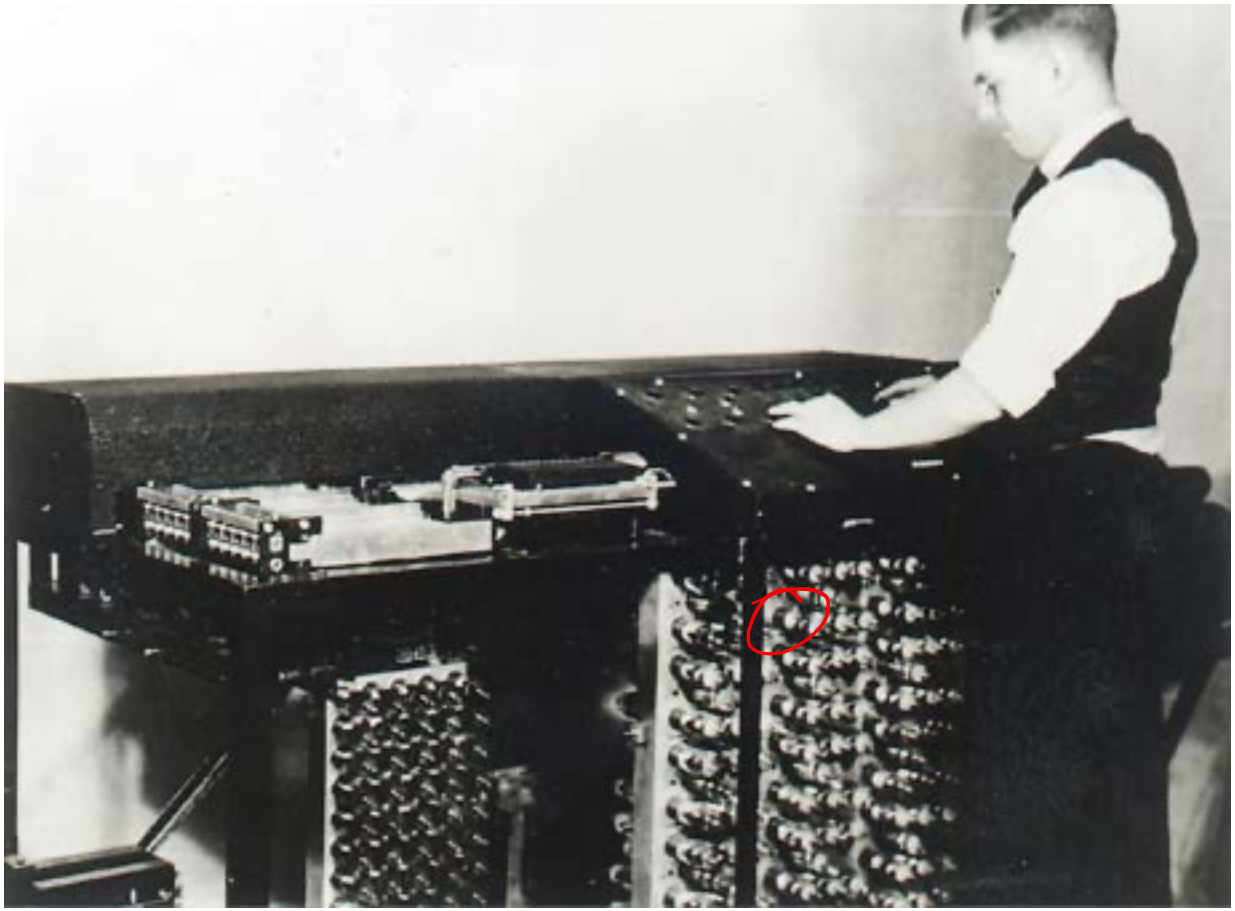
Atanasoff's Design Principles

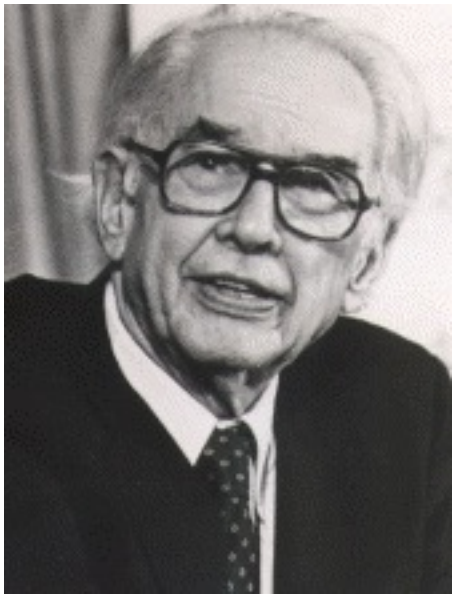
- Electronics technology for computational speed as opposed to mechanical or electromechanical technology
- Binary arithmetic for simplicity of implementation as opposed to decimal arithmetic
- Digital calculations for accuracy as opposed to analog calculations
- dynamically refreshed memory for low cost and reliability

Development of Electronic Computers in 1930s

- Atanasoff has demonstrated the proof-of-concept in Oct 1939
- This was followed by the full scale computing machine to solve system of equations
  - By Atanasoff Berry Computers (ABC)
- Post Office Research Lab in London has independently develop the electronic computer called Colossus
  - Demonstrated in March 1943
  - Prototype was developed by code breaking facility (Station X)

Atanasoff Berry Computer

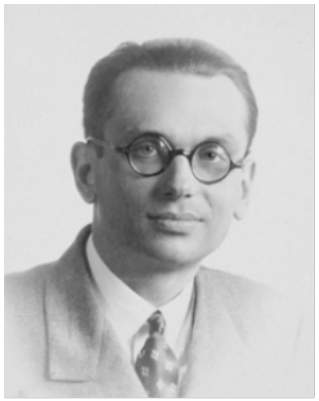




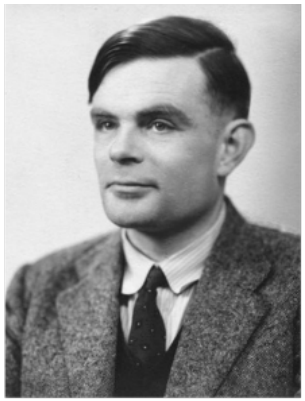
John Vincent Atanasoff

Clifford Berry

Computation Models



Kurt Gödel



Alan Turing

Alonzo Church

Theory of Computing

- Alan Turing (1912-1954) gave a model of computing in 1936 – *Turing Machine*.
- Original paper: A. M. Turing, "On Computable Numbers with an Application to the *Entscheidungsproblem**," *Proc. Royal Math. Soc.*, ser. 2, vol. 42, pp. 230-265, 1936.
- Recent book: David Leavitt, *The Man Who Knew Too Much: Alan Turing and the Invention of the Computer (Great Discoveries),* W. W. Norton & Co., 2005.

