80 Years of Computer History

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Lifetime Learning Institute

of Northern Virginia

Summer 2019

Lecture 1 of 3

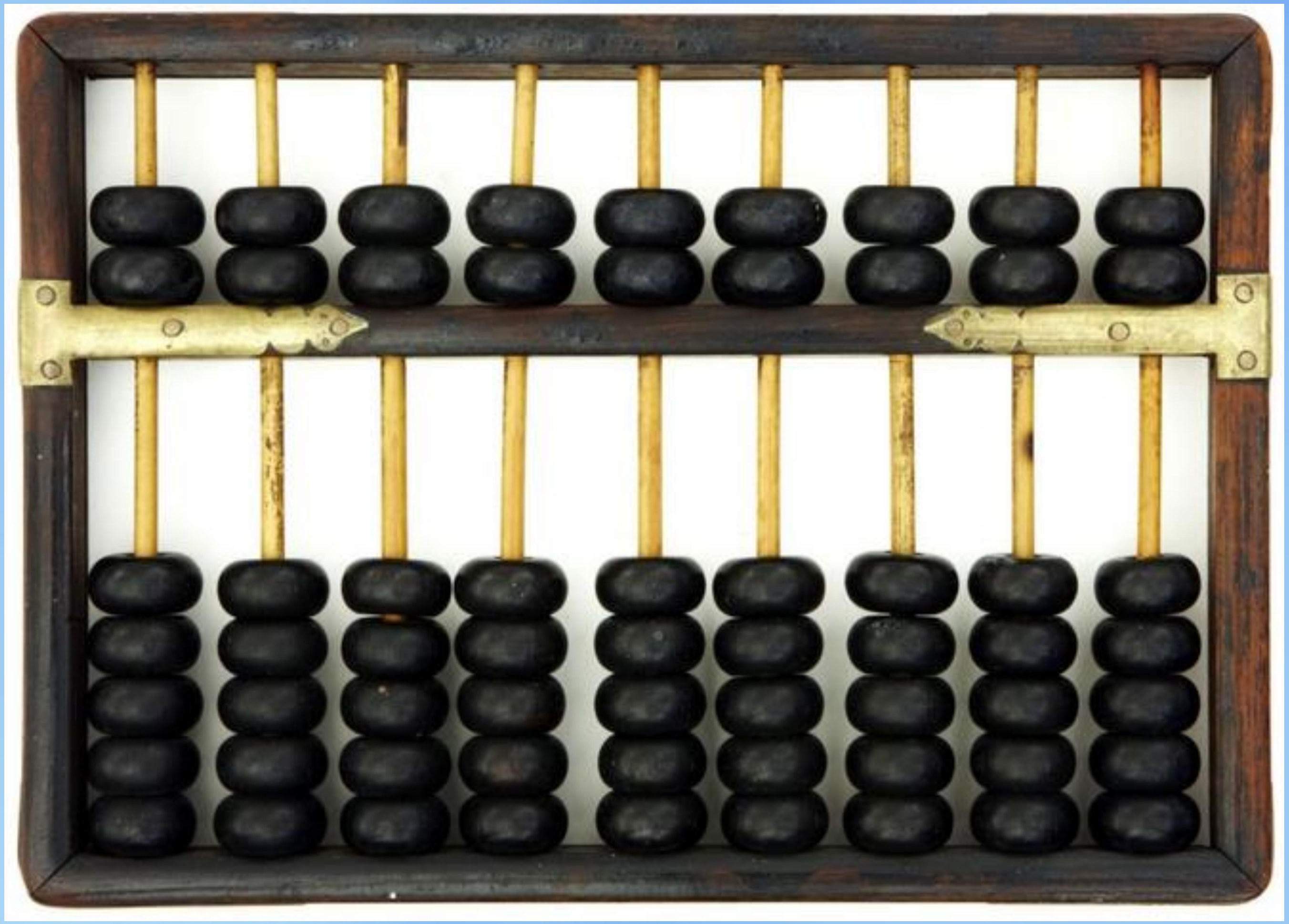
August 22, 2019

Course Outline

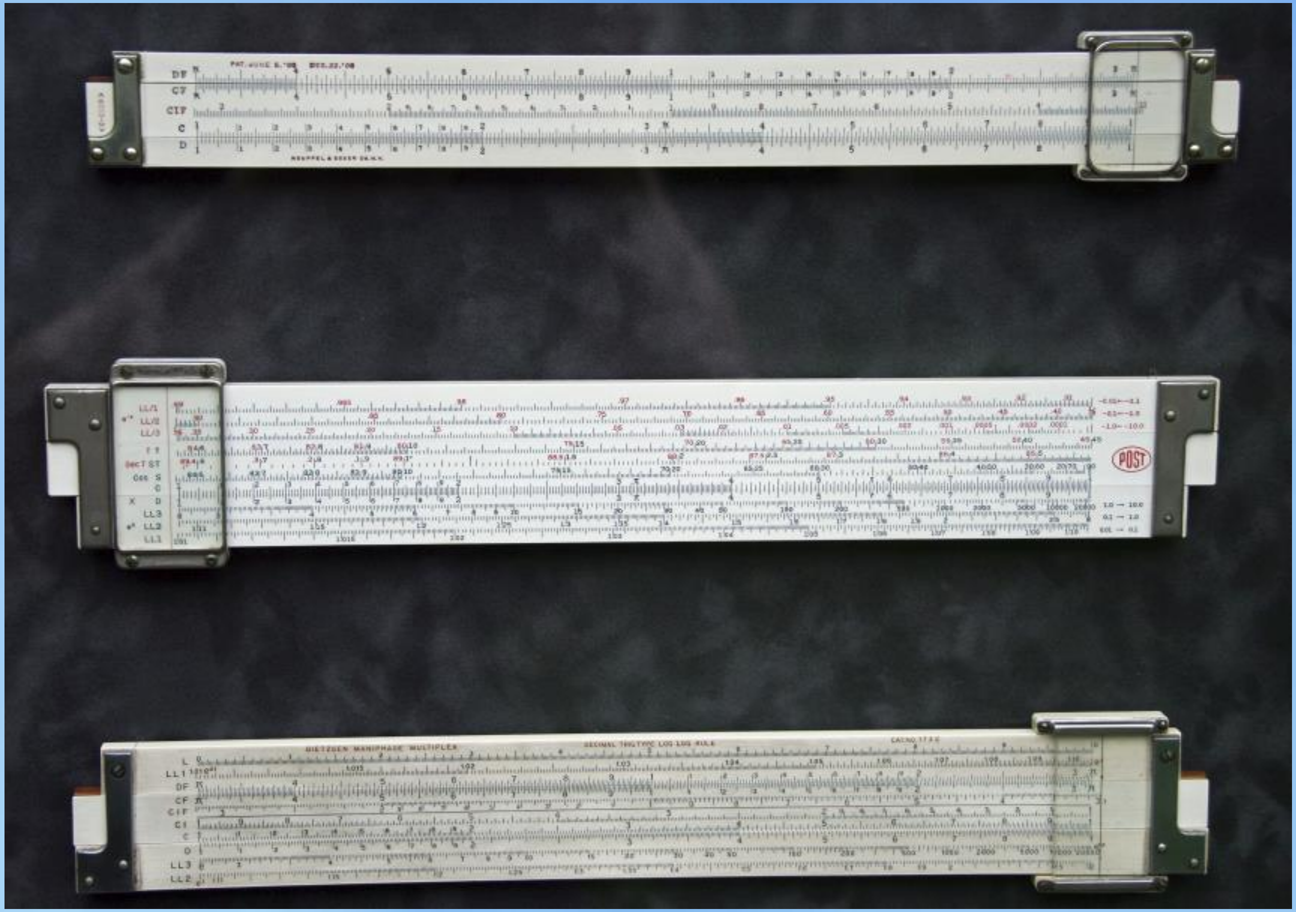
- Why 80 years?
- Events presented chronologically
- Prominent contributing individuals
- A little rudimentary math
- Relevant contemporaneous historical events
- Often “the first” is difficult to determine
- Conflicting dates are sometimes reported
- My apologies for the inevitable errors!

Before Computers — There Were Computers

← active hypertext link



Before Computers — There Were Computers



Harvard's Computers (~1919)

Williamina Fleming

Before Computers — There Were Computers

Human Computers at NASA
1950s & 60s


NASA
2103
Katherine G. Johnson
Computational Research Facility
1 Lindbergh Way

What is a Computer?
(As We Know It Today)

An electronic device

for storing and processing data,

typically in binary form,

according to instructions given to it in a variable program

Types of Computers

- **PCs**
- Tablets
- Smartphones
- Hand-held Calculators
- **Minicomputers**
- **Workstations**
- **Servers**
- **Mainframes**
- **Supercomputers**
- **Internet of Things (IoT)**

PCs

- Used by individuals
- $200 to $3,000
- Used for:
  - E-mail
  - “Surfing” the Web
  - Office automation (Word, PowerPoint, Excel, etc.)
  - Photo/video editing
  - Gaming

Minicomputers

- Midrange machines

  PC < Mini < Mainframe
- Multiuser
- $20,000 to $100,000
- Attached to other devices
  - CAT scanners
  - X-ray refractormeters
  - Mass spectrometers
- Replaced by workstations

Workstations

- "Super" PCs
- $5,000 to $20,000
- Individual users
- Networked
- Used for:
  - CAD/CAM applications
  - Video editing
  - Music production
  - Data analysis

Servers

- Provide storage and services for other networked computers
- $400 to $4,000
- Types:
  - Application servers
  - Database servers
  - Printer servers
  - DNS servers

Mainframes*

- Businesses
  - Banking
  - Insurance
  - Health care
  - Inventory control
  - E-commerce
- Governments
  - Military
  - IRS
  - Social Security

- Large enterprise computers
- $75,000 to millions
- High availability & redundancy
- Hot swapping of components
- **Backward compatible software**
- Thousands simultaneous users
- High transaction throughput
- Large storage capacity

* “Big Iron”

IBM's "Intrepid"
165,000 CPUs

Supercomputers

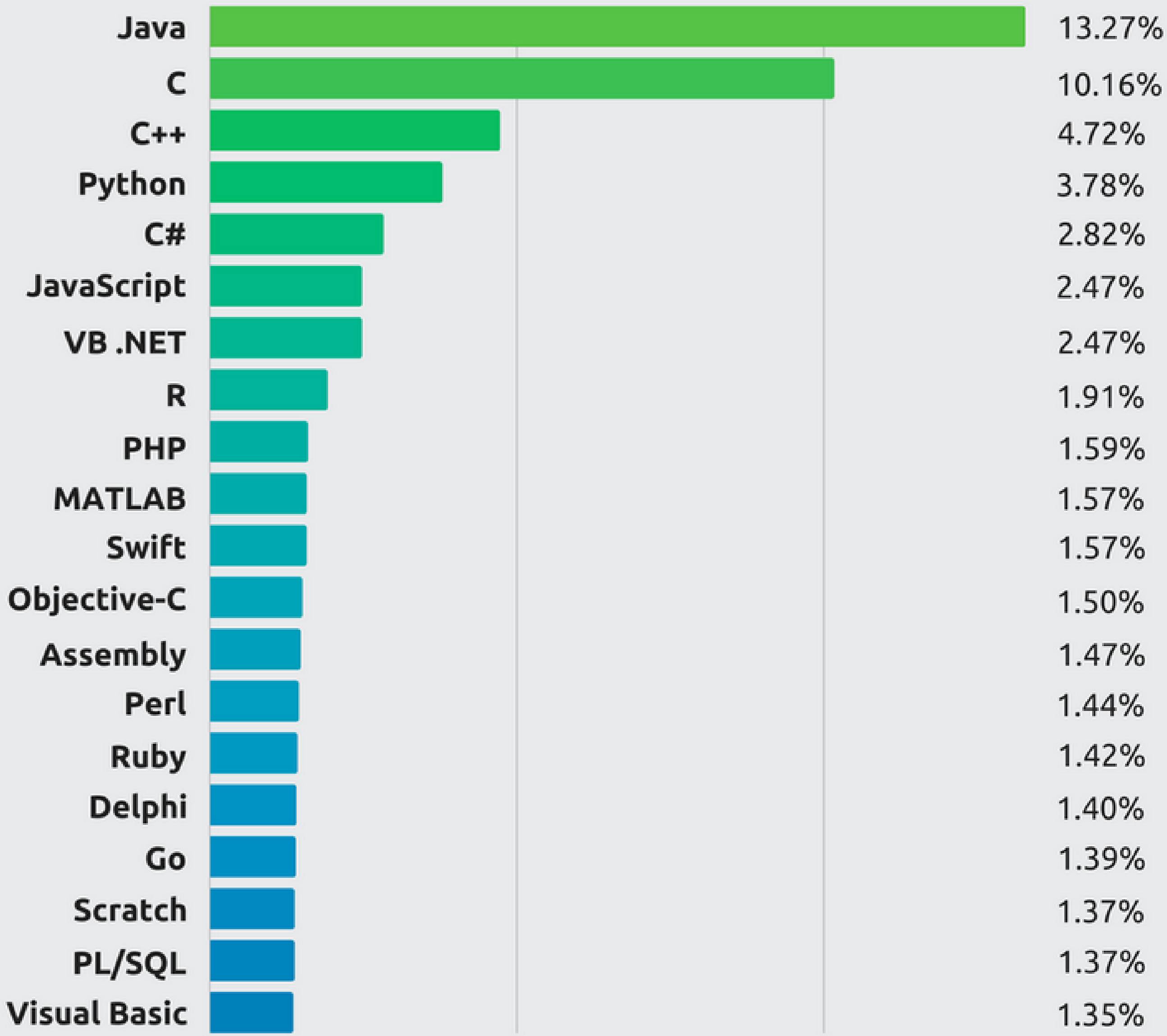
- Extreme numeric performance
- $100 to $250 million
- 1000s CPUs
- Many/most use Linux
- Used for:
  - Weather forecasting
  - Molecular modeling
  - Weapons design
  - Quantum mechanics
  - Petroleum exploration

Software

- A collection of instructions that tell a computer what to do
- Types
  - System, including operating systems
  - Applications (apps), aka programs
  - Utilities
- Approximately 500-2,000 active programming languages

Top Programming Languages

Tiobe Index - December 2017



Software (cont.)

- **In the BASIC language (1964)**

10 PRINT “Hello World!" ← source code

The result? **Hello World!**

Software

- **In the "C" language (1972)**

```
/* A "C "program to print Hello World!  */

#include  <stdio.h>

int main()
{
    printf ("Hello World!\n");
    return 0;
}
```

The result? **Hello World!**

Software (cont.)

- **In the C++ language (1979)**

```
#include <iostream>

int main ( )
{
	std::cout << “Hello World”;
}
```

The result? **Hello World**

Software (cont.)

- **In the Java language (1995)**

```
public class Hello {
        public static void main (String [ ] args) {
              System.out.println ("Hello World");
        }
}
```

The result? **Hello World**

Software (cont.)

- **In the FORTRAN language (1957)**

```
PROGRAM HELLOWORLD
10 FORMAT  (1X, 11HHELLO WORLD)
WRITE (6,10)
END
```

The result? **Hello World**

Software (cont.)

- **In the COBOL language (1959)**

```
IDENTIFICATION DIVISION.
PROGRAM-ID.  Hello.
ENVIRONMENT DIVISION.
DATA DIVISION.
PROCEDURE DIVISION.
          Display  ‘Hello World!’.
          STOP RUN.
```

The result? **Hello World!**

Software (cont.)

- **IBM 360/370/390 BAL (Basic Assembler Language, 1964)**

```
// EXEC ASSEMBLY
          START
MAIN BALR 2,0
          USING *,2
          OPEN PRINT
          MVC BUF,HW
          PUT PRINT
          CLOSE PRINT
          EOJ
HW     DC          CL132 'HELLO WORLD'
BUF    DS          CL132
PRINT DTFPR     IOAREA1=BUF, DEVADDR=SYSLST,BLKSIZE=132,
*
                   DEVICE=3203,CONTROL=YES,PRINTOV=YES
       END MAIN
/*
// EXEC LNKEDT
// EXEC
/*
/&
```

The result? **Hello World**

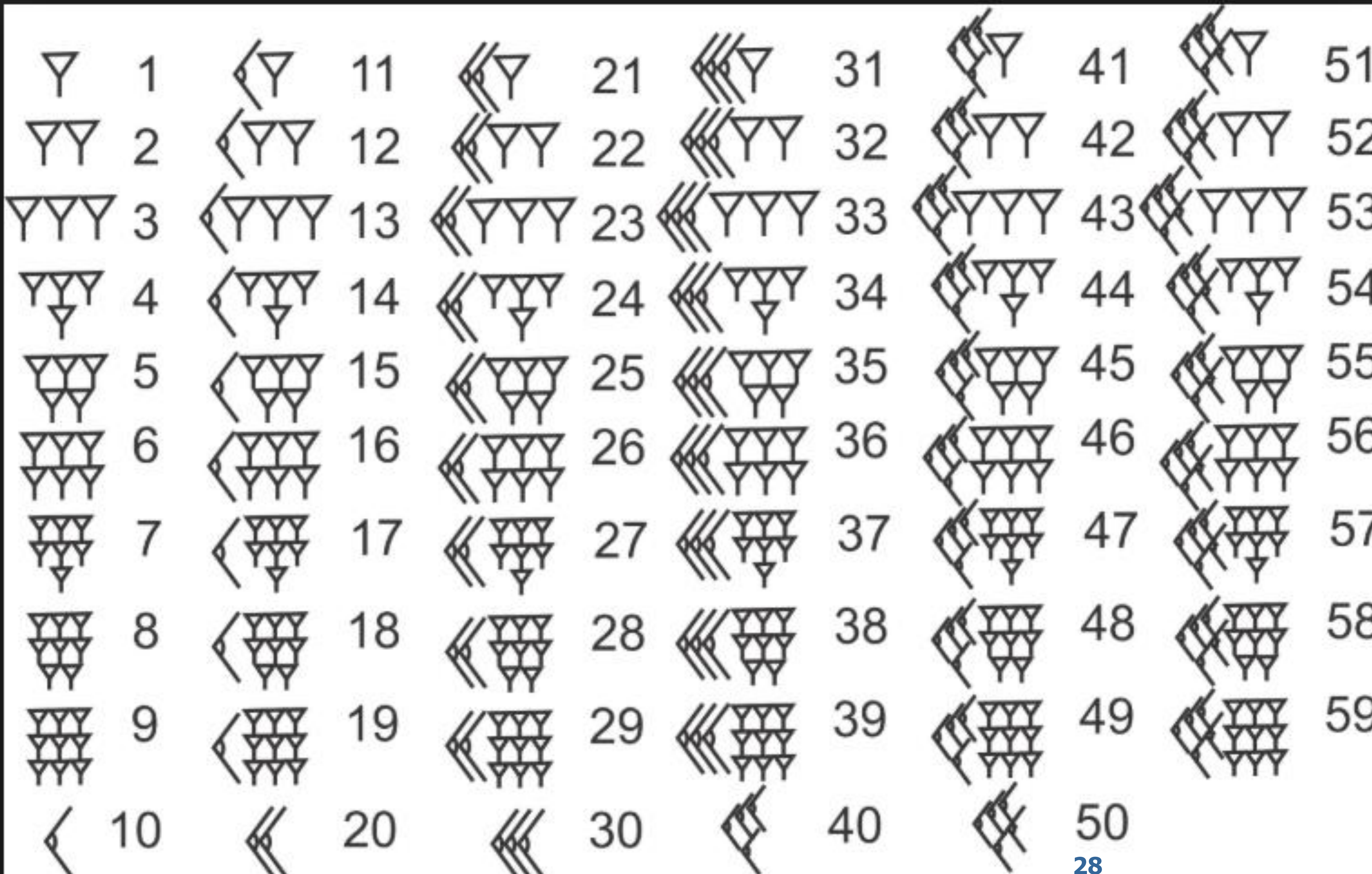
Let's Talk Numbers

An important aside…

Math phobes?

Woof!
Hang
loose…

Babylonian Numbers



“Modern Babylonian Numbers”

- Time
  - 60 seconds/minute
  - 60 minutes/hour
- Mathematics
  - 360° in a circle
  - trigonometric functions
- Geography/Navigation
  - 38° 52’ 38” N   77° 17’ 20” W

1, 2, 3, 4, 5, 6, 7, 8, 9…

Basic Modern Arithmetic

Symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

999 Nine hundred and ninety-nine

↑ ↑ ↑

nine hundreds PLUS

nine tens PLUS

nine "things"

Basic Modern Arithmetic (cont.)

Symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

101_{10} One hundred and one

One hundred PLUS zero tens PLUS 1 “thing”

10^2 10^1 “things”

↑ one (100s)

↑ zero (10s)

↑ 1 count of things

…10^{1000}……10^4 10^3 10^2 10^1 “0➔9 things”

Binary Numbers

Basic Computer Arithmetic

Symbols: 0 and 1 (binary)

101_2 Equal to five in decimal (4 + 0 + 1 = 5)

↑ a "1"
↑ Zero twos
↑ One four

$\ldots 2^7 \quad 2^6 \quad 2^5 \quad 2^4 \quad 2^3 \quad 2^2 \quad 2^1 \quad$ 0 or 1

Decimal 128 64 32 16 8 4 2 0 or 1

$11111111_2 = 128+64+32+16+8+4+2+1 = 255_{10}$

Base 60: $\ldots 60^4 \quad 60^3 \quad 60^2 \quad 60^1 \quad 1 \rightarrow 60$

Base 12: $\ldots 12^4 \quad 12^3 \quad 12^2 \quad 12^1 \quad 1 \rightarrow 12$

American Standard Code for Information Interchange

Letter	ASCII Code	Binary	Letter	ASCII Code	Binary
a	097	01100001	A	065	01000001
b	098	01100010	B	066	01000010
c	099	01100011	C	067	01000011
d	100	01100100	D	068	01000100
e	101	01100101	E	069	01000101
f	102	01100110	F	070	01000110
g	103	01100111	G	071	01000111
h	104	01101000	H	072	01001000

ASCII character “9” = 00111001

Number 9 = 00001001

Letter	ASCII Code	Binary	Letter	ASCII Code	Binary
					01001011
					01001100
					01001101
n	110	01101110	N	078	01001110
o	111	01101111	O	079	01001111
p	112	01110000	P	080	01010000
q	113	01110001	Q	081	01010001
r	114	01110010	R	082	01010010
s	115	01110011	S	083	01010011
t	116	01110100	T	084	01010100
u	117	01110101	U	085	01010101
v	118	01110110	V	086	01010110
w	119	01110111	W	087	01010111
x	120	01111000	X	088	01011000
y	121	01111001	Y	089	01011001
z	122	01111010	Z	090	01011010

Foundations of the Modern Computer

Alois Senefelder

(1771-1834)

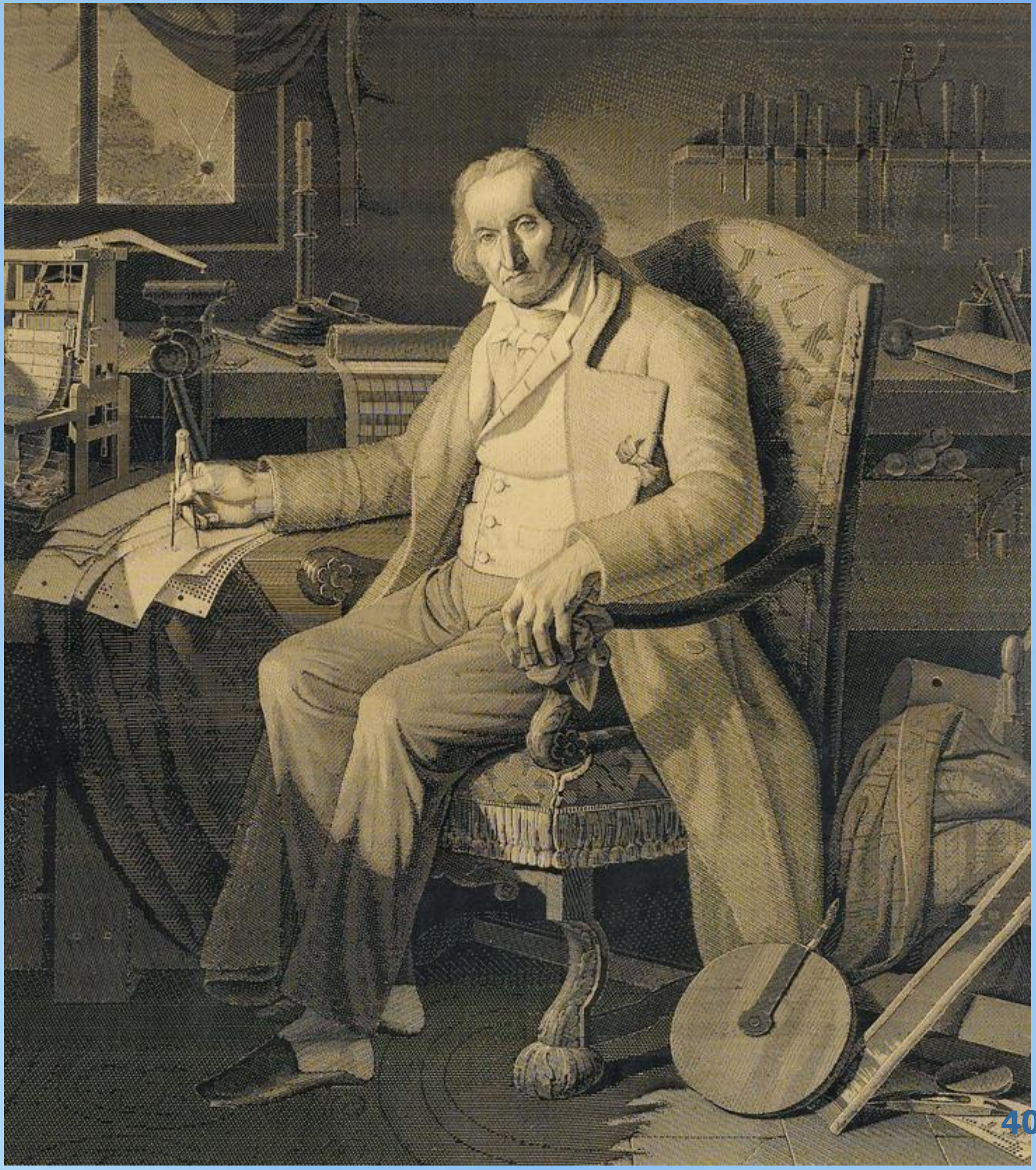
Alois Senefelder

- Actor, playwright, engineer, inventor
- Invented stone printing (Steindruck) 1796
  - to print his plays
- Lithography (from the French)
- 1818—published “A Complete Course of Lithography”
  - currently available on Amazon.com (free)


Archive of lithographic stones in München

Joseph Marie Jacquard
(1752-1834)

Science Museum
London

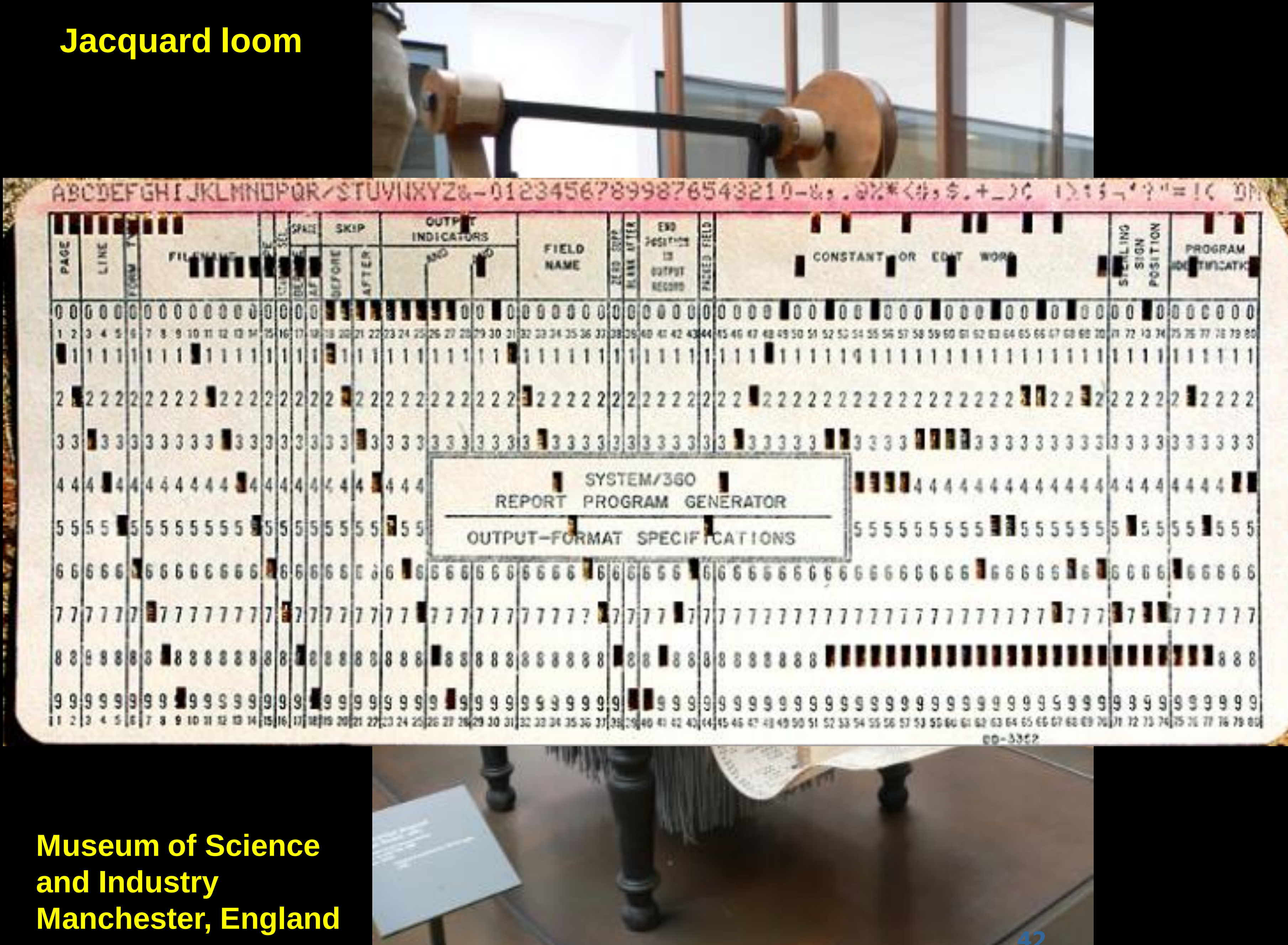


Tapestry woven on
Jacquard loom ➔

The Jacquard Loom

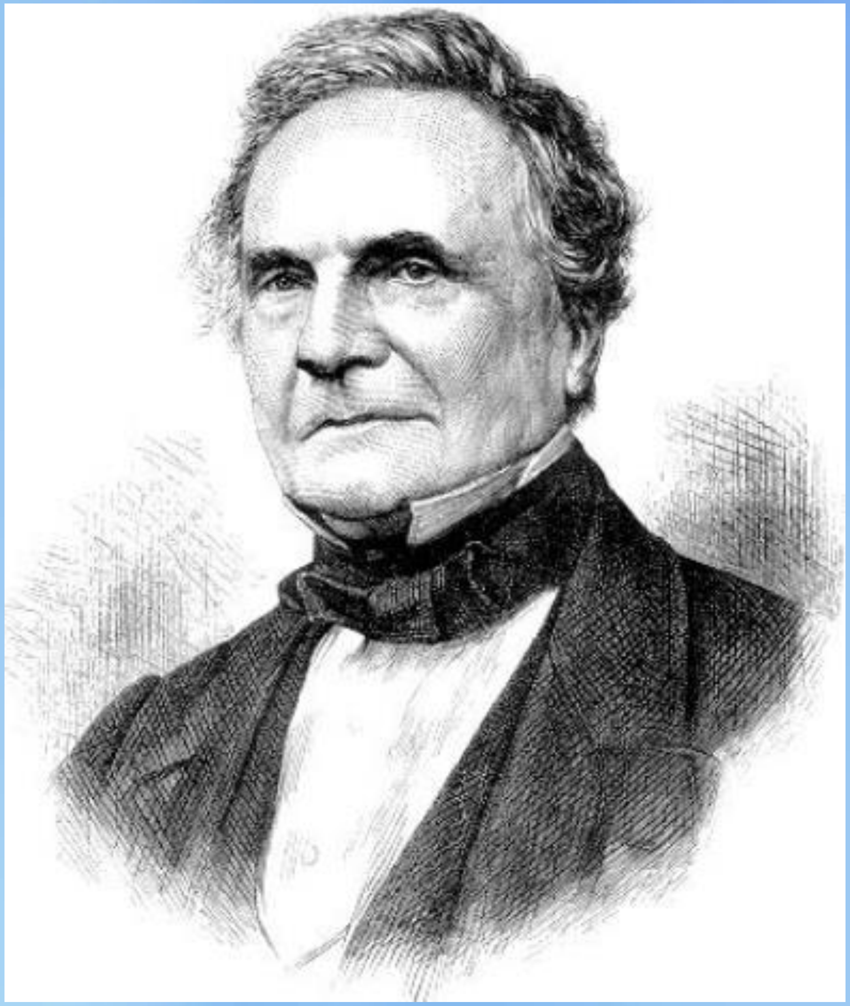
- Invented in 1804
- Punched cards activate hooks and rods on a loom to create intricate patterns
- Revolutionized weaving
  - greatly reduced labor costs
  - reduced price of intricate cloth
  - caused considerable civil unrest due to job loss

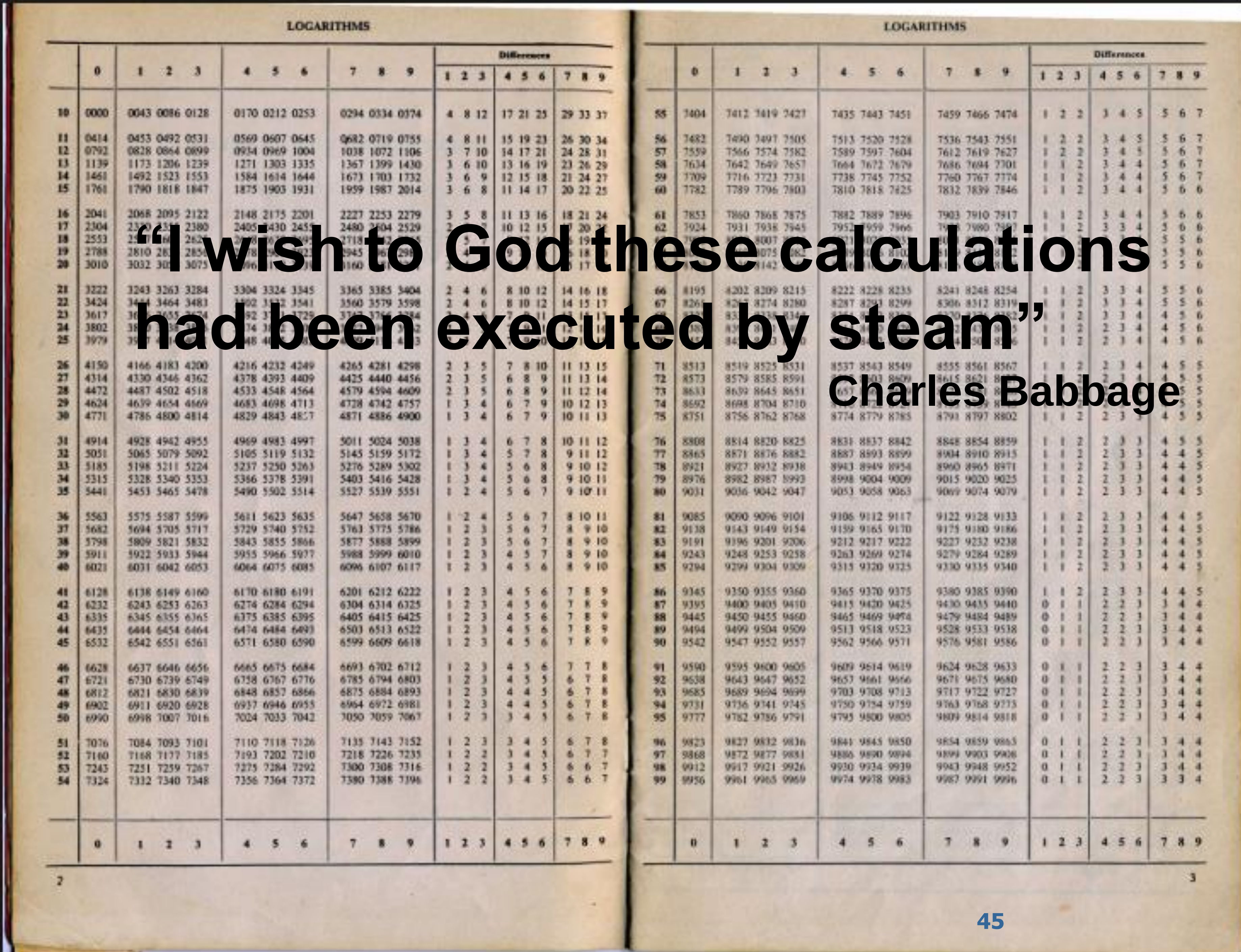
Jacquard loom



Museum of Science and Industry Manchester, England

Charles Babbage (1791-1871)





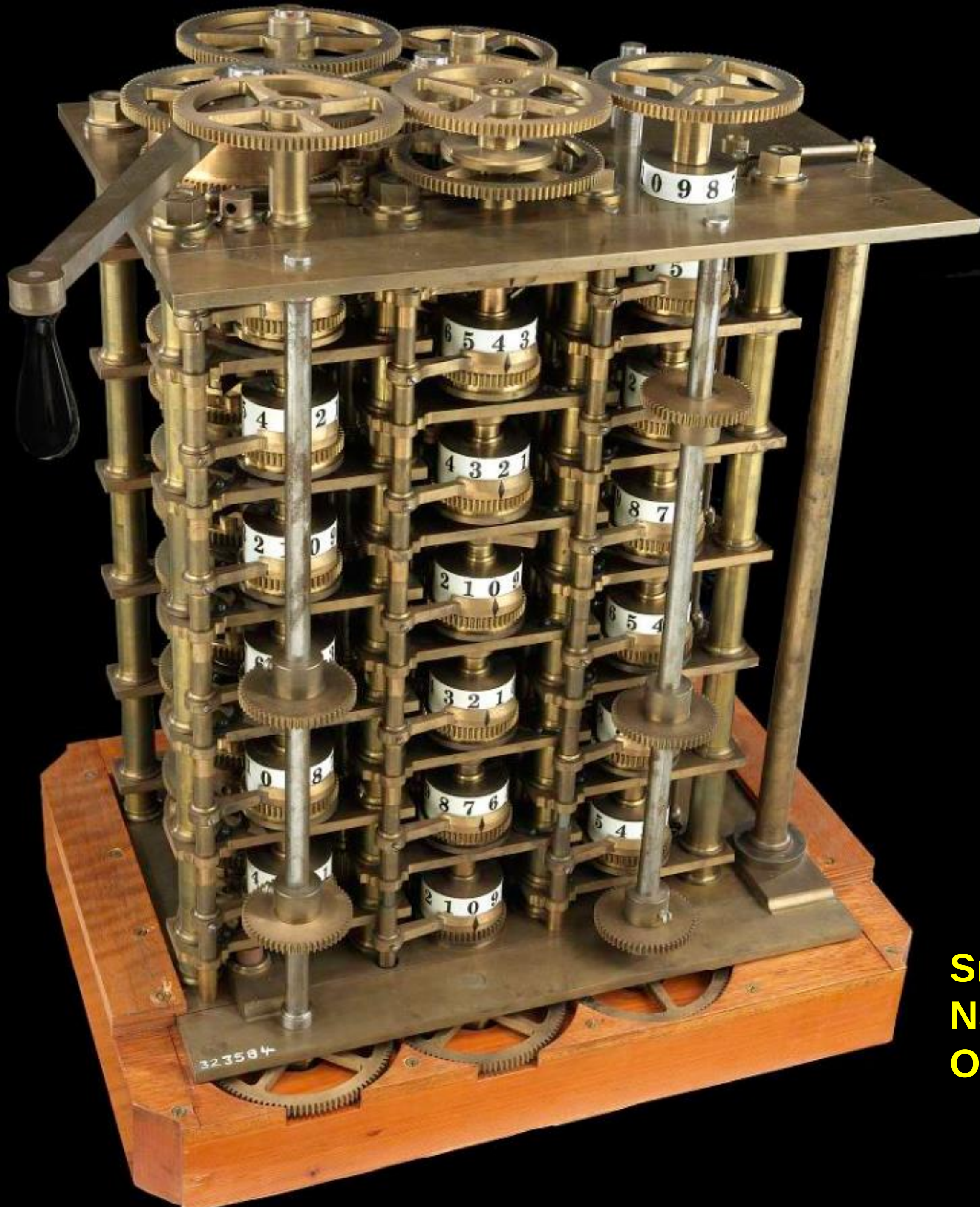
“I wish to God these calculations had been executed by steam”

Charles Babbage

The Difference Engine—1821

- Created values for:
  - logarithms
  - trigonometric functions, etc.
  - using the method of finite differences in evaluating polynomials
- Sample polynomial: $f(x) = 2x^4 – 5x^3 + 2x^2 + 17$
- Could compute 31-digit values for polynomials with terms up to X^7
- 1827—published accurate table of logarithms for 1 to 108,000