* *The question of decidability, posed by mathematician Hilbert.*

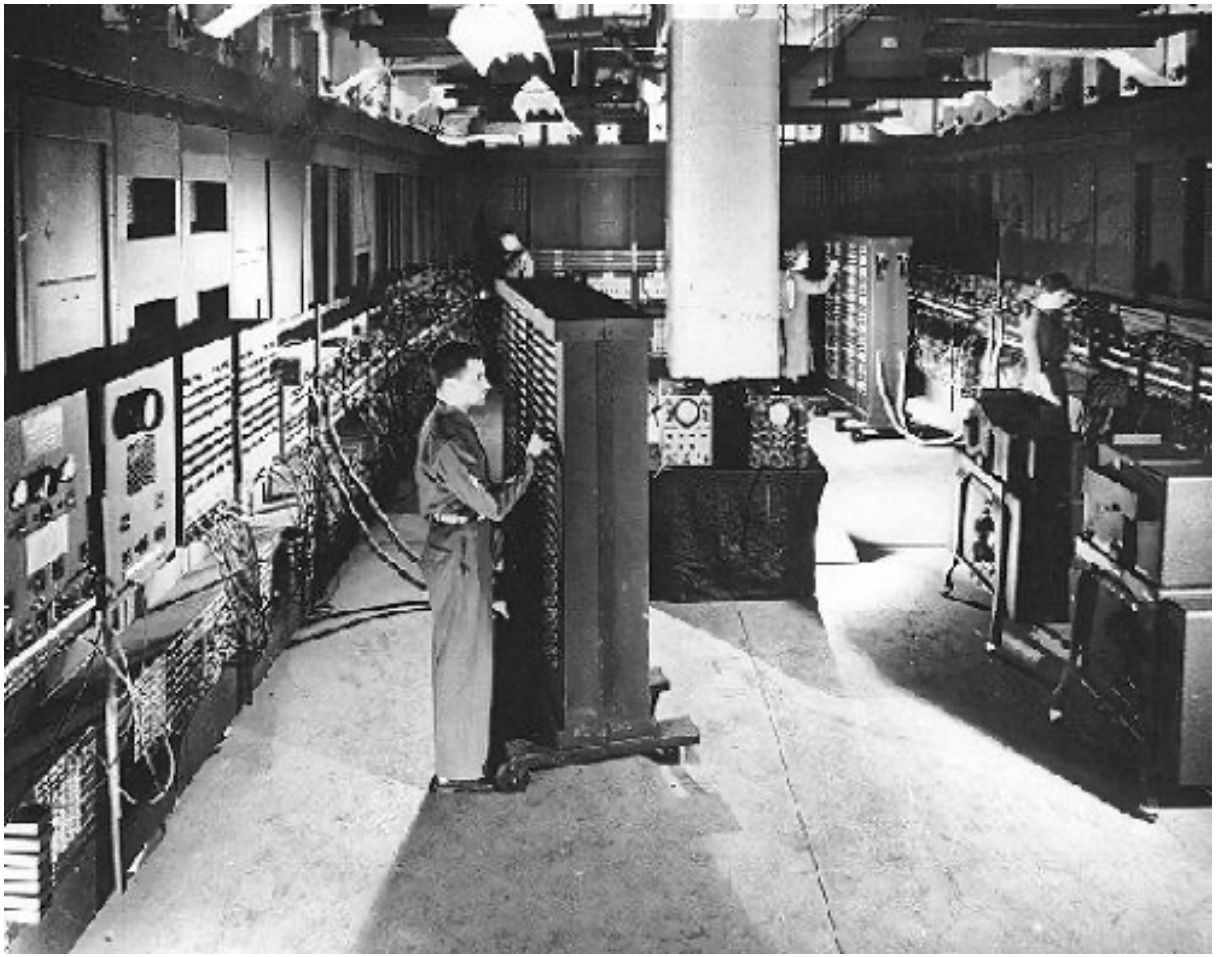
Development of Electronic Computers in 1940s

- An independent project was started by Persper Eckert and John Mauchly in June 1943 at Univ. of Pennsylvania
- This was called Electronic Numerical Integrator and Computer (ENIAC)
  - Became operational in Dec 1945
- In 1941, Mauchly visited Atanasoff in Iowa State Univ.
- Atanasoff submitted a patent application to ISU
- Atanasoff to Mauchly: "I have no qualms about having informed you about our device, but it does require that we refrain from making public any details for the time being."

Electronic Computer: ENIAC

First Computer ENIAC: made of huge number of vacuum tubes 1946

Big size, huge power, short life time filament



AIEE and IRE

- AIEE setup a sub-committee on Large-scale Computing Devices under Basic Sciences cte. in 1946
  - Charles Concordia as first chair
- In Jan 1948, the sub-committee was elevated to full committee on Computing Devices
- IRE was most scientific in first first half of 20th Cent.
- IRE formed Technical Committee on Electronic Computers as subcommittee in 1946
- In 1951 IRE established a Professional Group on Electronic Computers (PGEC)

TC on Electronic Computers

- IRE TC played a very important role in 50s and 60s
- IRE National Convention in 1947
  - 122 Papers
  - 5 papers in session Electronic Digital Computers
  - Authors: J.W. Forrester (MIT), SN Alexander (NBS), HH Goldstein (IAS), JA Rajchman (RCA), P Crawford (ONR)
    - Inaugural members of TC
  - Special demonstration of components of Electronic Discrete Variable Computers (EDVAC)
    - Declassified a week ago

TC on Electronic Computers

- In 1947, IRE had 73 meetings
- 1947 Arthur Berks published highly cited paper on ENIAC in *Proceedings of IRE*
- In 1947, IRE Executive committee approved the bylaws amendment to include TC on Electronic Computers
  - James Weiner as first chairperson
  - Dropped the word Digital

National Convention of IRE

- TC on Electronic Computers was very active in 1948

- In 1948 National Convention of IRE
  - 9 papers were presented in 2 sessions by TC
    - Computers I – Systems, Computers II – Components
  - Many authors were founding members of TC
  - Special session: Advances Significant to Electronics
    - Cybernetics – Norbert Wiener (MIT)
    - Information Theory: Claude Shannon (Bell Labs)
    - Computer Theory: John von Neumann (IAS)