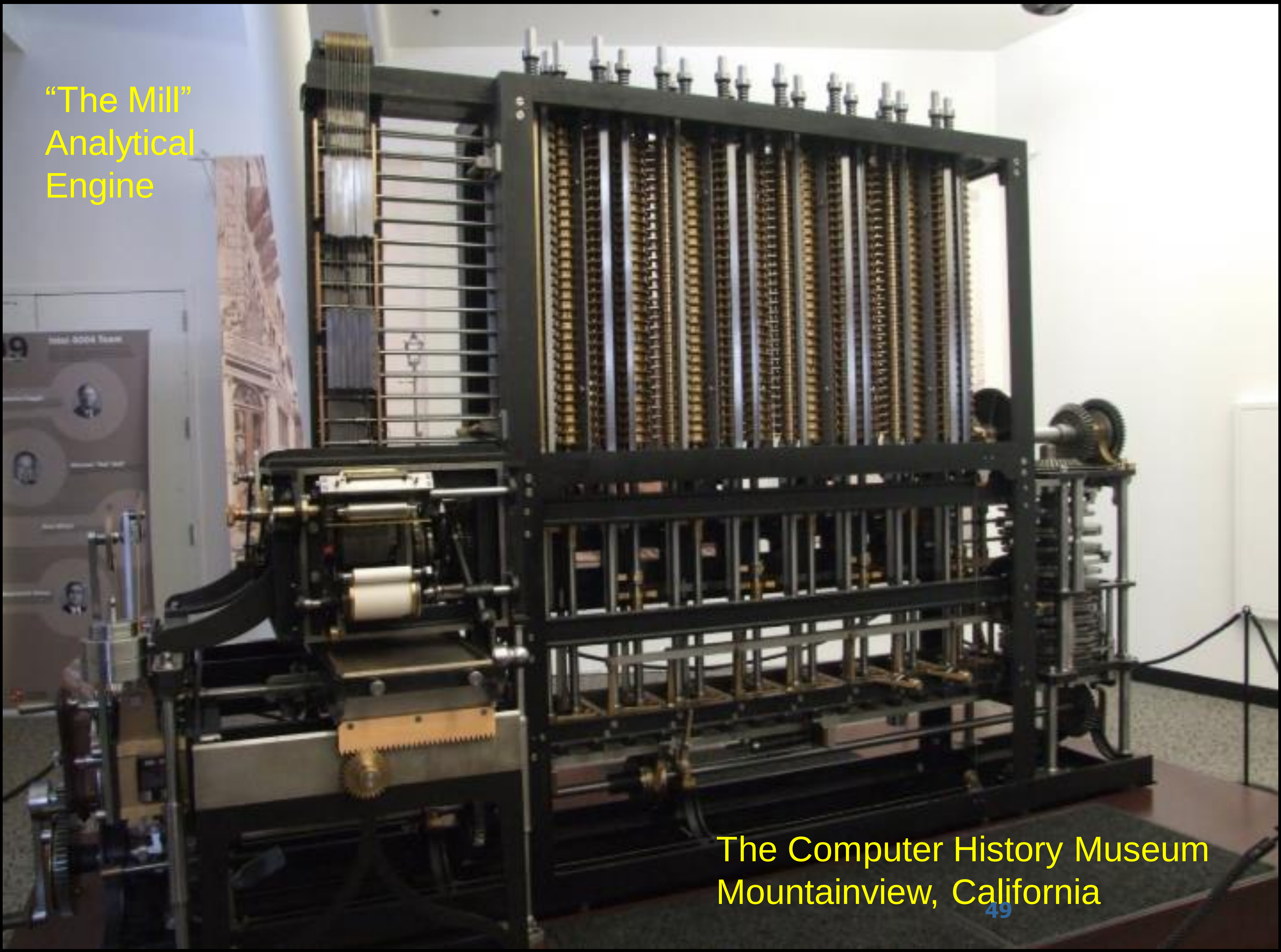
Replica Babbage's Difference Engine #1

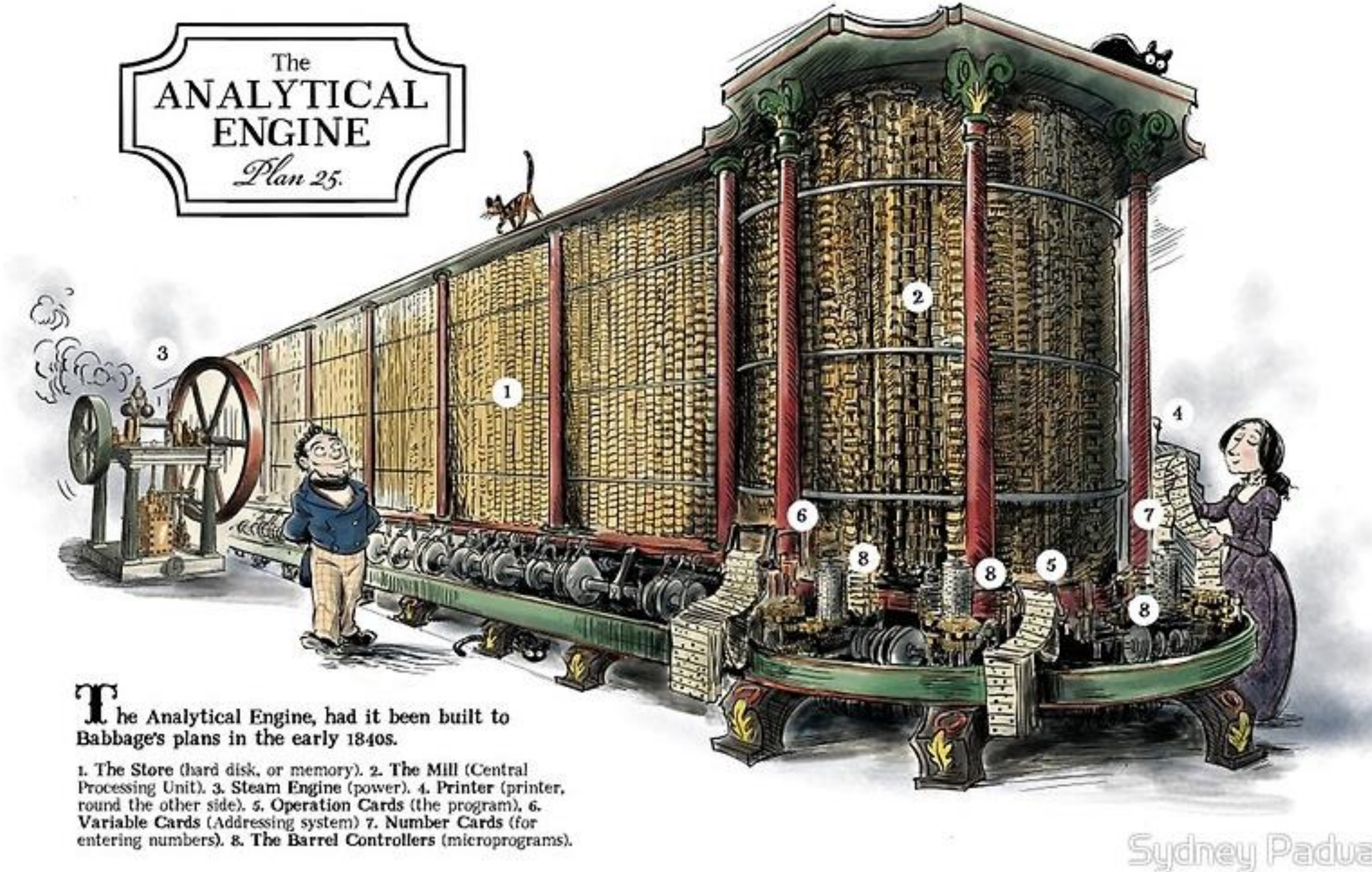


Smithsonian National Museum Of American History

The Analytical Engine—1837

- A mechanical general purpose computer
- Fully programmable
- Components:
  - **The mill** (CPU)
  - **The store** 1,000 50-digit numbers (RAM/HDD)
  - **The reader**—punch cards (input/output devices)
- Steam driven
- **Never built**


“The Mill”
Analytical
Engine
The Computer History Museum
Mountainview, California



The Analytical Engine, had it been built to Babbage's plans in the early 1840s.

1. The Store (hard disk, or memory). 2. The Mill (Central Processing Unit). 3. Steam Engine (power). 4. Printer (printer, round the other side). 5. Operation Cards (the program). 6. Variable Cards (Addressing system) 7. Number Cards (for entering numbers). 8. The Barrel Controllers (microprograms).

Babbage's Other Accomplishments

- Mathematician
- Reformed the British post office
- Pioneer in field of actuarial science
- Discovered weather of past years could be ascertained from tree rings
- **Invented the cow catcher**

Ada, Countess of Lovelace

From ”The Innovators” by
Walter Isaacson,
Simon & Shuster, 2014

Ada Lovelace

- Daughter of the poet Lord Byron
- A gifted mathematician
- Life-long friend of Charles Babbage
- 1980—the DoD named a computer language “Ada” in her honor

Luigi Federico Menabrea*
(1809-96)

* Became Prime Minister of Italy in 1867

Congress of Italian Scientists*

- Charles Babbage gave presentation on his Analytical Engine
- Menabrea took notes and published “Sketch of the Analytical Engine Invented by Charles Babbage” (1842)
- Ada Lovelace translated the article and appended “Notes by the Translator”
- “Notes by the Translator” becomes famous

* In Turin, Italy, August 1840

Sketch of *The Analytical Engine*

To return to the trigonometrical series. We shall only consider the first four terms of the factor ($A + A_1 \cos\theta$ + &c.), since this will be sufficient to show the method. We propose to obtain separately the numerical value of *each coefficient* C_0, C_1, &c. of (1.). The direct multiplication of the two factors gives

$$\left.\begin{array}{l} BA + BA_1\cos\theta + BA_2\cos 2\theta \quad + BA_3\cos 3\theta \quad + \ldots\ldots\ldots\ldots\ldots\ldots \\ \qquad B_1A\cos\theta + B_1A_1\cos\theta\cdot\cos\theta + B_1A_2\cos 2\theta\cdot\cos\theta + B_1A_3\cos 3\theta\cdot\cos\theta \end{array}\right\} \qquad (2.)$$

a result which would stand thus on the engine:—

Variables for Data

V_0	V_1	V_2	V_3	....	V_{10}	V_{11}
A	A_1	A_2	A_3		B	B_1
	$\cos\theta$	$\cos 2\theta$	$\cos 3\theta$			$\cos\theta$

Variables for Results

V_{20}	V_{21}	V_{22}	V_{23}	..	V_{31}	V_{32}	V_{33}	V_{34}
BA	BA_1	BA_2	BA_3		B_1A	B_1A_1	B_1A_2	B_1A_3
	$\cos\theta$	$\cos 2\theta$	$\cos 3\theta$		$\cos\theta$	$(\cos\theta\cdot\cos\theta)$	$(\cos 2\theta\cdot\cos\theta)$	$(\cos 3\theta\cdot\cos\theta)$

they have not in fact resolved the double problem which the question presents, that of *correctness* in the results, united with *economy* of time.

"Notes by the Translator"

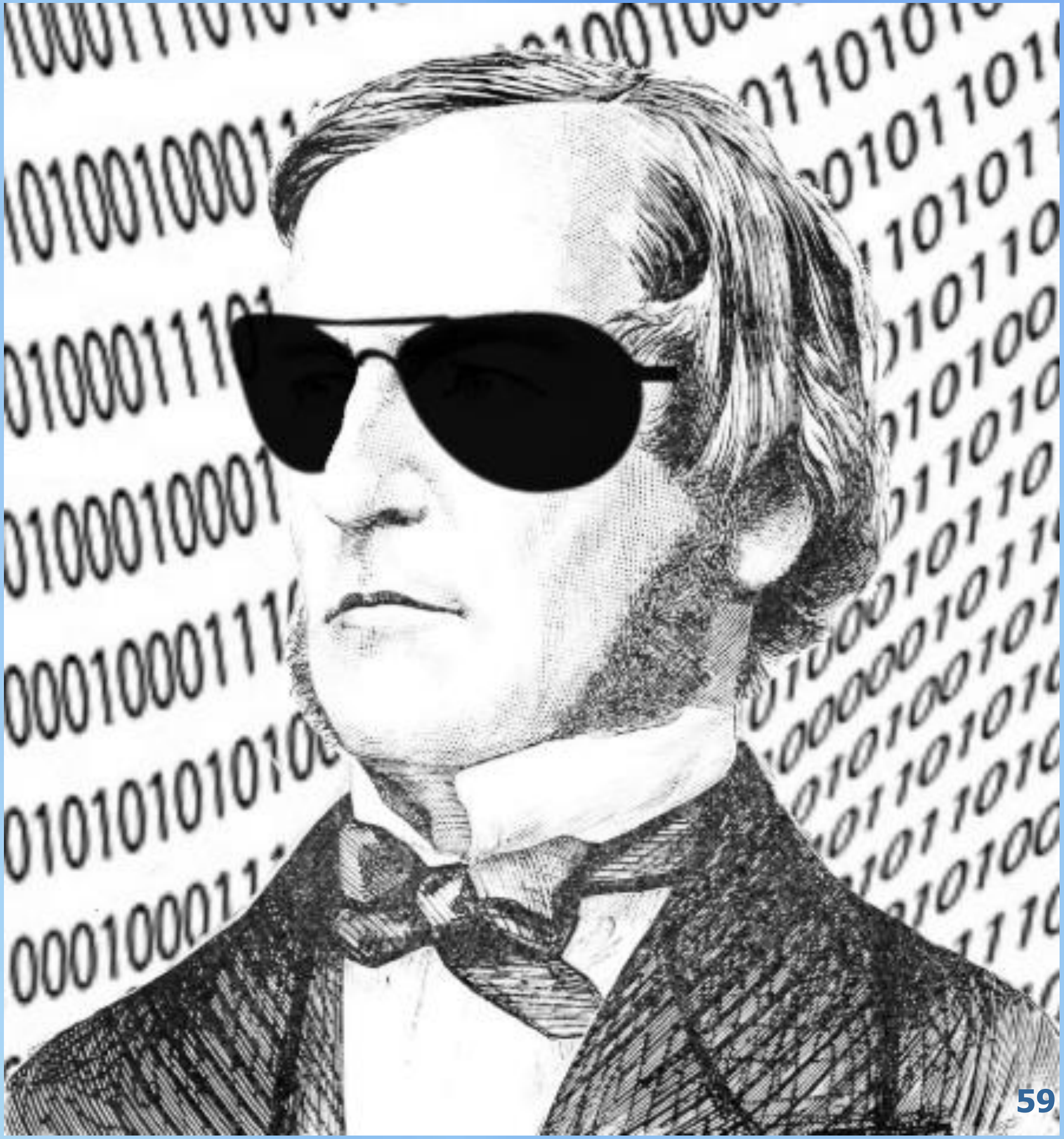
- Ada described an algorithm (program) to compute Bernoulli numbers

$$\frac{x}{\epsilon^x - 1} = \frac{1}{1 + \frac{x}{2} + \frac{x^2}{2 \cdot 3} + \frac{x^3}{2 \cdot 3 \cdot 4} + \&c.}$$

- Suggested the Analytical Engine could be used for things other than numbers
  - musical notes
  - symbols such as letters

George Boole (1815-64)

“Cool Boole”



Boolean Algebra (1854)

- A branch of algebra that involves true and false values
  - T or 1 for true
  - F or 0 for for false

Boolean Algebra (cont.)

- The **AND operator** (symbolically: ∧) also known as **logical conjunction** requires both p and q to be True for the result to be True

p	q	p∧q
T	T	T
T	F	F
F	T	F
F	F	F

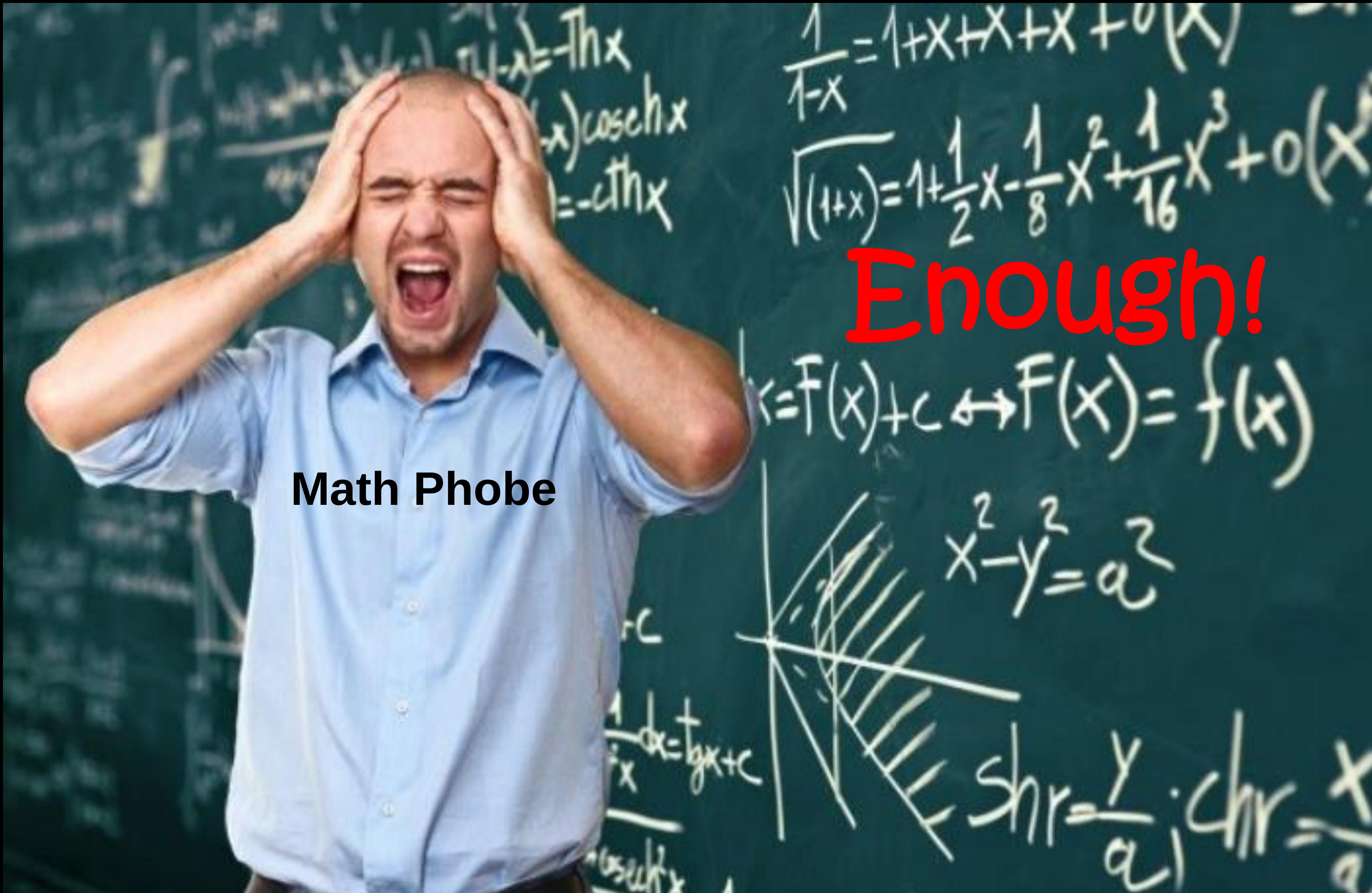
1 = T or true
0 = F for false

Boolean Algebra (cont.)

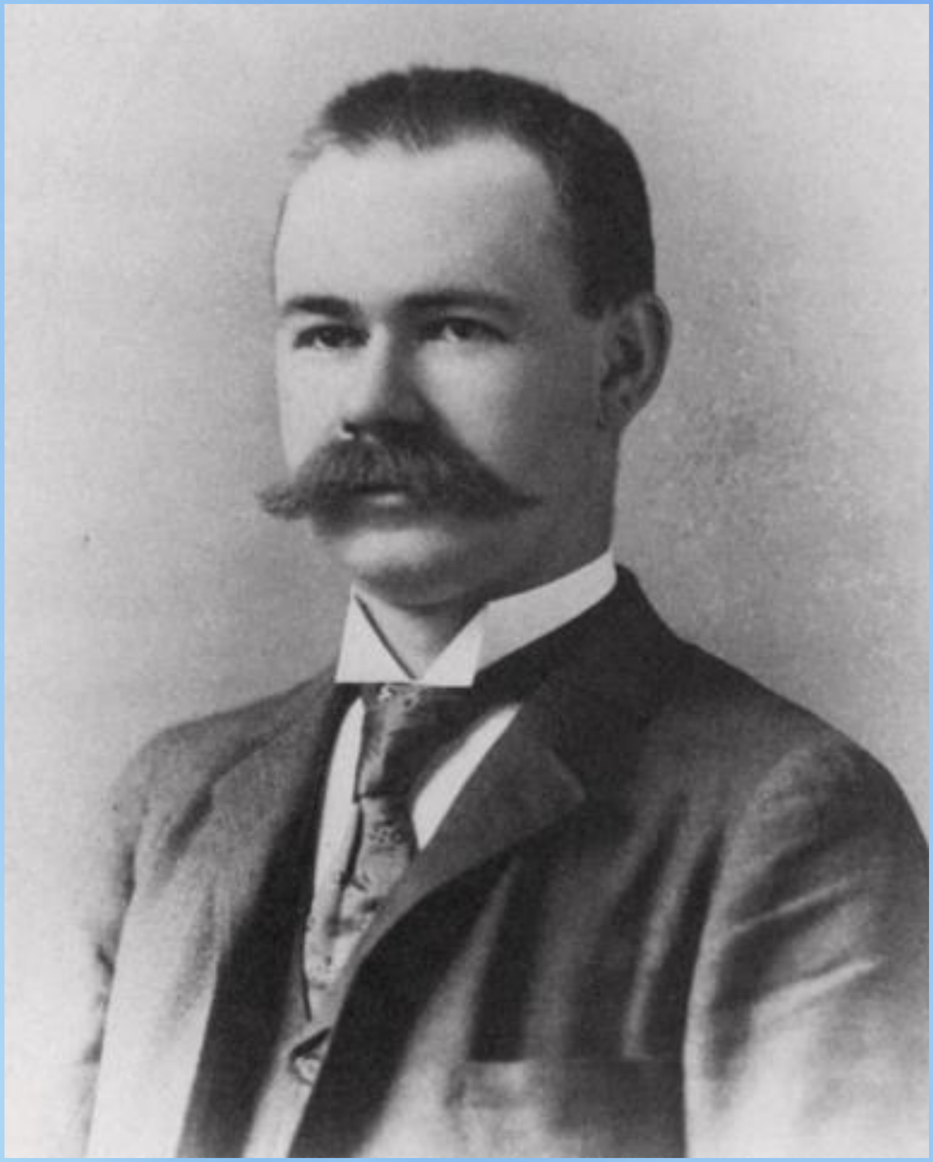
- The **OR operator** (symbolically: ∨) requires only one value to be True for the result to be True

p	q	p∨q
T	T	T
T	F	T
F	T	T
F	F	F

1 = T or true
0 = F for false


Enough!
Math Phobe

Herman Hollerith (1860-1929)