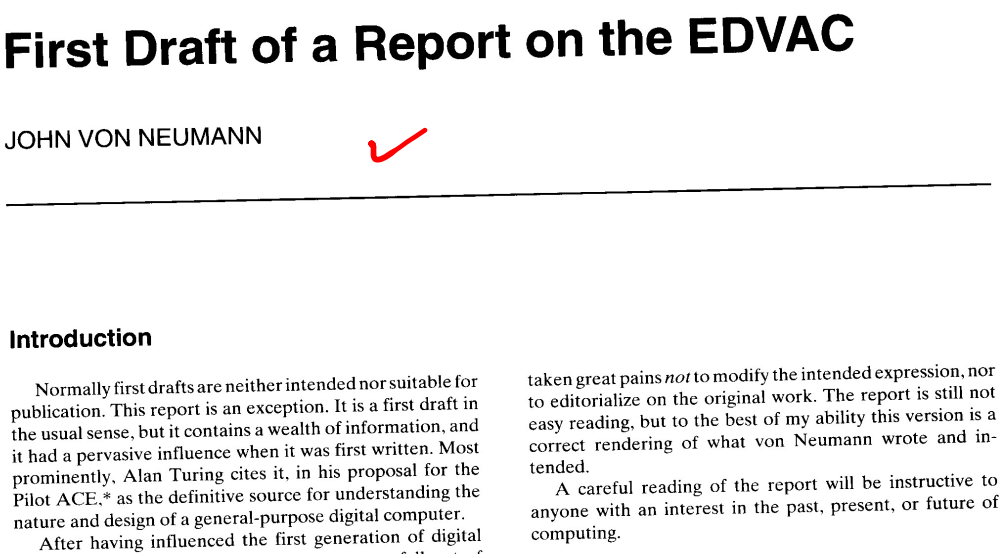
Development of Electronic Computers in 1940s

- 1943: Post Office Research Lab in London has independently develop the electronic computer called Colossus
  - Demonstrated in March 1943
  - Prototype was developed by code breaking facility (Station X)

- 1944: Howard Aiken used "separate data and program memories" in MARK I – IV computers – *Harvard Architecture*.

First Draft of EDVAC

1945-52: John von Neumann proposed a "*stored program computer*" EDVAC (Electronic Discrete Variable Automatic Computer) – *Von Neumann Architecture* – use the same memory for program and data.



First Draft of a Report on the EDVAC

JOHN VON NEUMANN

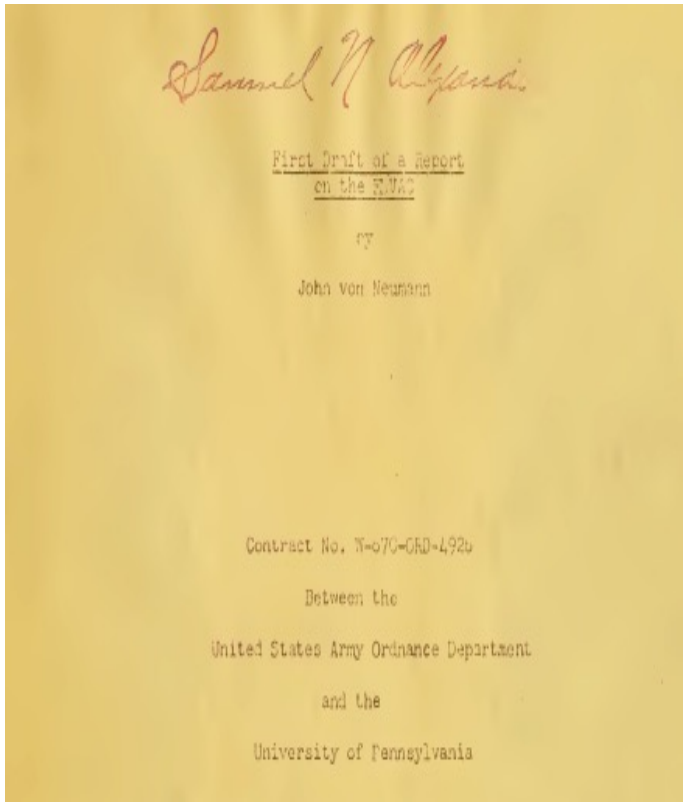
Introduction

Normally first drafts are neither intended nor suitable for publication. This report is an exception. It is a first draft in the usual sense, but it contains a wealth of information, and it had a pervasive influence when it was first written. Most prominently, Alan Turing cites it, in his proposal for the Pilot ACE,* as the definitive source for understanding the nature and design of a general-purpose digital computer.

After having influenced the first generation of digital

taken great pains *not* to modify the intended expression, nor to editorialize on the original work. The report is still not easy reading, but to the best of my ability this version is a correct rendering of what von Neumann wrote and intended.

A careful reading of the report will be instructive to anyone with an interest in the past, present, or future of computing.



Samuel N Alyana.

First Draft of a Report on the EDVAC

by

John von Neumann

Contract No. W-670-ORD-4926

Between the

United States Army Ordnance Department

and the

University of Pennsylvania

Most Influential Document

- "Preliminary Discussion of the Logical Design of an Electronic Computing Instrument," 1946 report by A. W. Burks, H. H. Holdstine and J. von Neumann. Appears in *Papers of John von Neumann*, W. Aspray and A. Burks (editors), MIT Press, Cambridge, Mass., 1987, pp. 97-146.

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Preliminary discussion of the logical design of an electronic computing instrument[1]

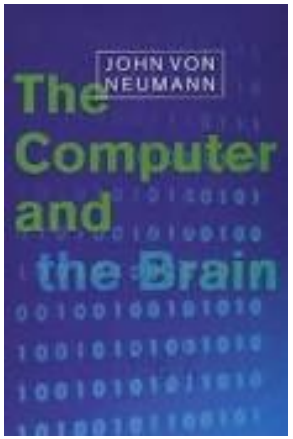
Arthur W. Burks / Herman H. Goldstine / John von Neumann