Herman Hollerith

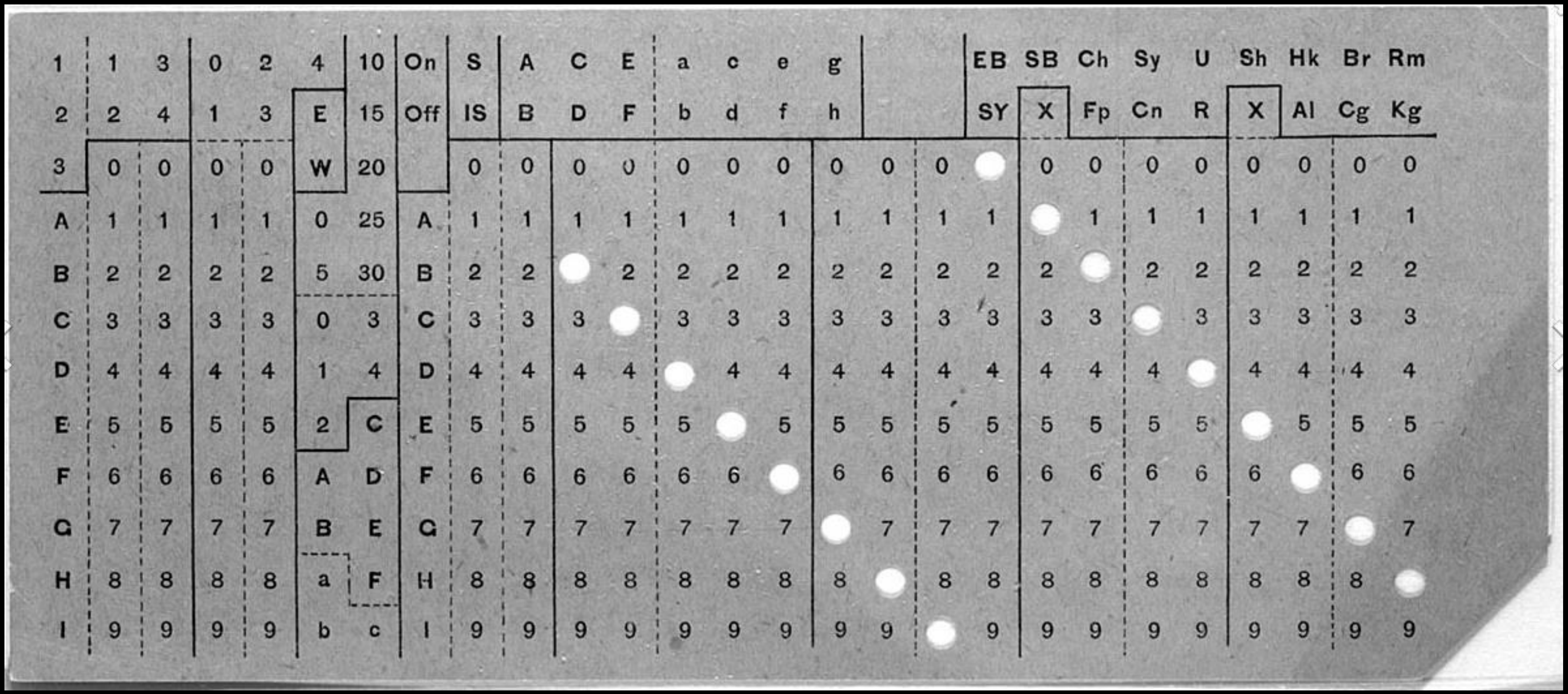
- Degree in “Engineering of Mines” from Columbia University in 1879
- Ph.D. from Columbia in 1882
- Professor of mechanical engineering at MIT
- U.S. Census Bureau statistician
- Invented a electromechanical punched card sorter and tabulator

Hollerith's Tabulator and Sorter

Hollerith's Pantograph Punch

December 31, 1919

Hollerith's Punch Card



First Mass Storage Device

(Most of the 1890 records destroyed by a fire at the Commerce Department in 1921)

Counting the U.S. Population

- 1880 U.S. census took eight years to tabulate
- 1890 census took one year
- First major use of electrical circuits to process information

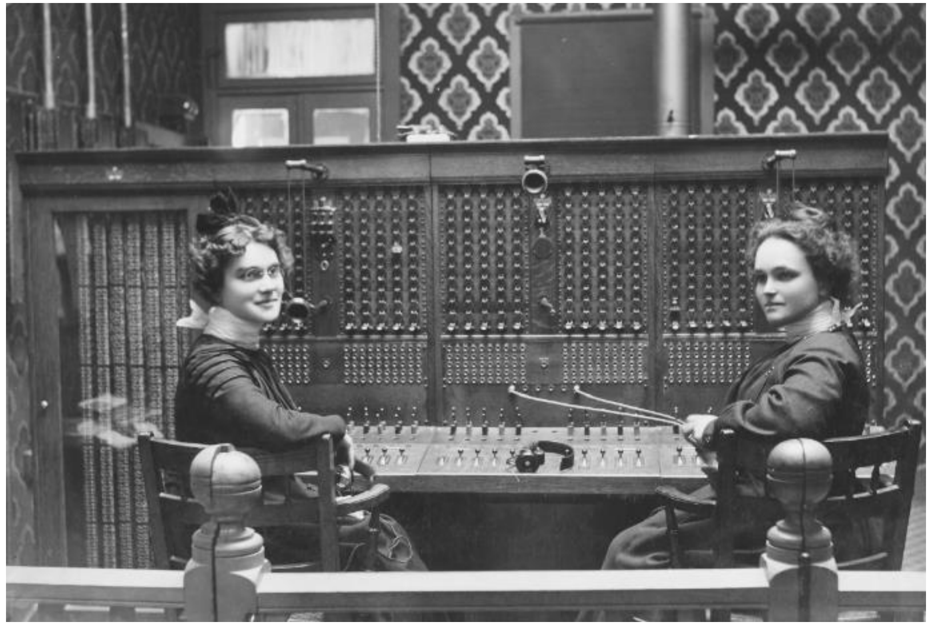
Tabulating Machine Company

- Formed by Hollerith in 1896
- With two additional companies evolved into the Computing-Tabulating-Recording Company (C-T-R) in 1911
- Evolved into International Business Machines (IBM) Corporation in 1924

Foundations of the Modern Computer

Telephone

Telephone (cont)



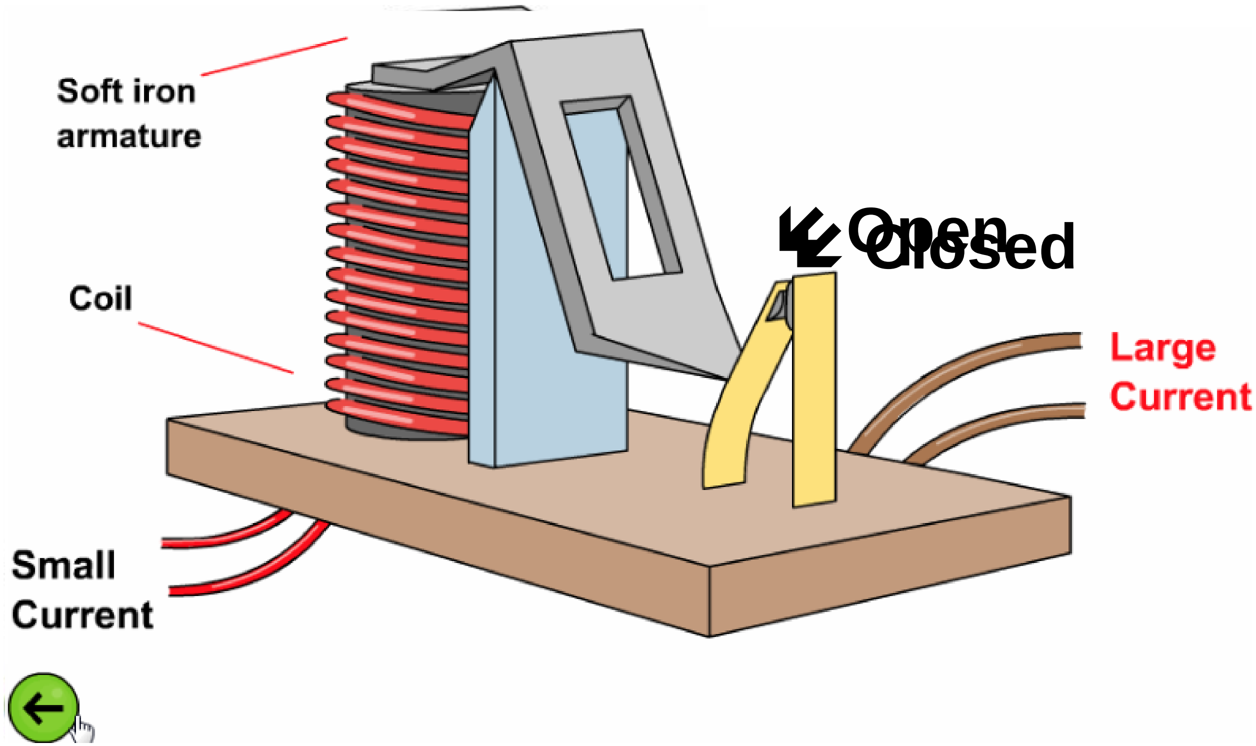
Miss Crook or Miss Mickey

(<u>switch</u> operators or operators)

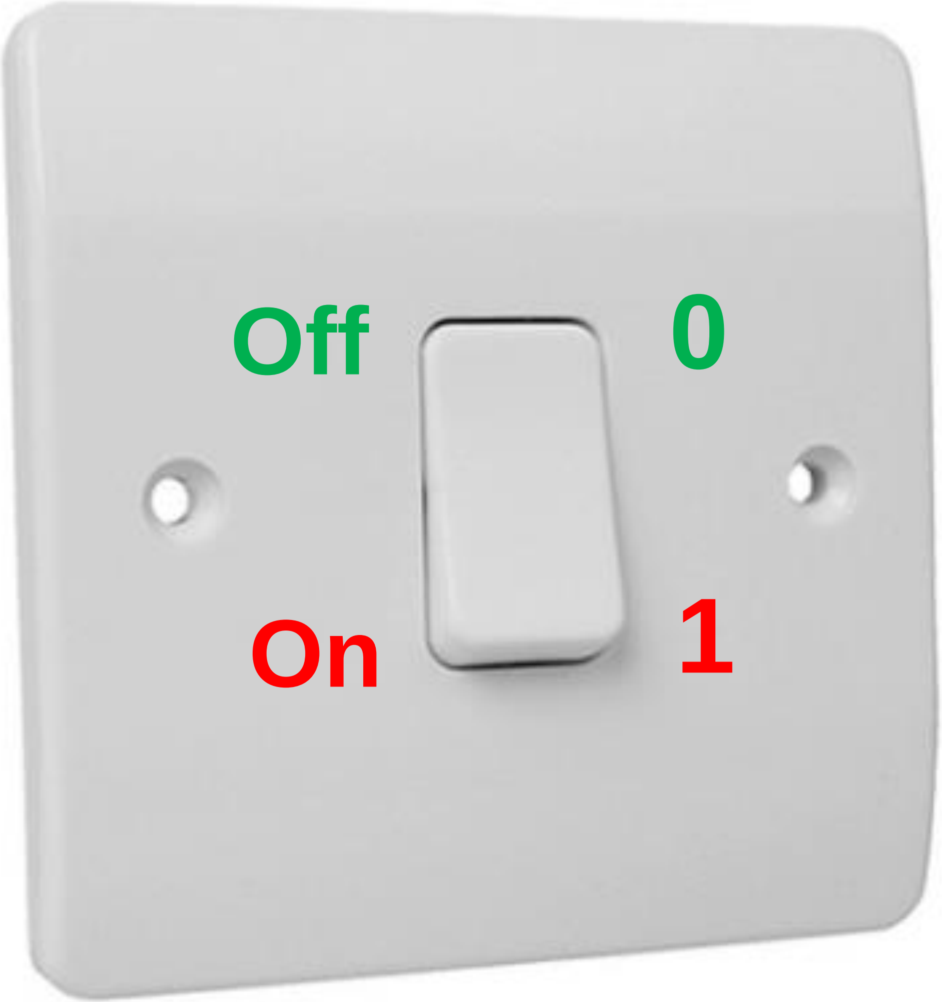
Telephone (cont)

Electro-mechanical switching equipment ~1900

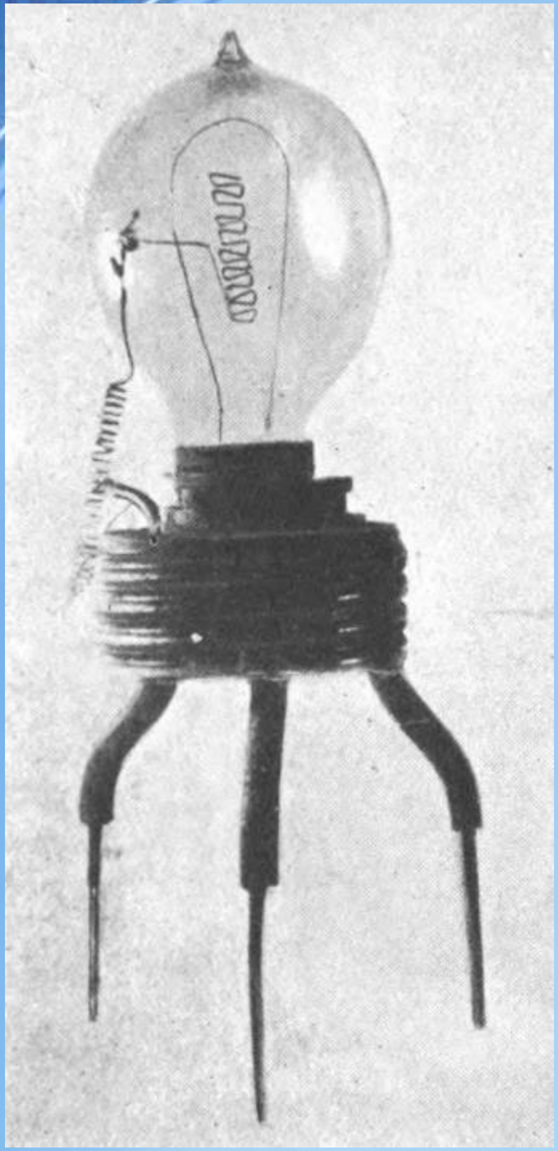
Simple Switch/Relay



Switching



Vacuum Tube



Fleming's 1st Diode

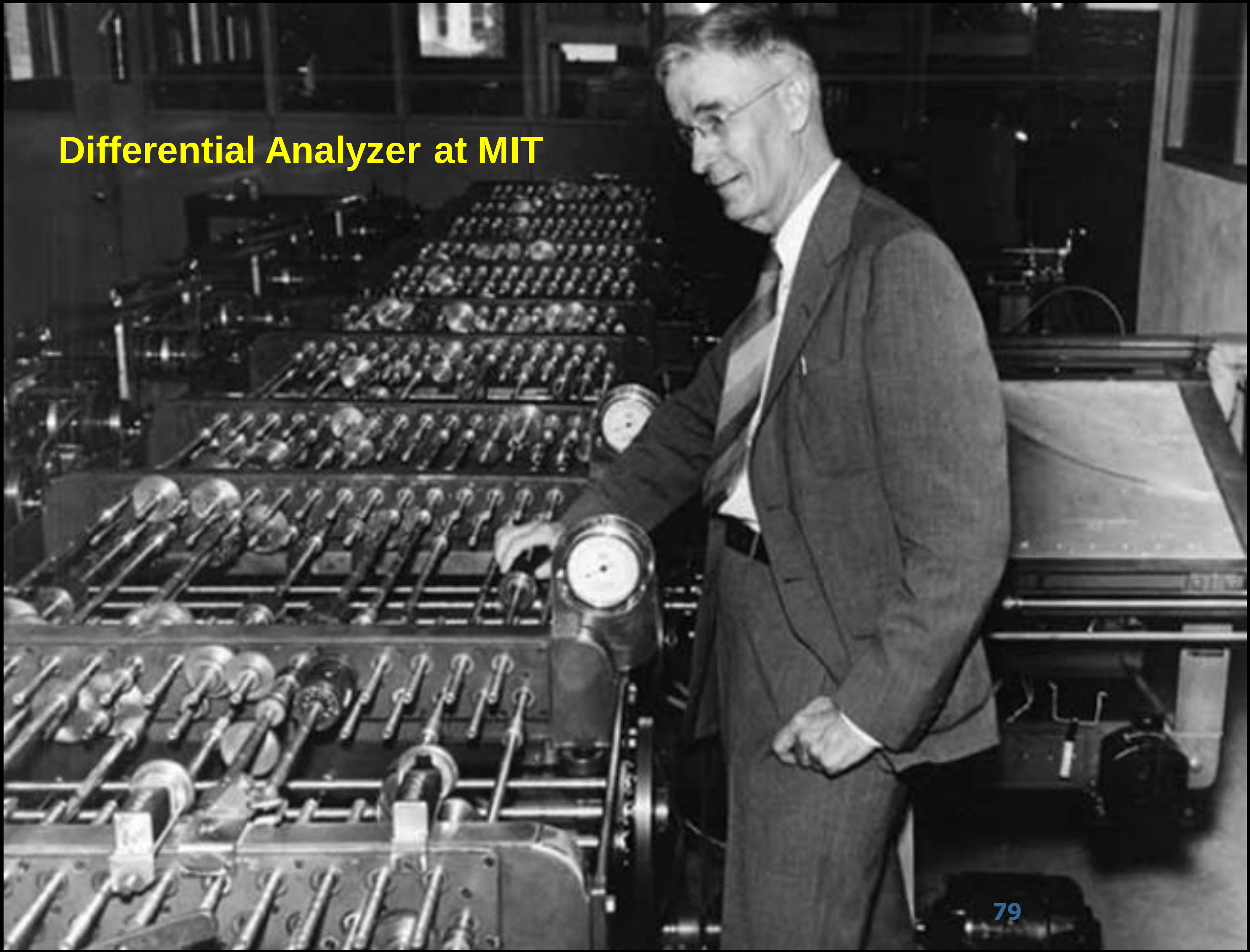
- 1904—John Ambrose Fleming invented the diode
- 1906— Robert von Lieben receives a patent for the triode
- 1907— Lee De Forest improves (invents?) the triode
- 1913—AT&T bought De Forest's patent for $50,000 ($1.27 million in 2019)
- 1915—First U.S. coast-to-coast telephone call facilitated by vacuum tube amplifiers **$21/3-min ($522 in 2019)**

1930s

Ford cars—a transportation metaphor

Vannevar Bush (1890-1974)

URL

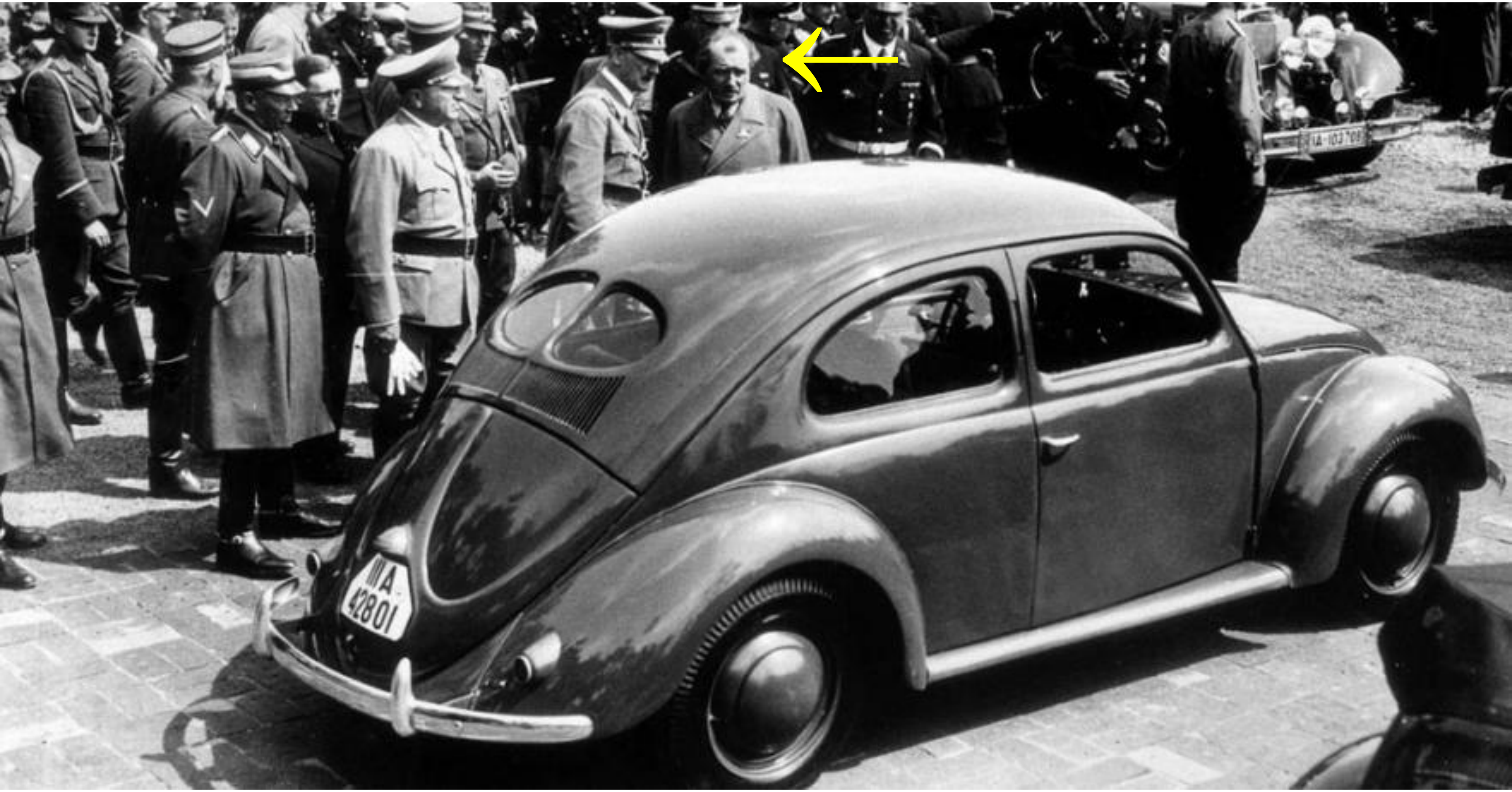


Differential Analyzer* (1928-31)

- World's first analog electrical-mechanical computer
- To solve differential equations by integration
- Could solve equations with up to 18 independent variables
- Subsequent Analyzer versions used to calculate artillery firing tables
- Influential in training and inspiring the next generation of computer pioneers

* aka Continuous Integraph

1937—a Big Year in Computer Science



For the history of the VW ”Beetle” see

Konrad Zuse (1910-95)

Konrad Zuse

- Design engineer—Henschel Flugzeug Werke
- 1935-37—created floating point binary mechanical calculator, the Z1
- 1940—Z2 a revised Z1 with telephone relays
- Employed movie film instead of paper tape
- 1941—Z3 the first fully (?) operational electromechanical digital computer

Konrad Zuse (cont.)