PART I

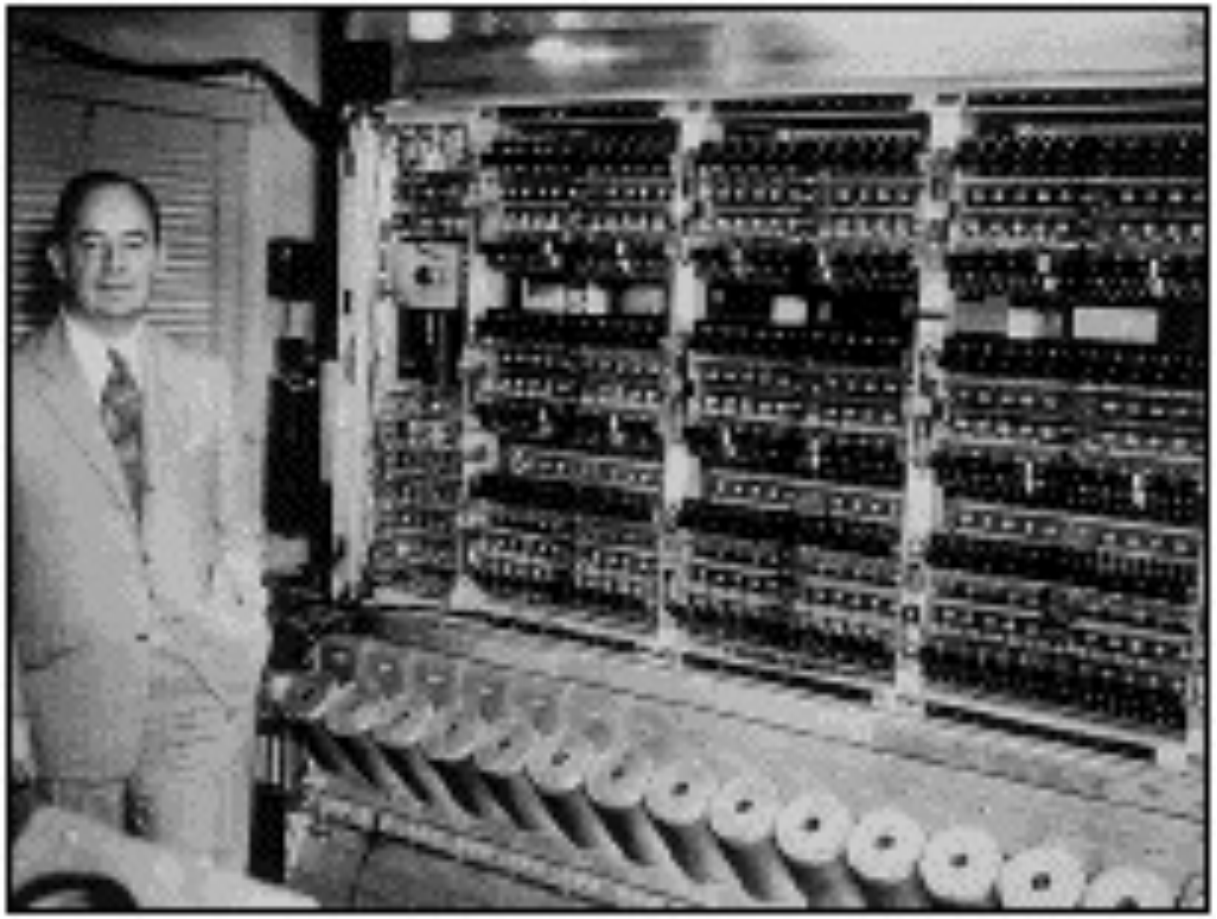
1. Principal components of the machine

1.1. Inasmuch as the completed device will be a general-purpose computing machine it should contain certain main organs relating to arithmetic, memory-storage, control and connection with the human operator. It is intended that the machine be fully automatic in character, i.e. independent of the human operator after the bers and orders. The coding of orders into numeric form is discussed in 6.3 below.

1.4. If the memory for orders is merely a storage organ there must exist an organ which can automatically execute the orders stored in the memory. We shall call this organ the *Control*.



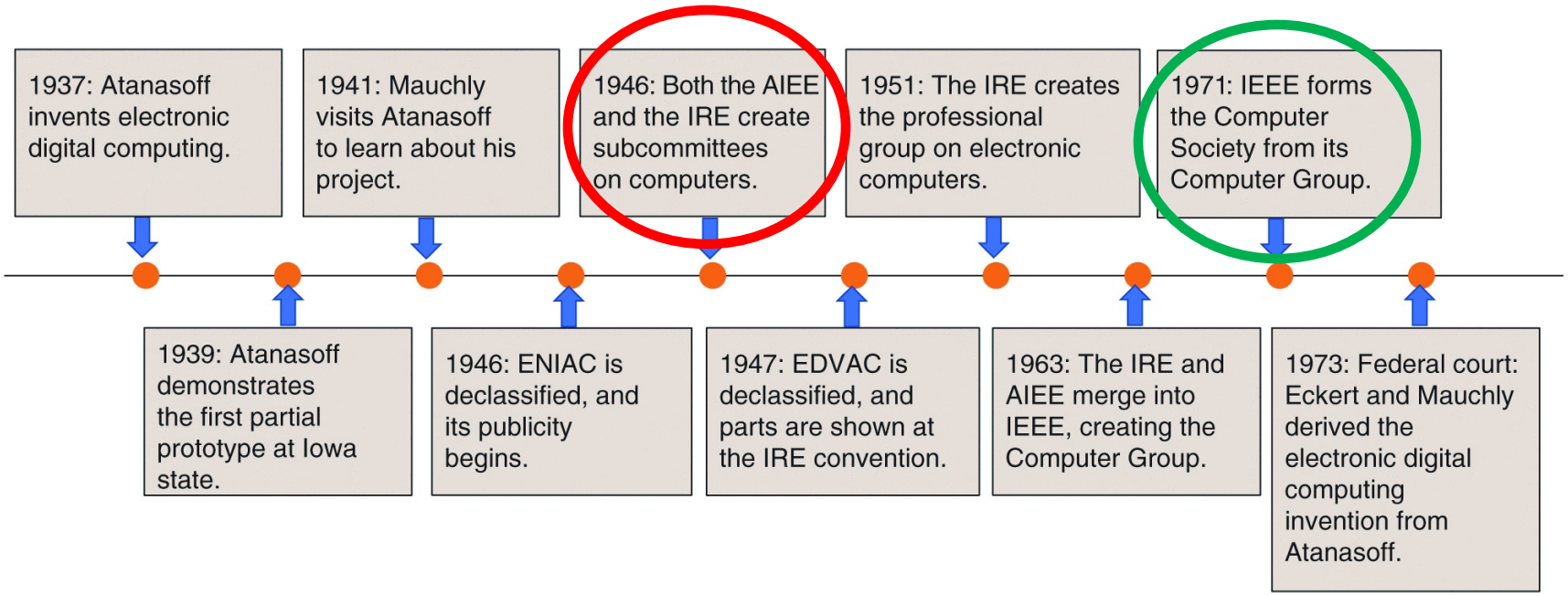
John von Neumann (1903-1957)



Development of Electronic Computers in 1950s

- 1946-52: Von Neumann built the IAS computer at the Institute of Advanced Studies, Princeton – *A prototype for most future computers*.
- 1947-50: Eckert-Mauchly Computer Corp. built UNIVAC I (Universal Automatic Computer), used in the 1950 census.
- 1949: Maurice Wilkes built EDSAC (Electronic Delay Storage Automatic Calculator), the first stored-program computer.

Time Line of Development of Computing System



Early Commercial Computers

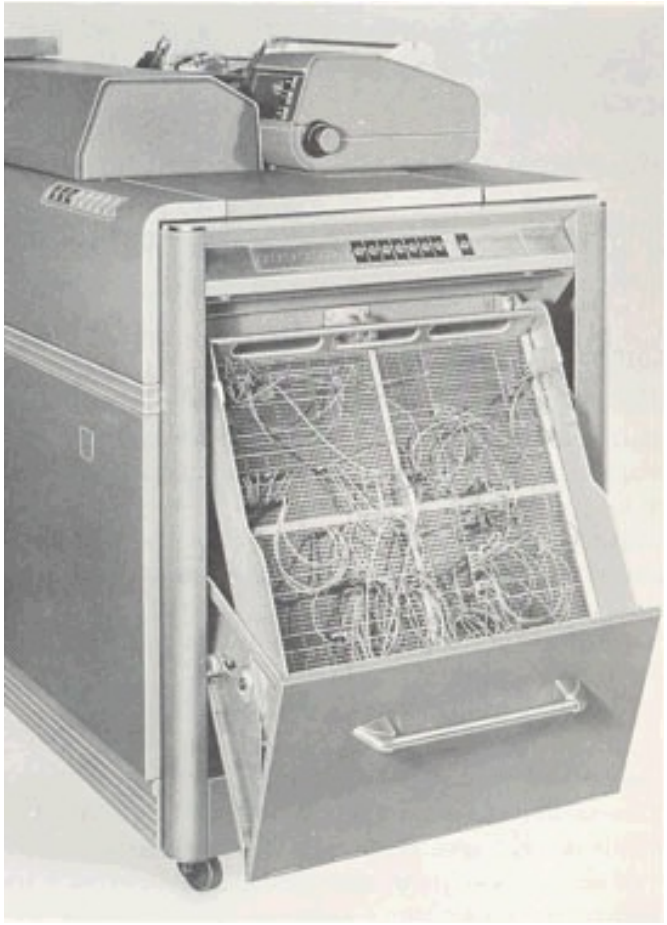
- CEC 30-103 by Consolidated Engineering Corporation in 1949
- Universal Automatic Computer (UNIVAC) I in 1951
- IBM 701 in 1952
- CEC 30-201 in 1954

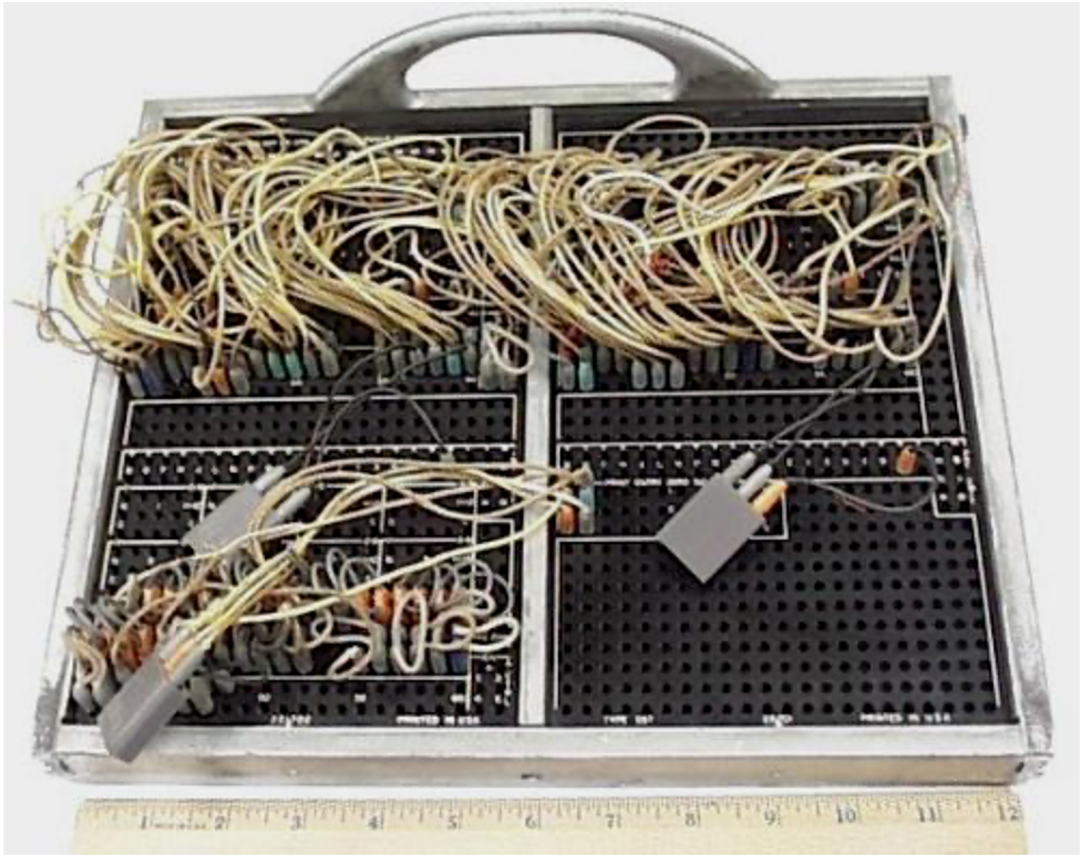
What was Computing Like?

- A data processing application involved passing decks of punched cards through electromechanical "unit record" machines.

- Repetitive sort, calculate, collate, and tabulate operations ...
  - ... were programmed with hand-wired plugboard control panels.