- 1945—computers and documentation destroyed in bombing attack on Berlin
- 1950—Z4 made public (very reliable)
- While working on the Z4 developed Plankalkül, the first high-level computer language
- IBM licensed several of Zuse's patents
- Founded several computer companies (Models Z1 through Z43)

Konrad Zuse’s Z3 (replica)

Deutsches Museum
München, Germany

John Vincent Atanasoff
(1903-95)

John Atanasoff at Iowa State ~1940

From "The Innovators" by
Walter Isaacson,
Simon & Shuster, 2014

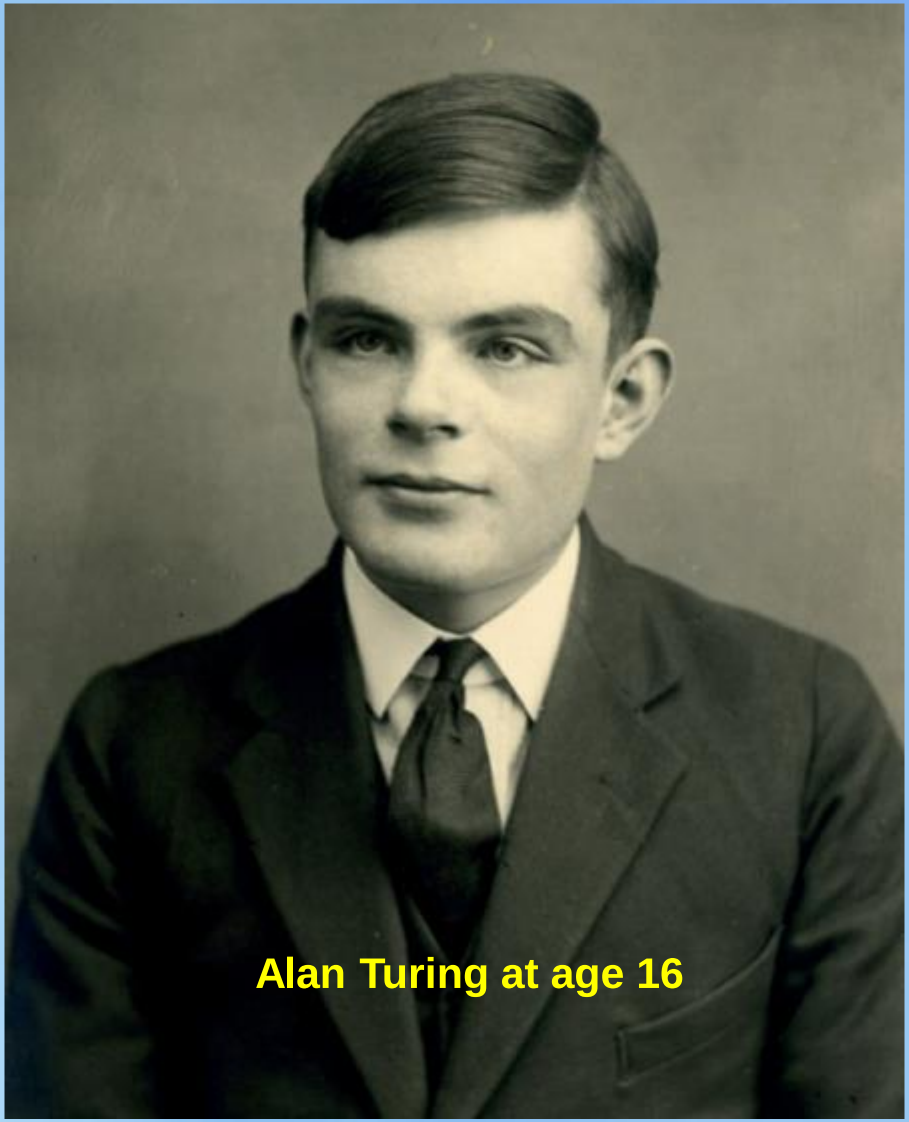
John Vincent Atanasoff

- Iowa State University, Ames
- Developed the Atanasoff-Berry computer (1937 into 40s)
  - "first" electronic digital computer
  - used vacuum tubes
  - used binary math
  - used Boolean logic
  - solve up to 29 simultaneous linear equations

Atanasoff-Berry Computer

- Computer obscure for many years (until 1960s)
- Rancorous lawsuits involving Mauchley and Eckert

Alan Turing (1912-54)



From ”The Innovators” by
Walter Isaacson,
Simon & Shuster, 2014

Famous 1937 Mathematics Article

- Title: "On Computable Numbers, with an Application to the Entscheidungsproblem"
  - *Proceedings of the London Mathematical Society*, Vols 2-42, Issue 1, 1 January 1937, pp. 230-265
- Published at the age of 24
- Undoubtedly the most famous theoretical paper in the history of computing

Famous 1937 Mathematics Article (cont.)

- A mathematical description of a universal machine to solve any mathematical problem that can be presented in symbolic form
- Known as Turing's computer

- 1935—Fellow at King's College, Cambridge University
- 1937—Turing and John von Neumann discussed what would later be called "artificial intelligence"

First page

ON COMPUTABLE NUMBERS, WITH AN APPLICATION TO THE ENTSCHEIDUNGSPROBLEM

By A. M. TURING.

[Received 28 May, 1936.—Read 12 November, 1936.]

The "computable" numbers may be described briefly as the real numbers whose expressions as a decimal are calculable by finite means. Although the subject of this paper is ostensibly the computable *numbers*, it is almost equally easy to define and investigate computable functions of an integral variable or a real or computable variable, computable predicates, and so forth. The fundamental problems involved are, however, the same in each case, and I have chosen the computable numbers for explicit treatment as involving the least cumbrous technique. I hope shortly to give an account of the relations of the computable numbers, functions, and so forth to one another. This will include a development of the theory of functions of a real variable expressed in terms of computable numbers. According to my definition, a number is computable if its decimal can be written down by a machine.

In §§ 9, 10 I give some arguments with the intention of showing that the computable numbers include all numbers which could naturally be regarded as computable. In particular, I show that certain large classes of numbers are computable. They include, for instance, the real parts of all algebraic numbers, the real parts of the zeros of the Bessel functions, the numbers π, e, etc. The computable numbers do not, however, include all definable numbers, and an example is given of a definable number which is not computable.

Although the class of computable numbers is so great, and in many ways similar to the class of real numbers, it is nevertheless enumerable. In § 8 I examine certain arguments which would seem to prove the contrary. By the correct application of one of these arguments, conclusions are reached which are superficially similar to those of Gödel†. These results

† Gödel, "Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I", *Monatshefte Math. Phys.*, 38 (1931), 173–198.

Last page

It may be proved that there is a formula V such that

$$\Big\{\{V\}(N_{\xi(n+1)})\Big\}(N_{\xi(n)}) \begin{cases} \text{conv } N_1 & \text{if, in going from the } n\text{-th to the } (n+1)\text{-th complete configuration, the figure 0 is printed.} \\ \text{conv } N_2 & \text{if the figure 1 is printed.} \\ \text{conv } N_3 & \text{otherwise.} \end{cases}$$

Let W_γ stand for

$$\lambda u\Big[\Big\{\{V\}\Big(\{A_\gamma\}\big(\{U_\gamma\}(u)\big)\Big)\Big\}\big(\{U_\gamma\}(u)\big)\Big],$$

so that, for each integer n,

$$\Big\{\{V\}(N_{\xi(n+1)})\Big\}(N_{\xi(n)}) \text{ conv } \{W_\gamma\}(N_n),$$

and let Q be a formula such that

$$\Big\{\{Q\}(W_\gamma)\Big\}(N_s) \text{ conv } N_{r(s)},$$

where $r(s)$ is the s-th integer q for which $\{W_\gamma\}(N_q)$ is convertible into either N_1 or N_2. Then, if M_γ stands for

$$\lambda w\Big[\{W_\gamma\}\Big(\Big\{\{Q\}(W_\gamma)\Big\}(w)\Big)\Big],$$

it will have the required property†.

The Graduate College,
Princeton University,
New Jersey, U.S.A.

Ph.D dissertation (Princeton)
"Systems of Logic Based
On Ordinals" (1938)

† In a complete proof of the λ-definability of computable sequences it would be best to modify this method by replacing the numerical description of the complete configurations by a description which can be handled more easily with our apparatus. Let us choose certain integers to represent the symbols and the m-configurations of the machine. Suppose that in a certain complete configuration the numbers representing the successive symbols on the tape are $s_1 s_2 \ldots s_n$, that the m-th symbol is scanned, and that the m-configuration has the number t; then we may represent this complete configuration by the formula

$$\Big[[N_{s_1}, N_{s_2}, \ldots, N_{s_{m-1}}],\ [N_t, N_{s_m}],\ [N_{s_{m+1}}, \ldots, N_{s_n}]\Big],$$

where

$$[a, b] \text{ stands for } \lambda u\Big[\Big\{\{u\}(a)\Big\}(b)\Big],$$

$$[a, b, c] \text{ stands for } \lambda u\Big[\Big\{\Big\{\{u\}(a)\Big\}(b)\Big\}(c)\Big],$$

etc.

Cryptography

- Mesopotamian clay tablets ~1500 BC
- Caesar cipher [Julius Caesar (100-44 BC)]

Cryptography (cont.)

- Thomas Jefferson’s cypher wheel (1795)
- Re-invented or improved by Etienne Bazeries (~1890)
- Basis for “M-94” cipher machine used by U.S. military from 1922 to ~1942

Jefferson’s Cipher Wheel*

* Reproduction—24 alphabet wheels

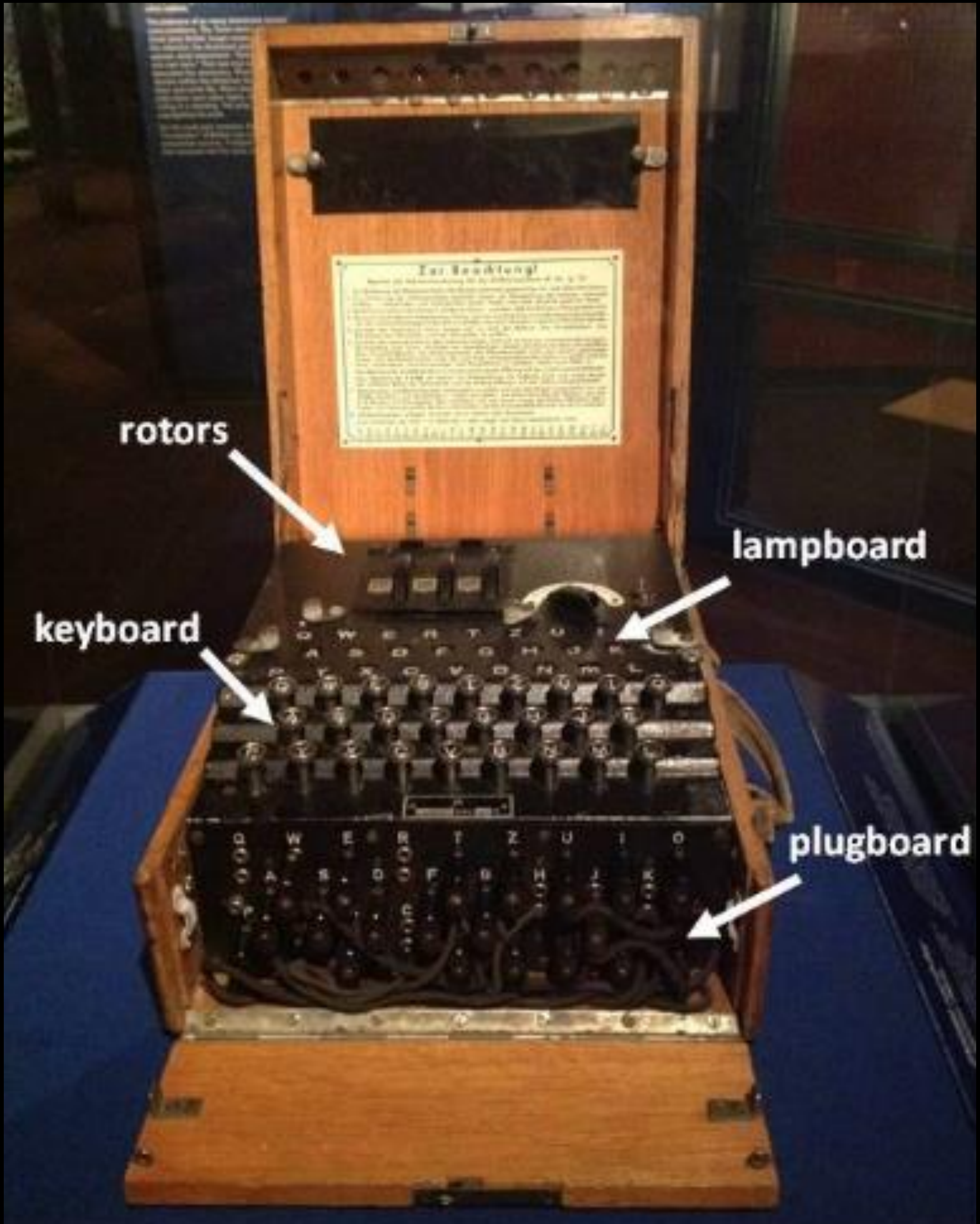
Enigma Machine (1926-1945)

- Invented by Arthur Scherbius
- First marketed to businesses (1926)
- Improved models produced over the years
- Widely used by the German military during World War 2—radio communications
- Used 3-8 alphabet rotors
- Plugboard swapped 10-13 character pairs (A → D, Z → L, M → B, etc.)
- 1.589 x 10^{20} machine settings (3 rotors)

Enigma Machine (cont.)

- Military—changed settings for rotors and plugboard daily
- Decryption required enormous number of calculations (impossible by brute force)
- Weaknesses
  - a letter in plain text could not appear as itself in cypher text
  - “Das Wetter heute ist…”
  - identical message sent in two different encryption systems

German Military Enigma Machine



Bletchley Park

Government Code & Cypher School (GC&CS)

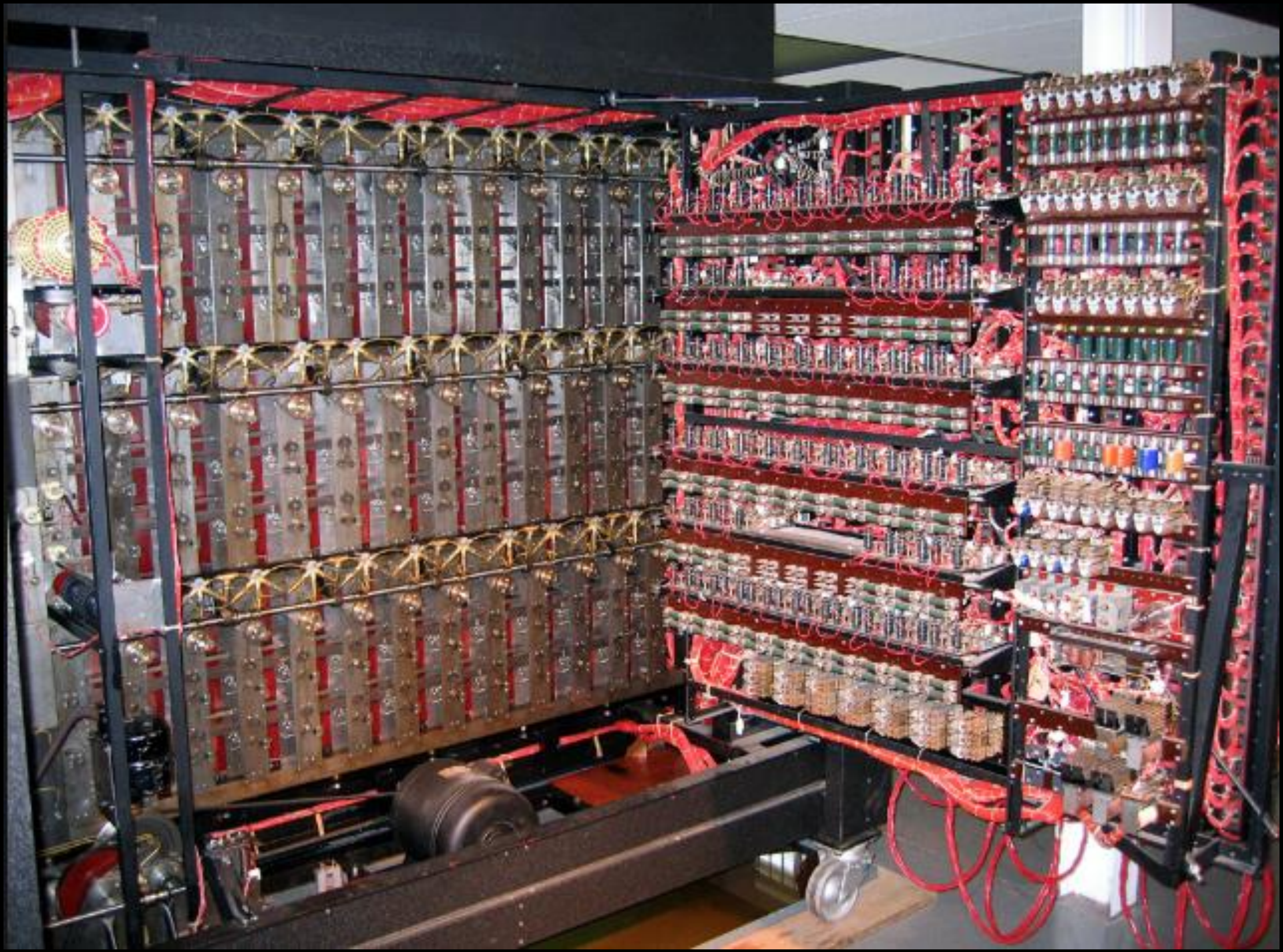
Bletchley Park

- Home of British codebreakers in WW2
- Purchased in 1938 by Hugh Sinclair with £6,000 of his money ($486,000 today)
- Many staff recruited from Oxford & Cambridge
  - Mathematicians
  - Linguists
  - Chess players
  - "Mathematicians worked alongside girls in pearls"
- 1938/9—a few dozen staff
- 1945—10,000 staff

Bletchley Park Bombe

- Originally developed by the Poles in 1930s (*bomba kryptologiczna)*
  - electro-mechanical device to help decipher German Enigma encrypts
- Re-designed by Alan Turing and improved by Gordon Welchman
- 1940—2 bombes operational
- 1945— ~200 working bombes
- Highly successful in breaking **German**, Italian, Russian codes… and others

Bombe Replica*

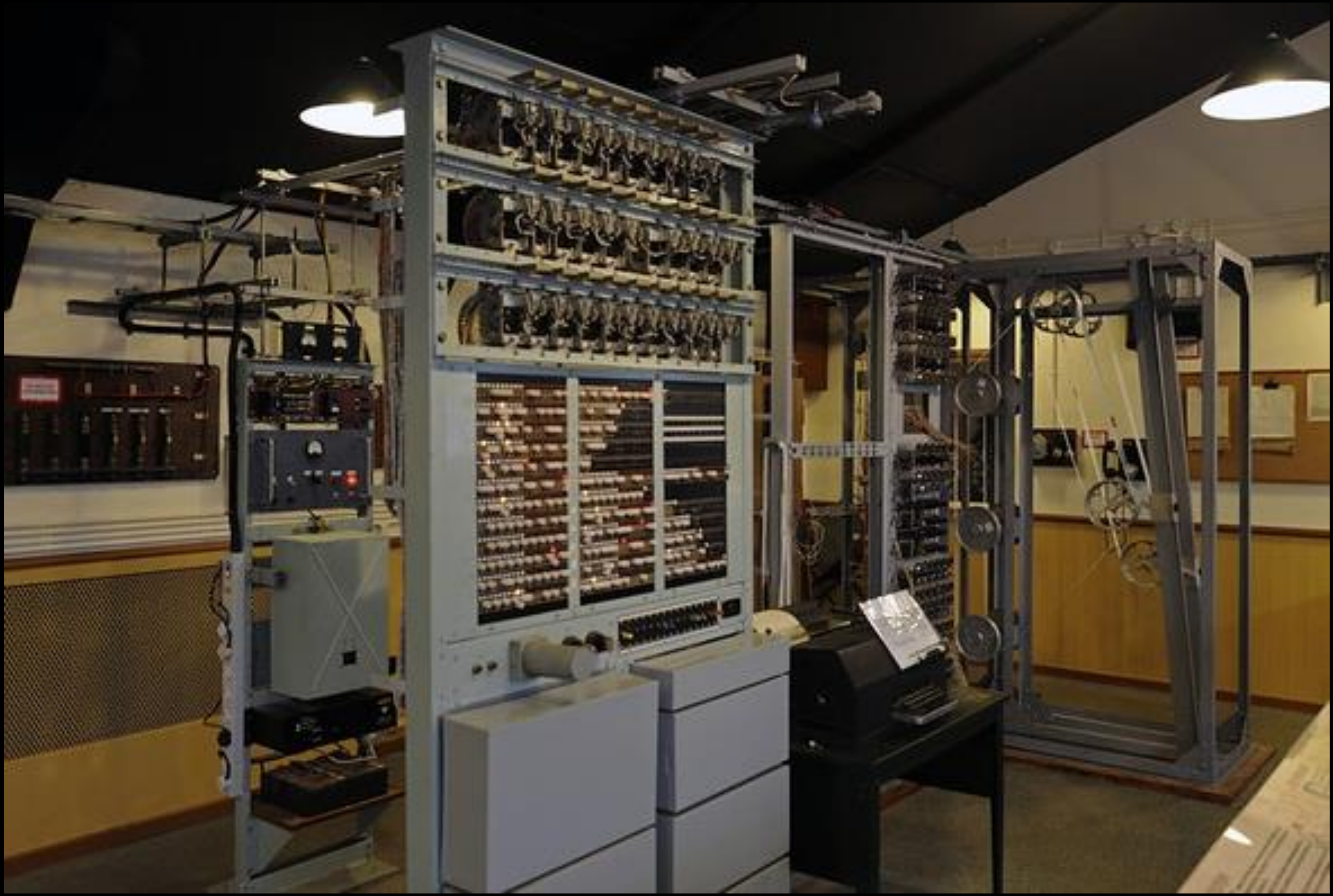


*** National Museum of Computing, Bletchley Park**

Bletchley Park “Heath Robinson”