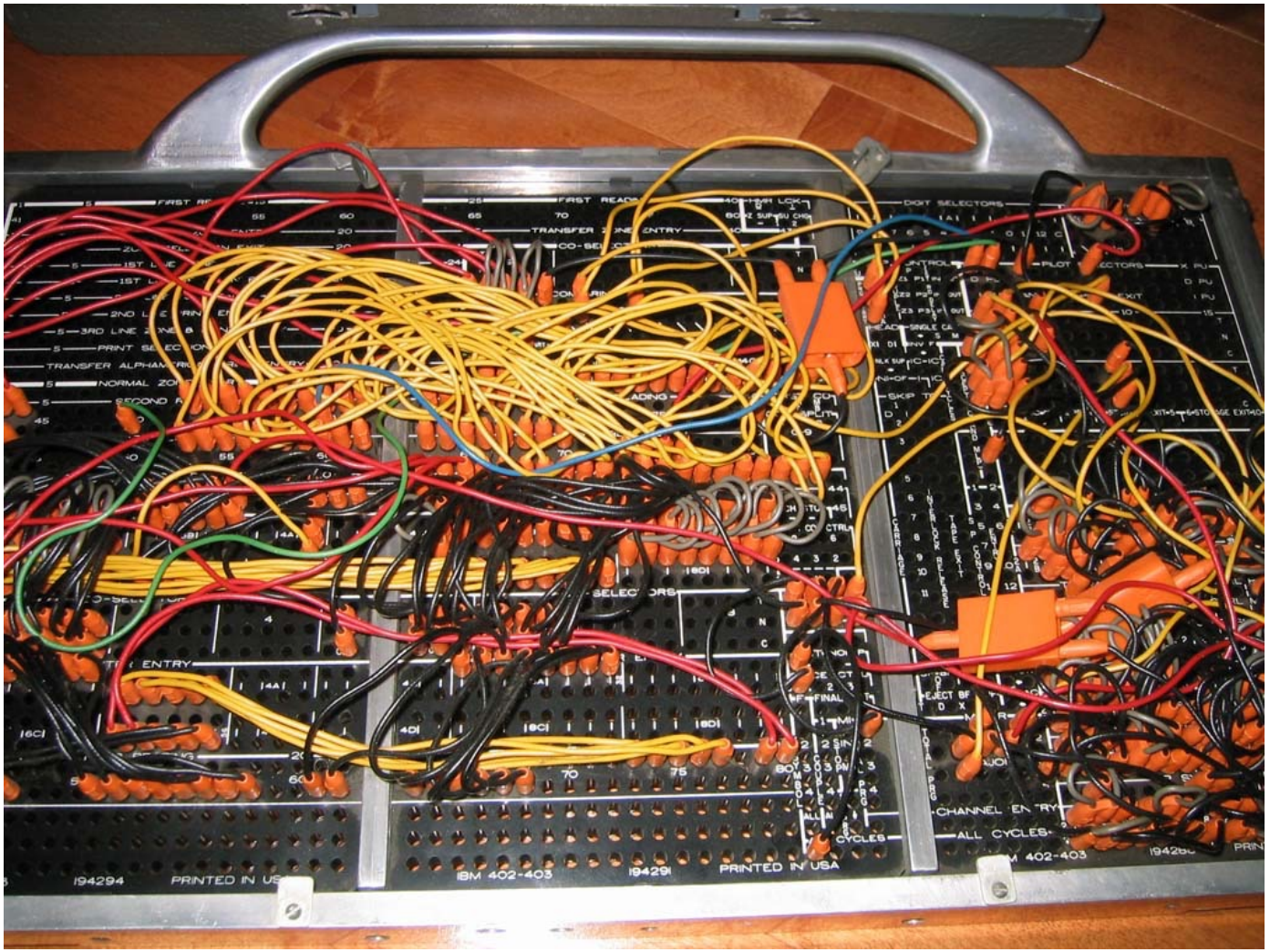
Plugboard Control Panel





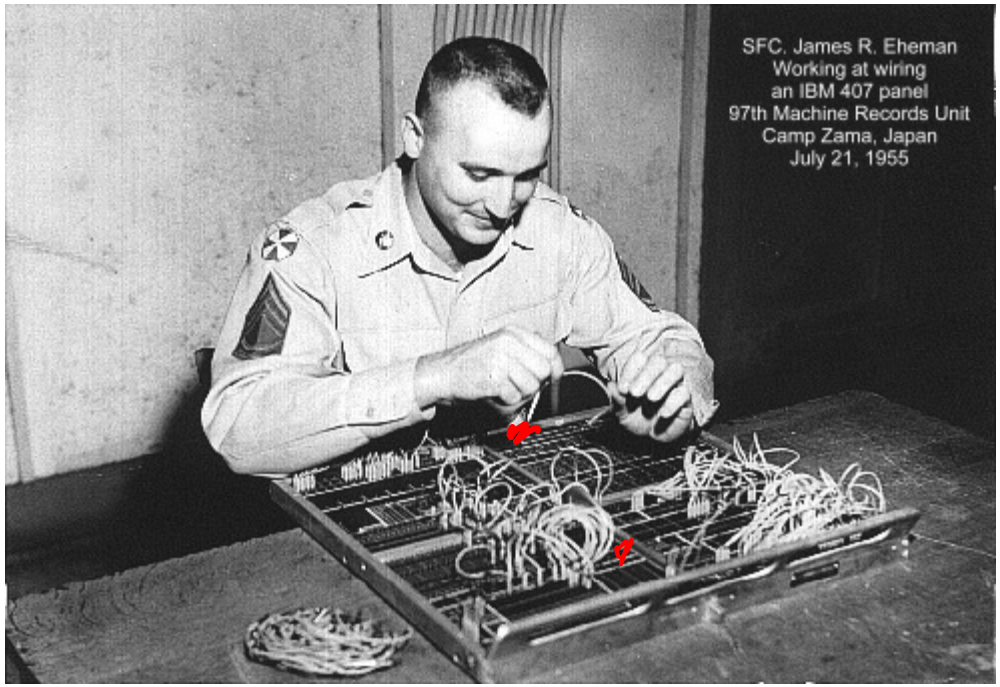
IBM 407 Accounting Machine (1949)

Plugboard Control Panel



Programming a Plugboard

- "Programming" was hand-wiring plugboards.



"Hmm, should I pass this parameter by value or by reference?"

Programming a Plugboard

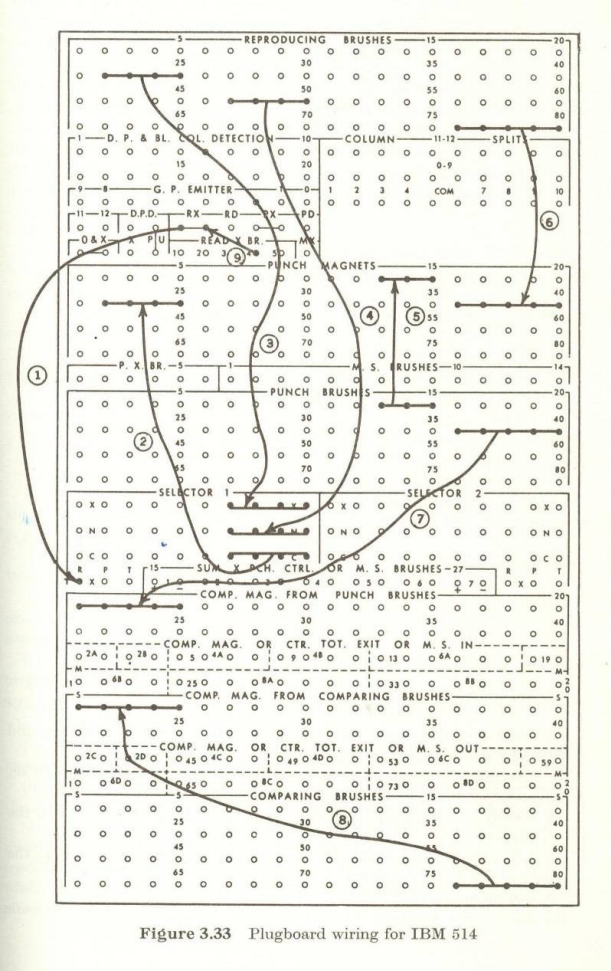


Figure 3.33 Plugboard wiring for IBM 514

- Plugboard wiring diagram
  - It doesn't look too complicated, does it?