- Electro-mechanical device to help decipher German Lorenz encrypts, 1943-5
- Communications for the German High Command and Adolf Hitler
- 10-12 rotors
- Teleprinter communications
- Radio communications later in the war
- British very adept in decoding

Heath Robinson Replica*



* National Museum of Computing, Bletchley Park

Thomas Harold Flowers (1905-98)

- Electrical Engineer
- General Post Office at Dollis Hill
- Explored use of electronics for telephone exchanges
- Alan Turing asked him to help

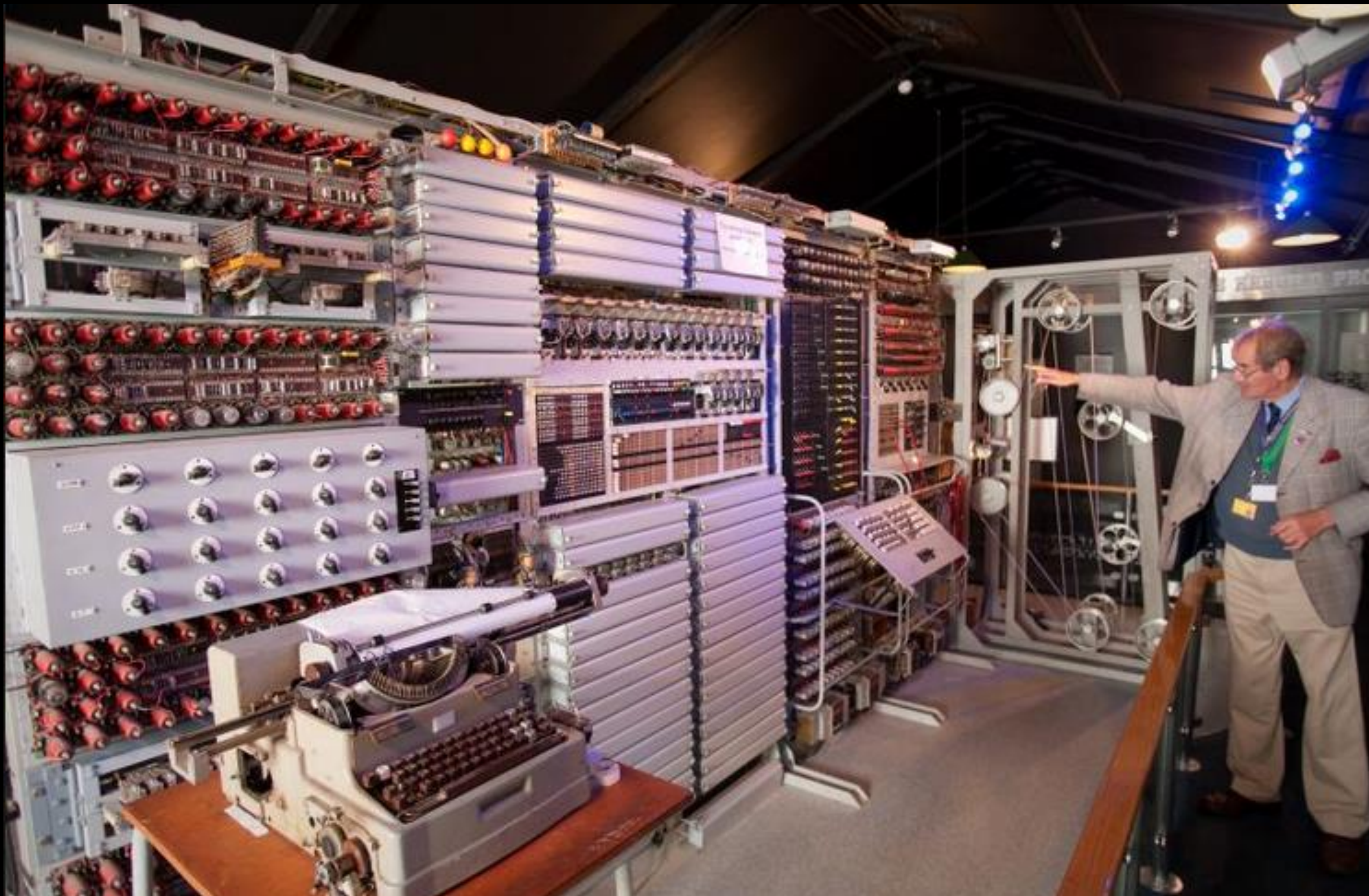
Bletchley Park Colossus

- Designed by Tommy Flowers
- Mark 2—2,400 vacuum tubes
- Five 6-bit shift registers
- Programmed by switches and plugs, not a stored program
- Paper tape input
- Electric typewriter output

Bletchley Park Colossus (cont.)

- Mark 1 worked in December 1943
- **Mark 2 in production June 1, 1944**
- 10 Colossi in use by end of war
- Used until 1960

Colossus Replica*



* National Museum of Computing, Bletchley Park

Bletchley Park

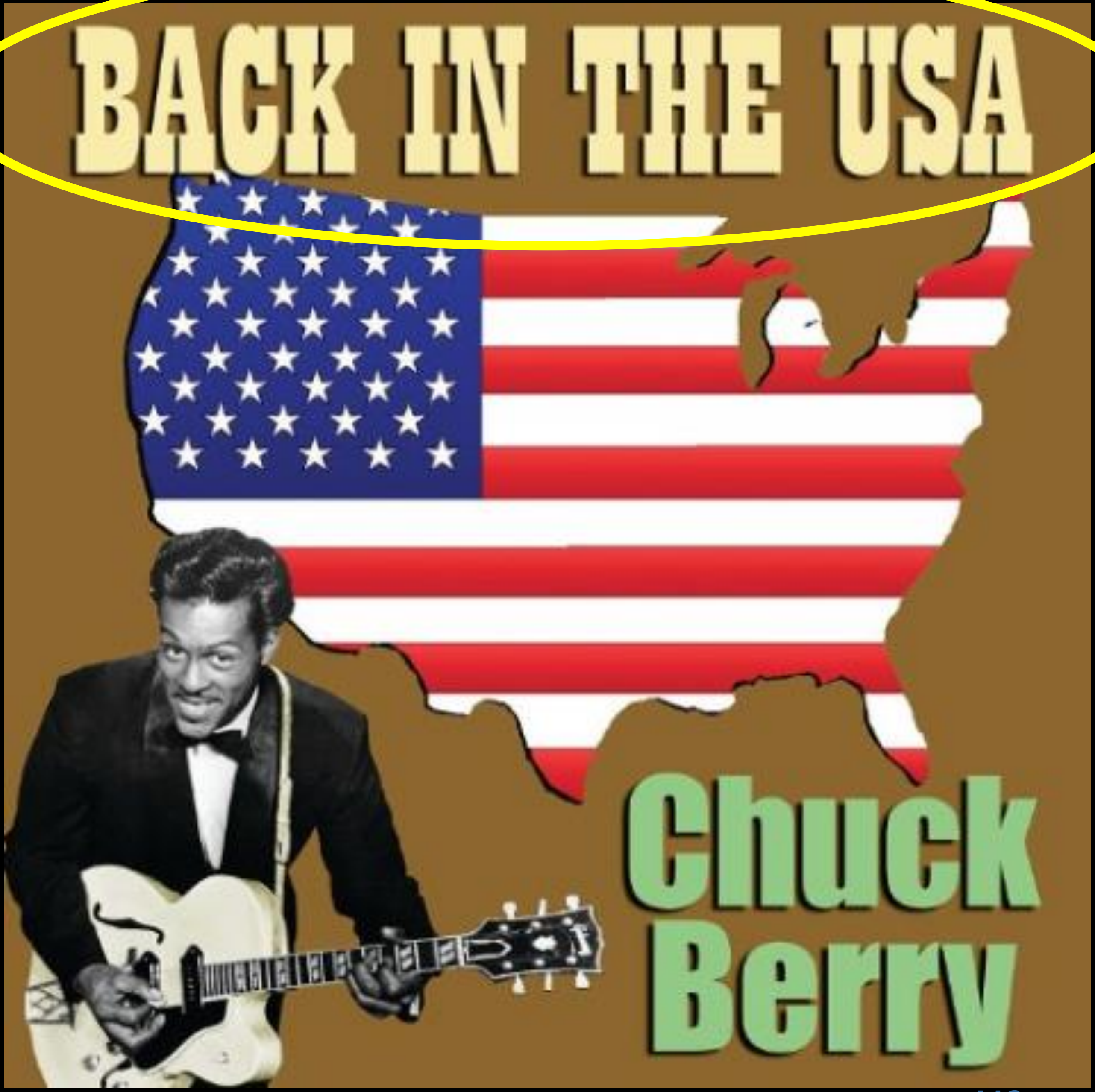
Secrecy prevailed until 1974

1974, F. W. Winterbotham Published *"The Ultra Secret"*

Th blem

- Soviet s 1940s 50s and
  – MI5 (I o FBI)
  – MI6 (I ar to CIA)
- "The Ca
  – Antho uted)
  – Guy B
  – John secuted)
  – Dona SR)
  – Kim P

* Worked at B to Russians


BACK IN THE USA
Chuck
Berry

John von Neumann (1903-57)

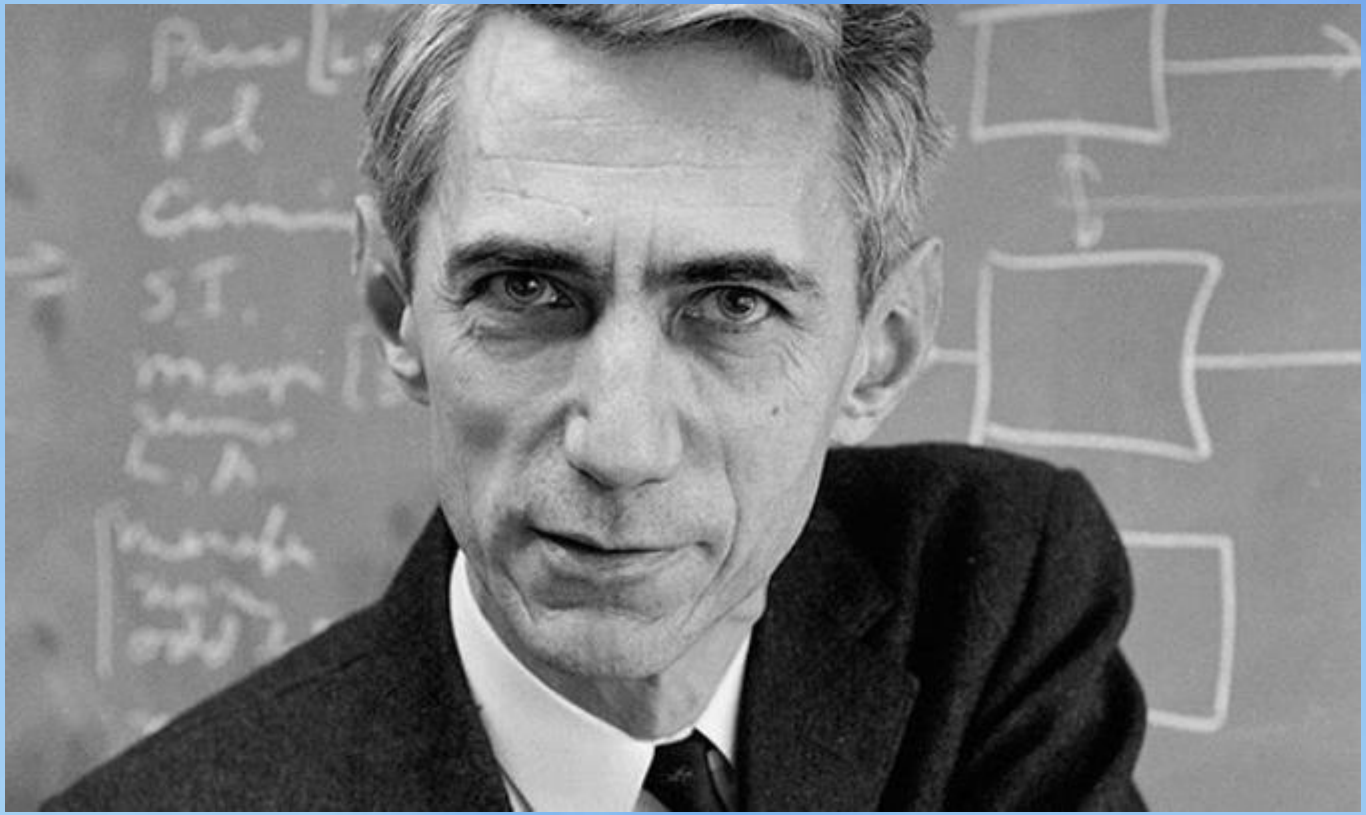
John von Neumann

- Born: Neumann János Lajos (Hungary)
- Father elevated to nobility in 1913
- At age 6 could divide two 8-digit numbers in his head
- Party trick: memorize page of phone book and recite names and phone numbers
- Age 15 studied advanced calculus
- Age 23 B.S. in chemical engineering **and** Ph.D. in mathematics
- Professor at Princeton University

John von Neumann (cont.)

- Cultivated and highly sociable
- His wife, “John can count anything but calories”
- Numerous accomplishments in mathematics
- Other contributions:
  - Von Neumann computer architecture
  - Quantum mechanics
  - Game theory (economics)
  - Statistics
  - Nuclear weapons design
  - Worked with Mauchly and Eckert on the ENIAC computer

Claude Shannon (1916-2001)



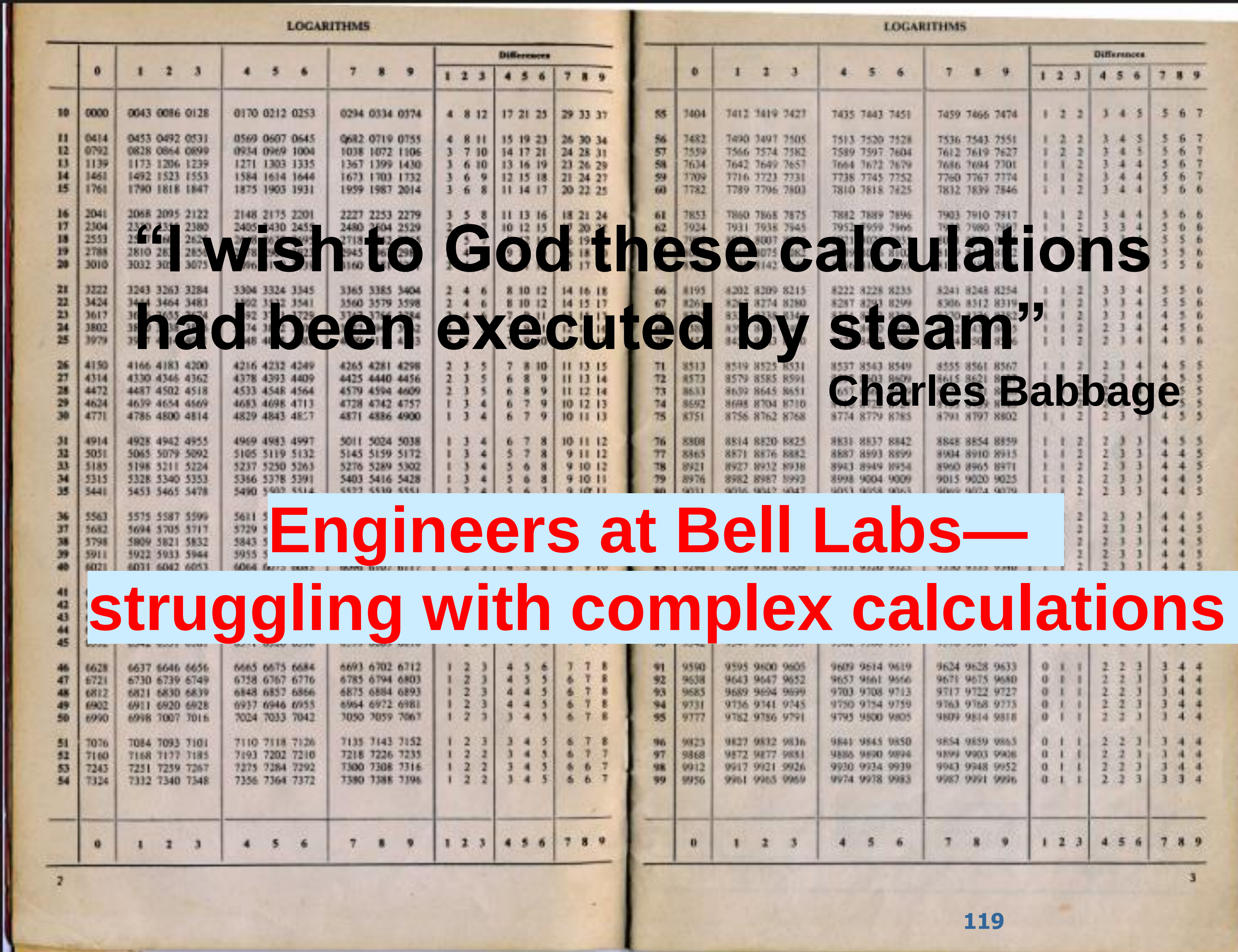
Claude Shannon

- A grad student under Vannevar Bush at MIT
- 1937—time off from MIT* worked at Bell Labs
- MS thesis: “A Symbolic Analysis of Relay and Switching Circuits”
  - switching circuits to simplify electro-mechanical relays (phone routing)
  - proved these circuits could solve all problems that Boolean algebra could solve

* Ph.D. from MIT in 1940

Claude Shannon (cont.)