Programming Languages

John Backus

Fortran by IBM in 1954

Grace Hopper

Flow-matic 1954

COBOL 1959

John McCarthy

LISP in 1958

Second Generation Computers

- 1955 to 1964
- Transistor replaced vacuum tubes
- Magnetic core memories
- Floating-point arithmetic
- High-level languages used: ALGOL, LISP, COBOL and FORTRAN
- System software: compilers, subroutine libraries, batch processing
- Example: IBM 7094

Data Processing

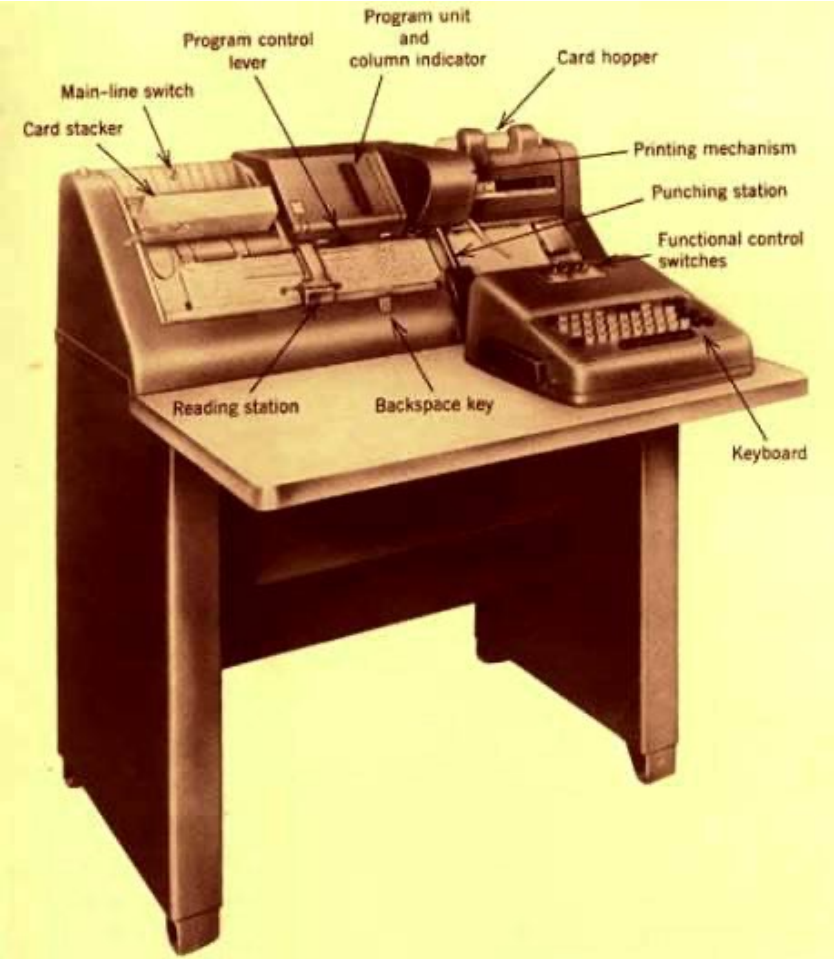
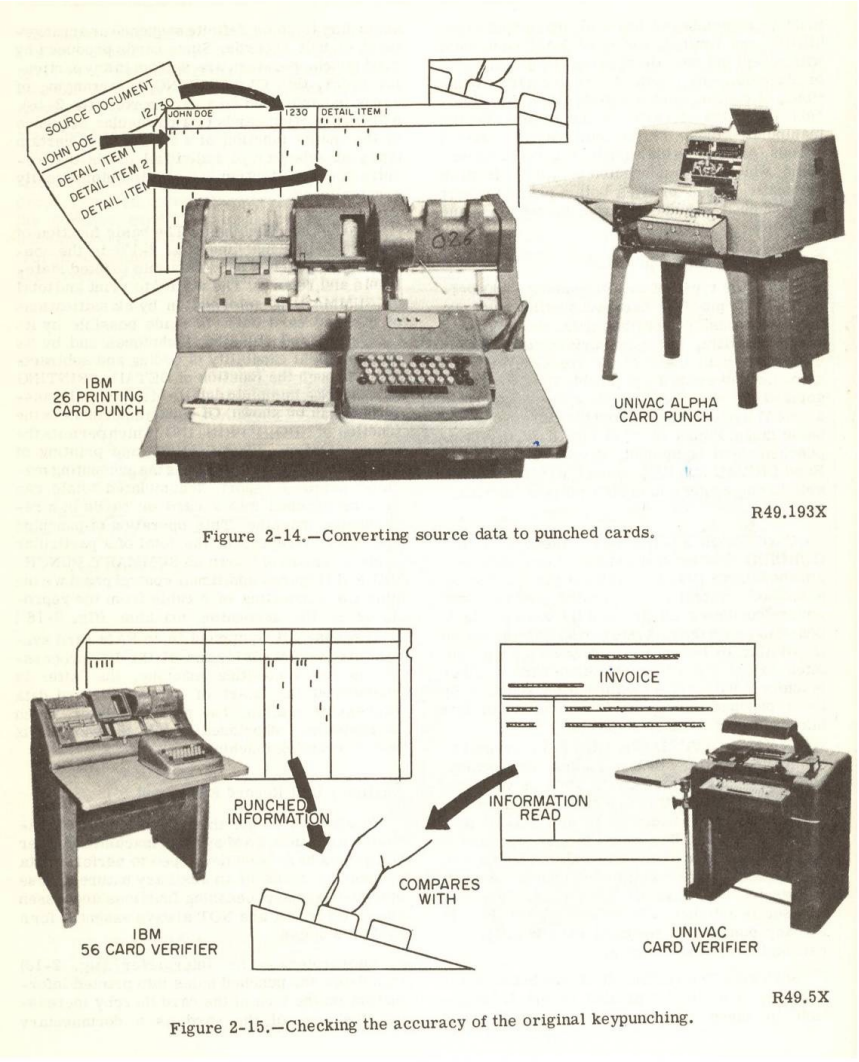


FIGURE 4.11 IBM 026 Keypunch (Courtesy IBM).

- Cards were punched manually at a keypunch machine.
  - Or they were punched automatically by unit-record equipment under program control.

Data Processing



- Cards were re-keyed on a verifier to ensure accuracy.
  - Good cards were notched at the top right edge.
  - Bad cards were notched at the top edge above each erroneous column.

Data Processing

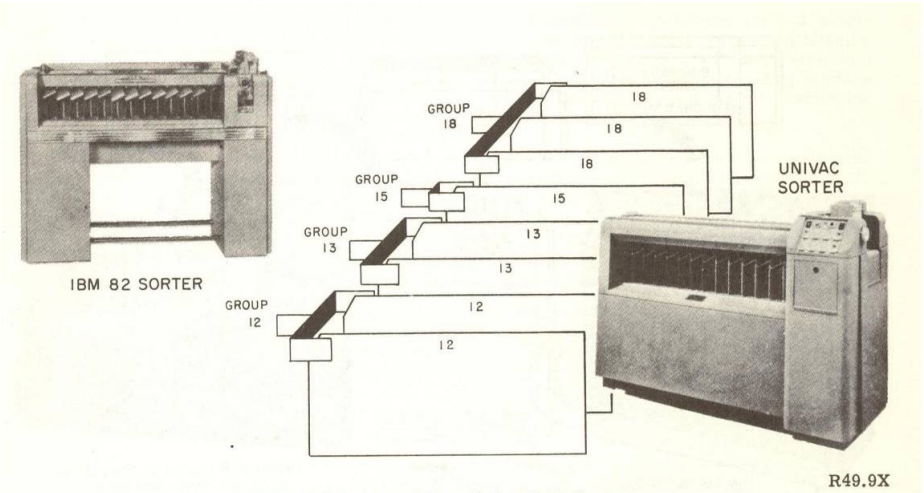


Figure 2-16.—Grouped cards in a definite sequence.