- 1940—National Research Fellow at Princeton's Institute for Advanced Study
  - contact with Hermann Weyl, John von Neumann, Albert Einstein and Kurt Gödel
- During World War 2
  - 1943 in contact with Alan Turing
  - worked with U.S. Navy's cryptanalytical service
- Considered the father of information theory (his MS thesis)

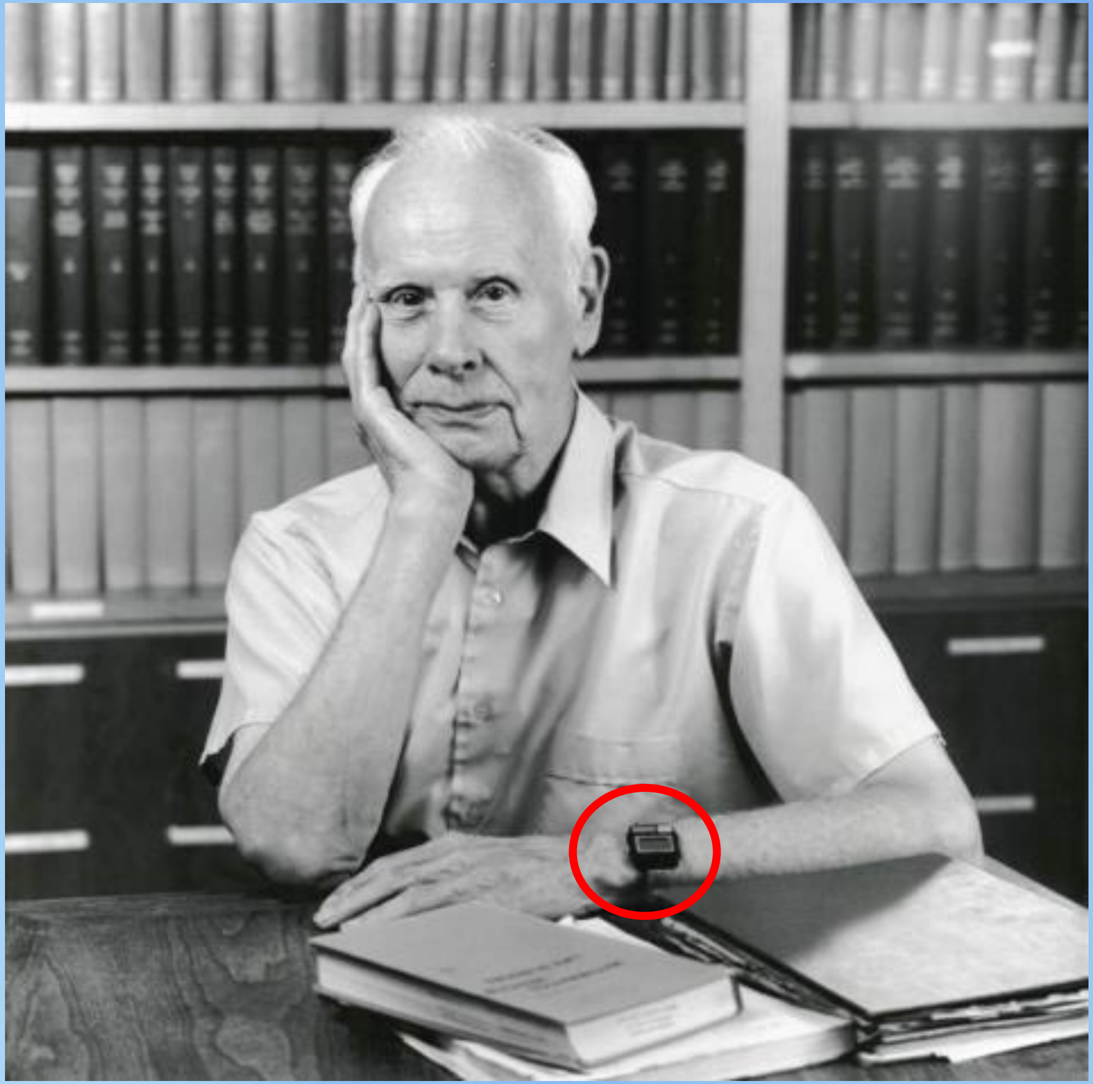


"I wish to God these calculations had been executed by steam"

Charles Babbage

Engineers at Bell Labs—struggling with complex calculations

George Stibitz* (1904-95)



* 1930 Ph.D. in mathematical physics, Cornell University

George Stibitz

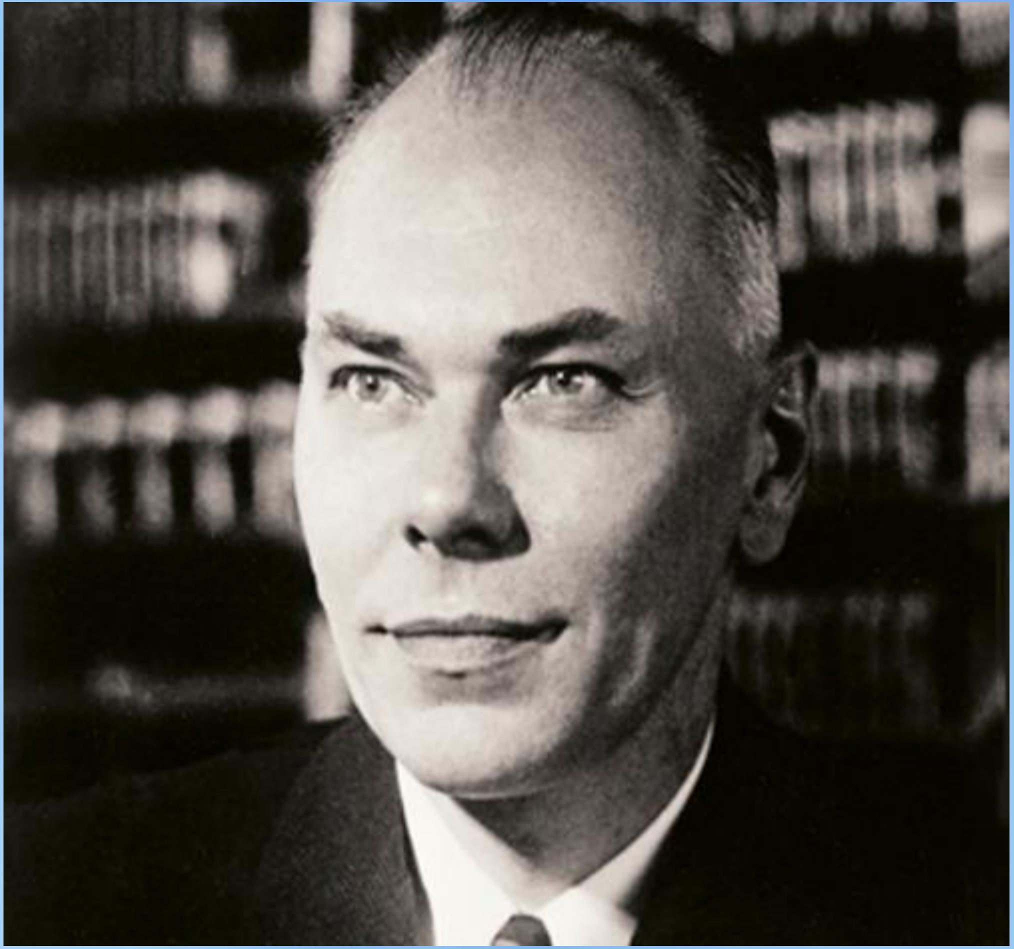
- A mathematician working at Bell Labs same time as Claude Shannon
  - worked on how to handle complicated calculations needed by phone engineers
- Created a circuit to add binary numbers using light bulbs and a tobacco tin—at his kitchen table (Model K-1)
- Proposed building a general calculator using an electric circuit (1937)

George Stibitz (cont.)

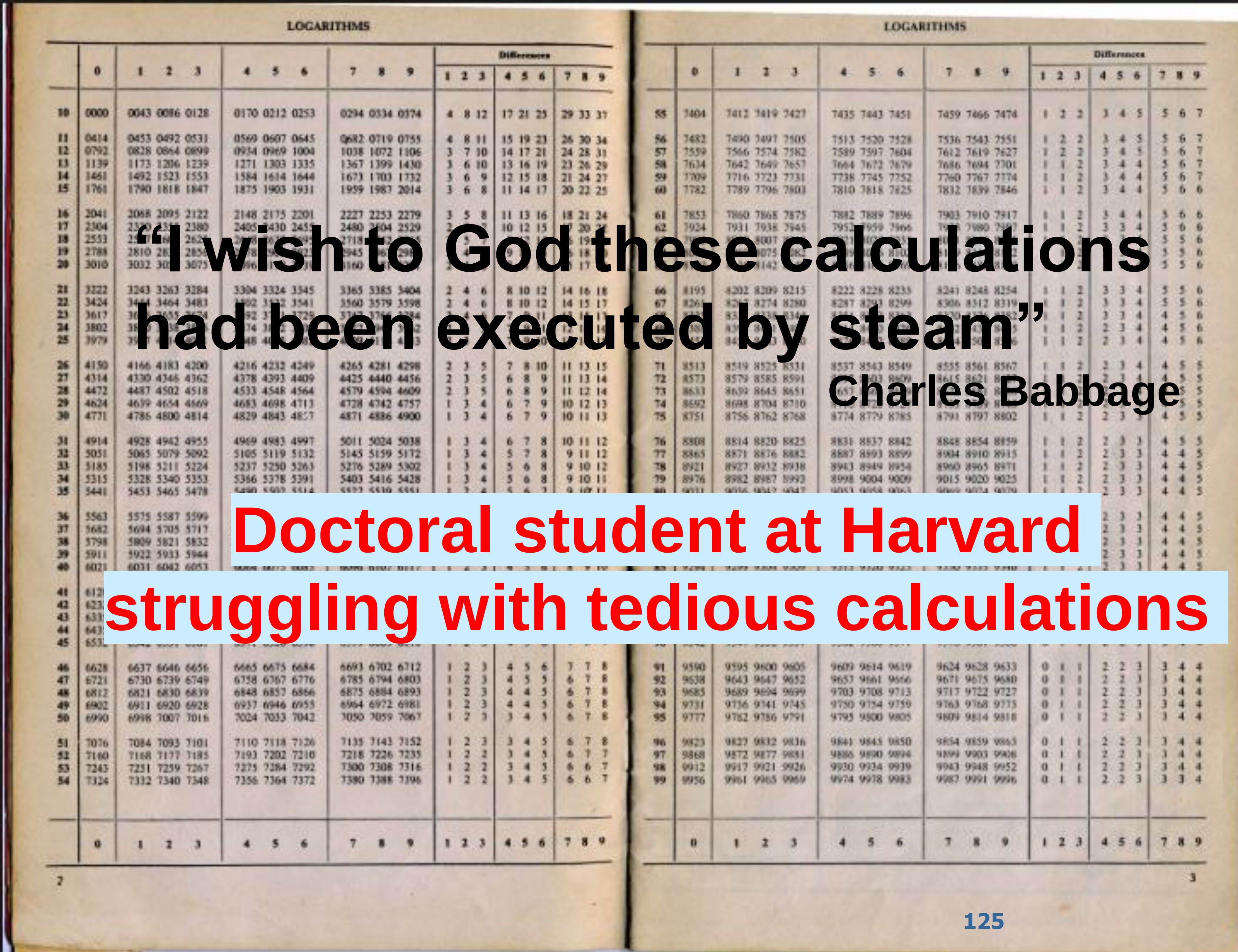
- Complex Number Calculator (1939)
  - 400 relays (switches)
  - each opening and closing 20x/sec
- Blindingly fast compared to mechanical calculators
- Glacially slow compared to vacuum-tube circuits just being invented

1940s

Howard Aiken* (1900-73)



* 1939 Ph.D. in physics, Harvard University



“I wish to God these calculations had been executed by steam”

Charles Babbage

Doctoral student at Harvard struggling with tedious calculations

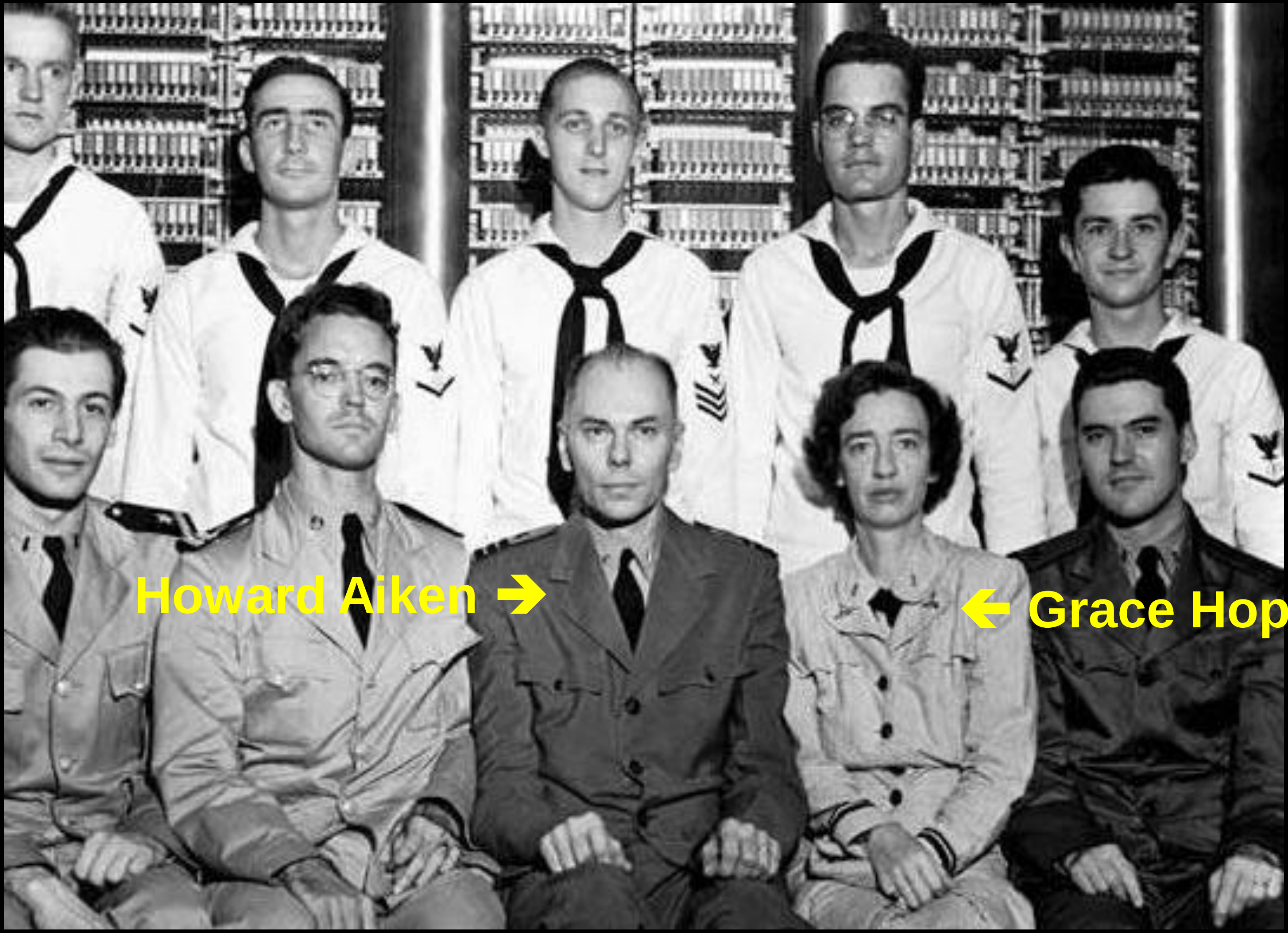
Howard Aiken

- Department head mentioned something in the attic that might help
- A demonstration model of Babbage's Difference Engine (~100 years old)
- 1939—wrote research proposal to IBM and Harvard faculty to create a modern version of Babbage's machine
- Harvard sniffed
- 1941—IBM constructed the machine to Aiken's specifications

Howard Aiken (cont.)

- 1941—Aiken joined the U.S. Navy
- Taught at the Naval Mine Warfare School in Virginia (Yorktown?)
- 1944—IBM shipped the Mark 1 computer to Harvard
- Navy assigned Aiken as “officer in charge” of the Mark 1
  - all Aiken’s staff U.S. Navy personnel
  - able to avoid academic bureaucracy
  - Harvard still sniffed (no professorship for you—not yet)

Harvard University—Mark I Computer



Harvard Mark I Computer*

*** aka ASCC (Automatic Sequence Controlled Calculator)**

Harvard Mark I

- 51 feet long, 8 feet high, 4.7 tons
- Digital (base 10) not binary
- Slow—765,000 electromechanical components (6 sec to do a multiplication)
- Programs and data entered by paper tape
- Ran for days without human intervention
- Fully automatic
- "Babbage's dream come true"—Howard Aiken

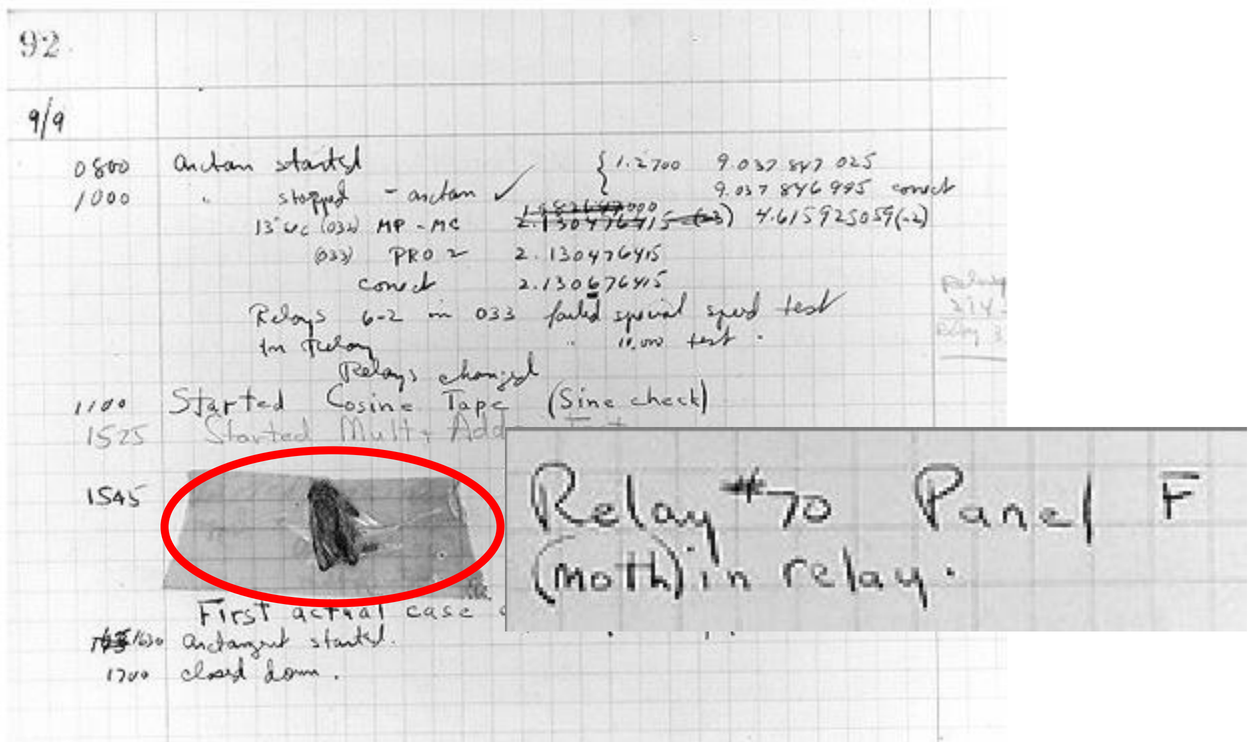
Harvard Mark I (cont.)

- Successors to Mark 1
  - Mark II (1947-8)
  - Mark III/ADEC (1949)
  - Mark IV (1952)
- Used for U.S. Navy and Air Force projects
- All the work of Howard Aiken

Commodore
Grace M. Hopper, USN
(1906-92)

- aka “Amazing Grace”
- Computer scientist and U.S. Navy officer (41 years active service)
- “Grandmother” of COBOL
- One of first Harvard Mark I programmers
- Developed first compiler for a computer language
- Coined term “computer bug”

The Original Computer Bug



80 Years of Computer History

Lorrin R. Garson

Lifetime Learning Institute

of Northern Virginia

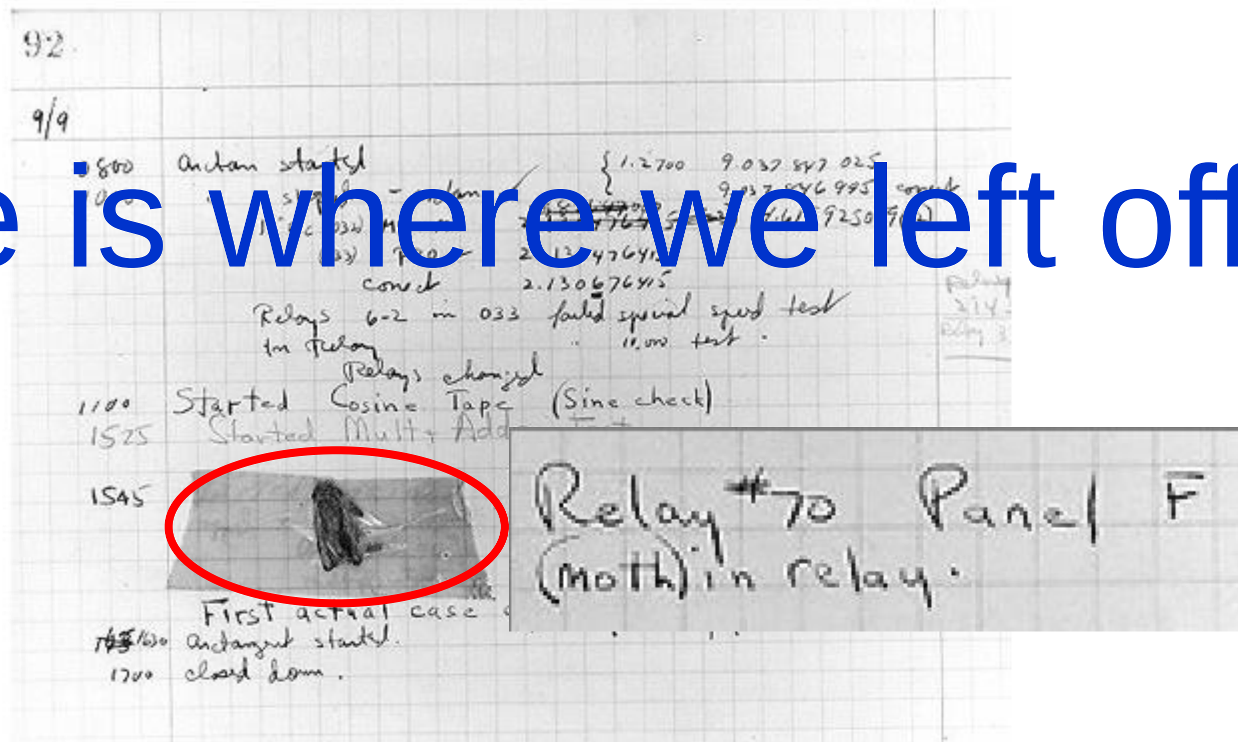
Summer 2019

Lecture 2 of 3

August 29, 2019

The Original Computer Bug

Here is where we left off…



↑ Grace Hopper’s research book

John Mauchly
(1907-80)

J. Presper Eckert
(1919-95)

From ”The Innovators” by
Walter Isaacson,
Simon & Shuster, 2014

ENIAC

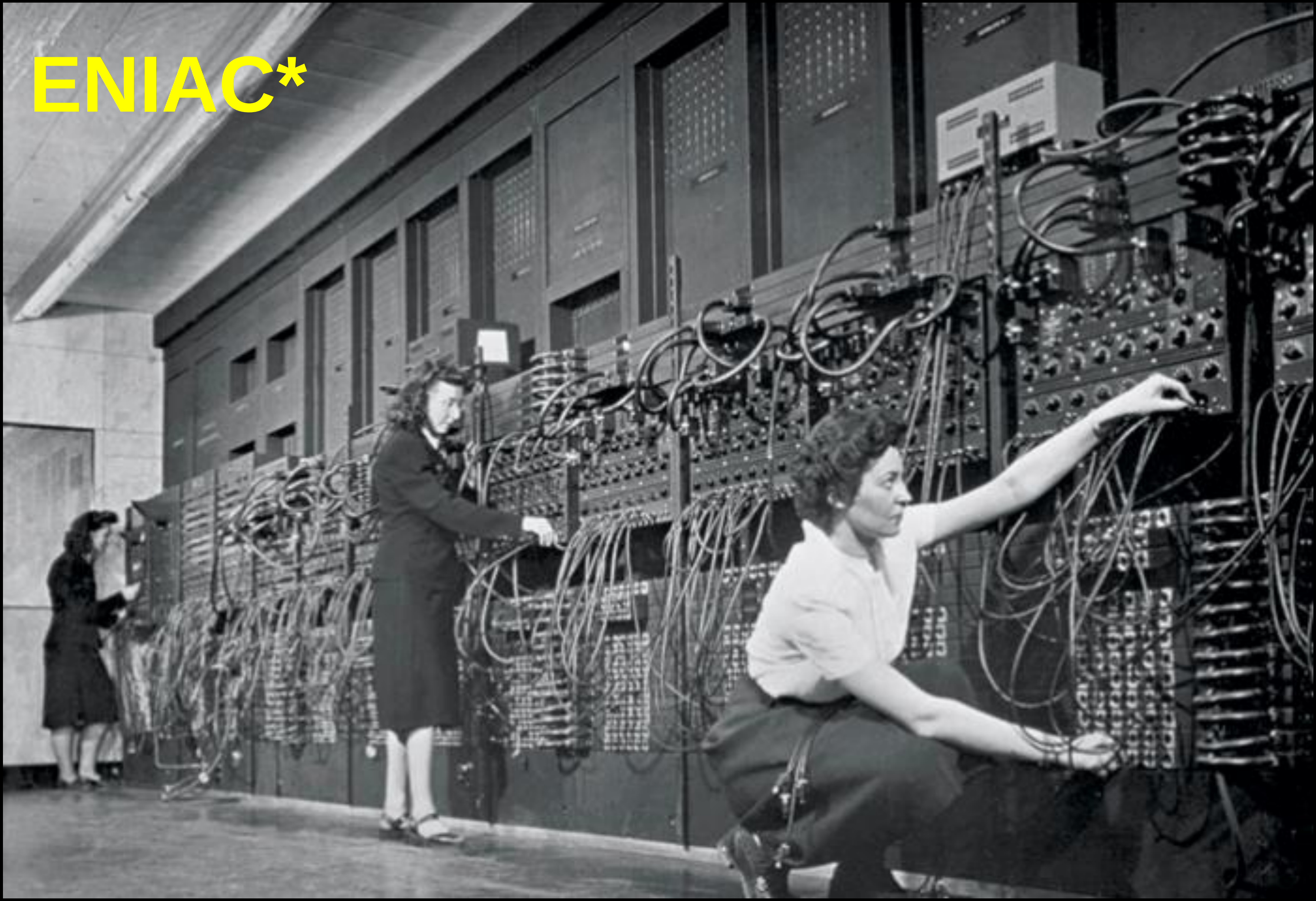
- Designed by Mauchly and Eckert
- Funded by U.S. Army to calculate artillery firing tables*
- Designed to be a general purpose computer
- Construction started in 1943
- Used decimal, not binary numbers
- 17,000 to 20,000 vacuum tubes
- Failure of 2-6 vacuum tubes/day 50% uptime**

* Also used in the development of the hydrogen bomb

** Longest continuous operation 116 hours

ENIAC (cont.)