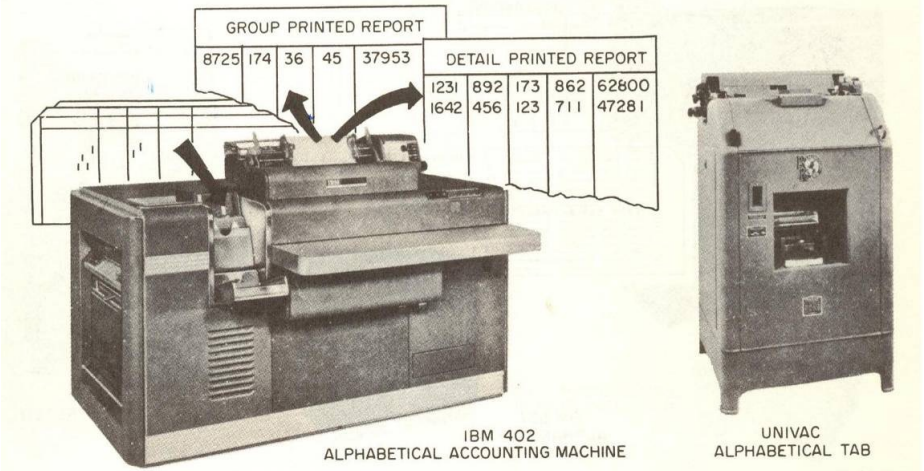


Figure 2-17.—End of the line processing.

- A sorter sorted cards one column at a time.
  - You had to run decks of cards multiple times through a sorter.
- Accounting machines performed arithmetic on card fields and printed reports.

Running a Data Processing Application ...

- ... meant passing decks of cards through a sequence of unit-record machines.
  - Each machine was programmed via its plugboard to perform its task for the application.
  - Each machine had little or no memory.
  - The punched cards stored the data records
  - The data records moved as the cards moved.

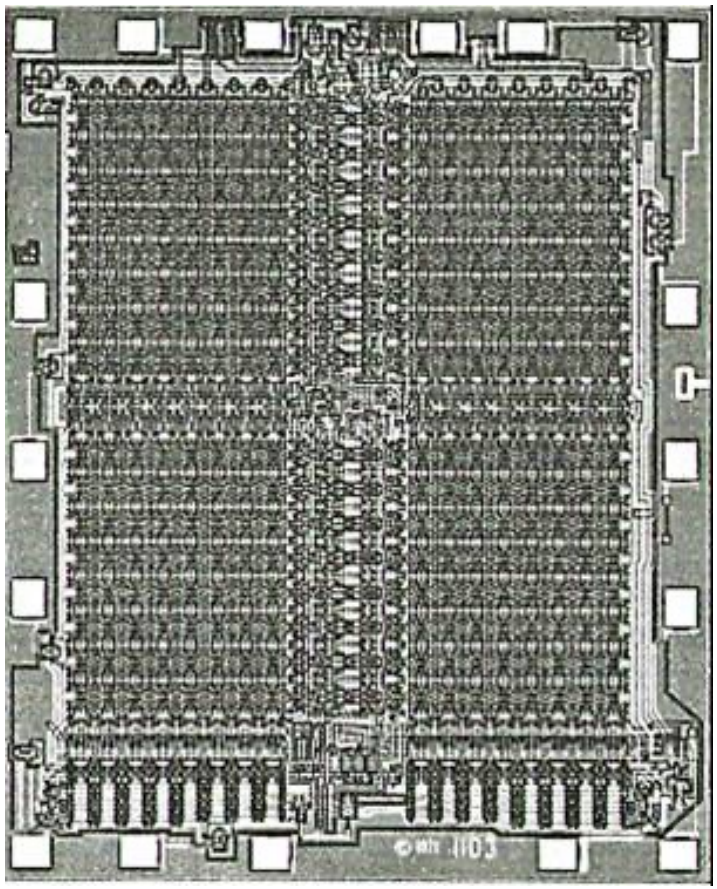
An entire work culture evolved around punched cards!

Third Generation Computers

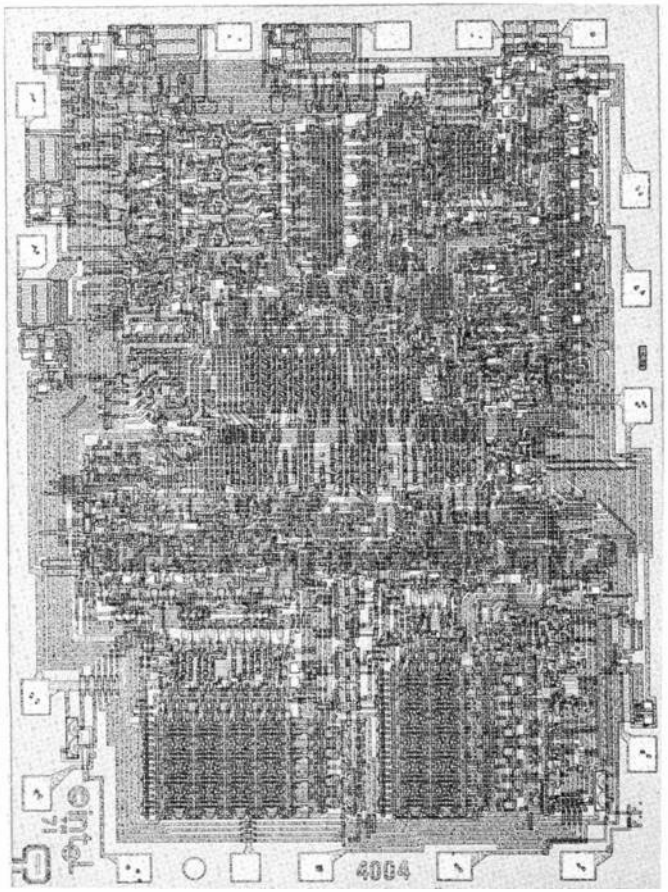
- Beyond 1965
- Integrated circuit (IC) technology
- Semiconductor memories
- Memory hierarchy, virtual memories and caches
- Time-sharing
- Parallel processing and pipelining
- Microprogramming
- Examples: IBM 360 and 370, CYBER, ILLIAC IV, DEC PDP and VAX, Amdahl 470

1971: 1st Generation of LSIs

DRAM Intel 1103



MPU Intel 4004



C Programming Language and UNIX Operating System

1972

Now

CADSL

The Current Generation

- Personal computers
- Laptops and Palmtops
- Networking and wireless
- SOC and MEMS technology
- And the future!
    - Biological computing
    - Molecular computing
    - Optical computing
    - Quantum computing

Thank You