- 98 ft long, 8 feet high, 3 feet deep; 30 tons
- Used subroutines and conditional branching
- 5,000 additions and subtractions per second—100 times faster than any previous computer
- Operational in 1945—in operation until 1955
- Development cost ~$500,000 in 1943 (~$7 million today)
- Origin of the commercial computer industry



* **ENIAC** = **E**lectronic **N**umerical **I**ntegrator **a**nd **C**omputer

EDVAC*

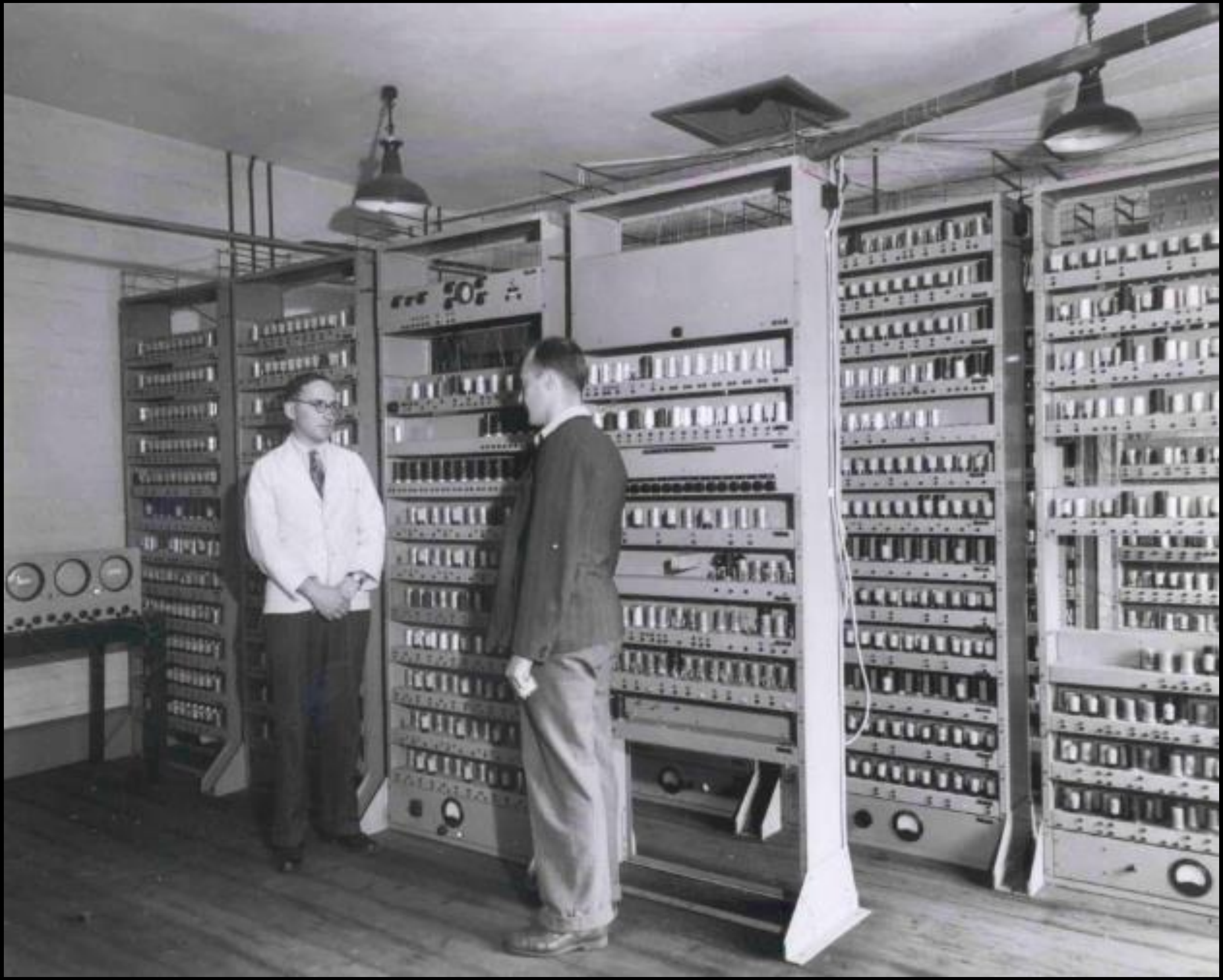
- Successor to the ENIAC
  - designed by Mauchly and Eckert
- Funded by U.S. Army
- Designed to be a general purpose computer
- Stored program
- 5.5 KB memory
- Floating point arithmetic (example 3.566×10^5)
- Used binary numbers
- Used magnetic tape

* Electronic Discrete Variable Automatic Computer

EDVAC (cont.)

- 6,000 vacuum tubes and 12,000 diodes
- Weighed 8.7 tons
- Consumed 56 kW electricity
- 1949—installed at the U.S. Army Ballistics Research Laboratory (Aberdeen, Maryland)
- Operating personnel—30 people per 8-hour shift
- Famous, influential report by John von Neumann on the EDVAC

EDVAC*



* **EDVAC** = **E**lectronic **D**iscrete **V**ariable **C**omputer

The Modern Computer

- A machine that is (a) electronic, (b) general purpose, (c) and programmable
- “Turing-complete”—can be used to solve any computation problem

So… Who Invented the Modern Computer?

Year	Computer	Binary	Electronic	Programable	General Purpose

Oops… an error, it’s Konrad Zuse

Thomas J. Watson, Sr. (1874-1956)

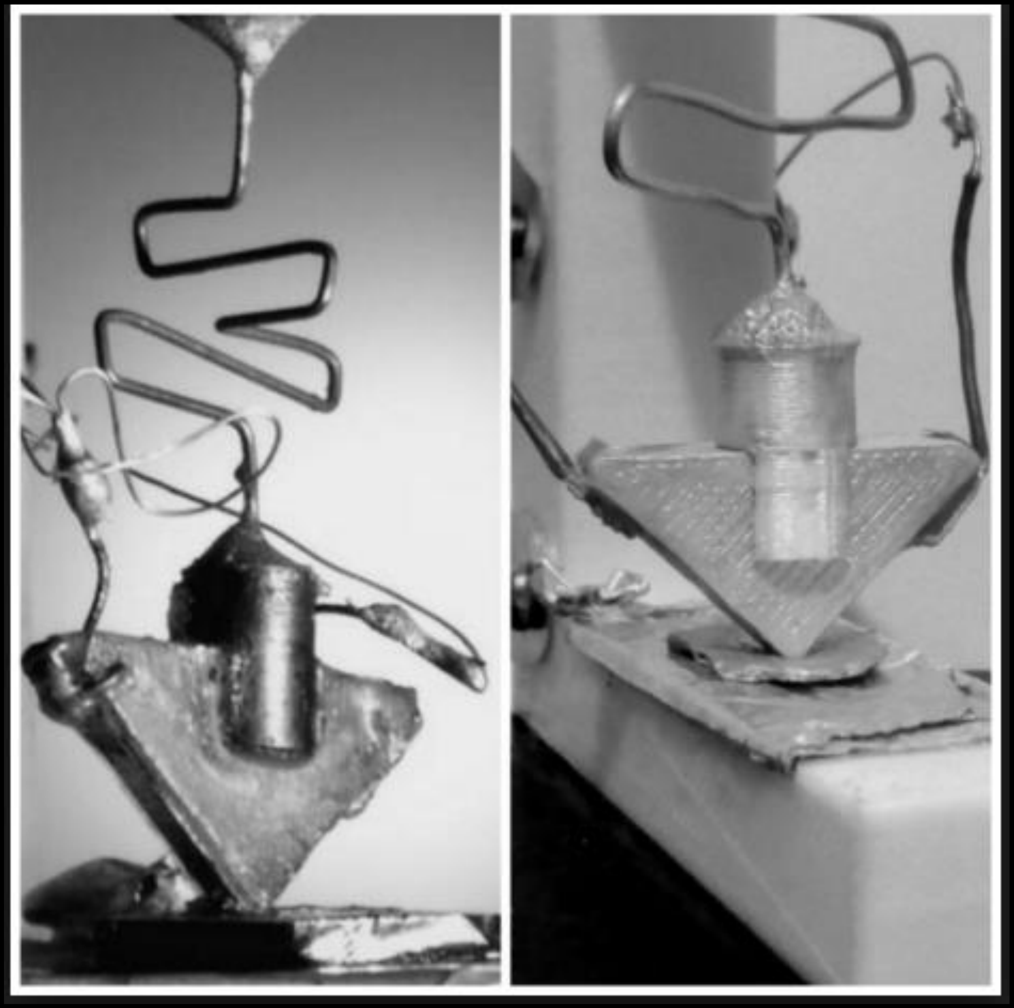
CEO & Chairman
IBM
1914-1956

"I think there is a world market for maybe five computers."

Bell Labs
(1925)
↓
Bellcore
[iconectiv]
(1983)
↓
Telcordia
Technologies
(1999)
↓
Ericsson
(2012)

The Transistor

December 16, 1947



Bell Laboratories

Bell Laboratories

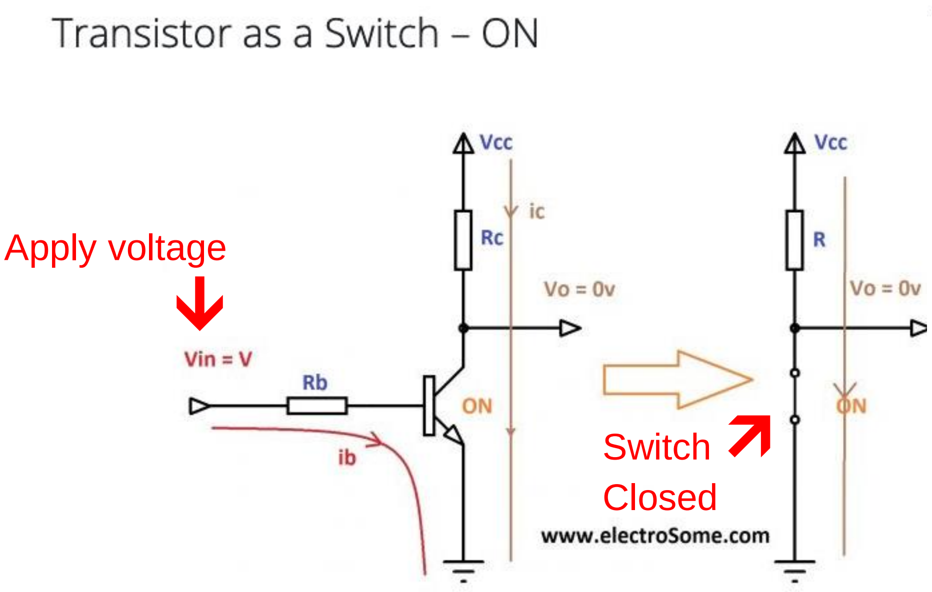
- Searching for a replacement for vacuum tubes for switching in telephone circuits
- Vacuum tubes:
  - expensive
  - faster than relay switches but slow
  - require lots of energy
  - short lifespan (high maintenance)

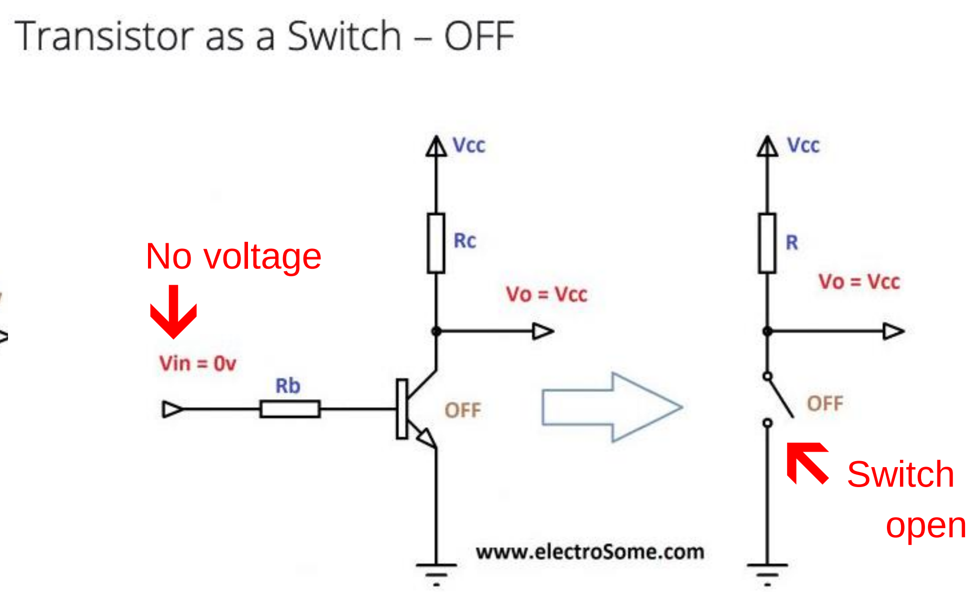
Today: Bell Laboratories "The world leader in rodent control technology"

The Inventors

Battle over patents see

Transistor as a Switch





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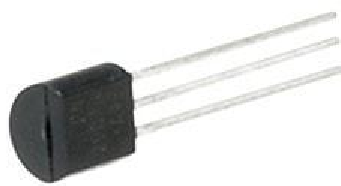
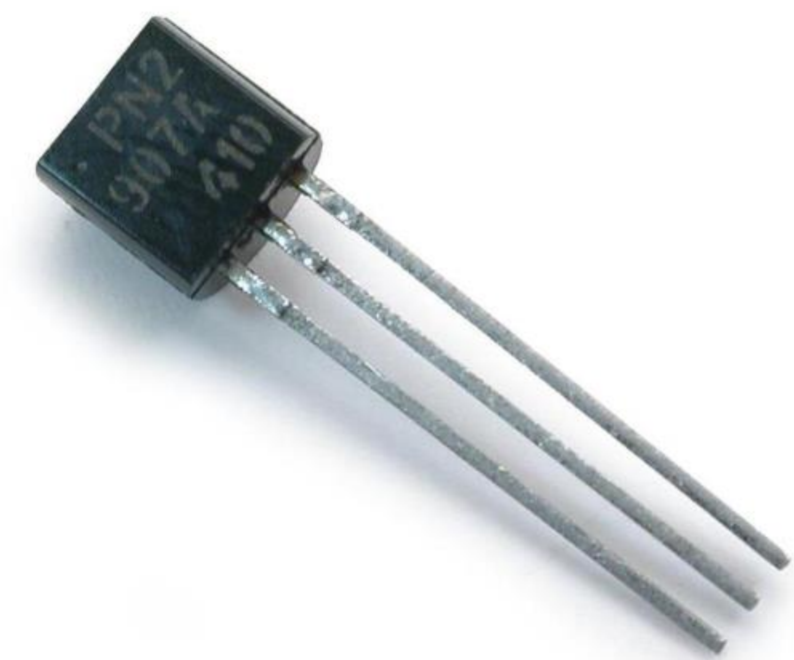
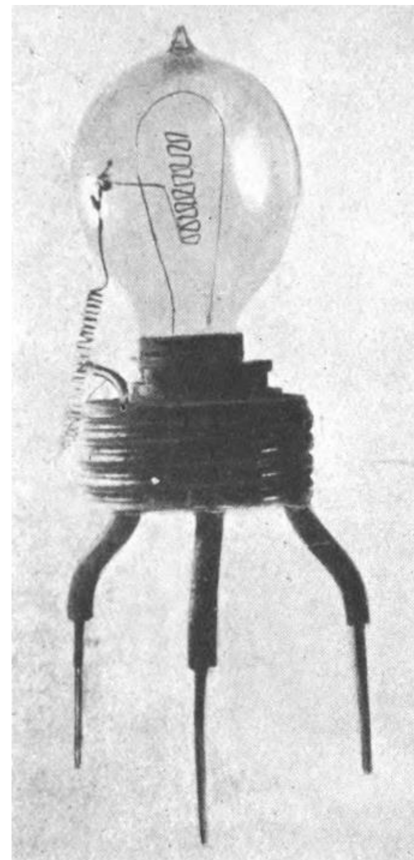






ART

has a power dissipation of 400mW.

Diode

Transistor Radio
Regency TR-1
November 1954

Texas Instruments
and I.D.E.A.

1950s

Man or Machine?

- Alan Turing published “Computing Machinery and Intelligence”*
  - a discussion of thinking and intelligence

- A human queries…
  - a computer
  - and a human
- If the answers from computer and human are indistinguishable…

* *Mind*, LIX (236), October 1950, pp. 433-460

Man or Machine? (cont.)

- …is the computer thinking? Does it have intelligence?
- The "Turing Test"
- The seminal paper in artificial intelligence
- "We may hope that machines will eventually compete with men in all purely intellectual fields."—Alan Turning

1951—Univac 1

At the U.S. Census Bureau

Univac 1

- Created by Eckert and Mauchly
- First commercial computer in U.S.
  - produced by Remington Rand
- 5,200 vacuum tubes, 14.5 tons
- 46 sold at $1 million each ($9 million today)
- 1952—from 1% of voting population, predicted Eisenhower winner over Stevenson

1952 presidential election Eisenhower vs. Stevenson

Printout from Univac 1

8.30 P.M.

IT'S AWFULLY EARLY, BUT I'LL GO OUT ON A LIMB.

UNIVAC PREDICTS--with 3,398,745 votes in--

	STEVENSON		EISENHOWER	
STATES	5		43	
ELECTORAL	93	89	438	442
POPULAR	18,986,436	27,375,090	32,915,049	34,075,529

THE CHANCES ARE NOW 00 to 1 IN FAVOR OF THE ELECTION OF EISENHOWER.

Programmers never imagined needing more than 2 digits

1952—IBM 701

IBM 701

- Beginning of IBM's entry into large computers (1953)
- Lease $15,000/month*
- First commercial scientific computer
- In production 3 years; 19 units leased
- Used by
  - aircraft manufactures
  - DoD nuclear weapons designers

* $140,000/month today

1956—IBM 350 Disk Drive

- First commercial HDD
- 50 platters
- 100 bytes/platter
- 5 million 6-bit characters
- Total storage 3.75 KB*
- Lease price
  $7,000/month
  (2019 dollars)

* Subsequent models had 5, 10, 15 or 20 MB

IBM’s Current Businesses

Watson
Uncover insights, engage in new ways and make more confident decisions

→ IBM Watson for smarter business

Cloud
Built for apps, AI-ready and designed with security in mind

→ IBM Cloud for smarter business

Services
Work with experts in technology, process and industry to create breakthroughs

→ IBM Services for smarter business

“Computer” isn’t mentioned

Blockchain
Drive more transparency and greater trust in transactions

→ IBM Blockchain for smarter business

Security
Protect what’s most important — your business and your clients

→ IBM Security for smarter business

IoT
Seamlessly connect physical and digital worlds by leveraging data and AI

→ IBM IoT for smarter business

391 San Antonio Road,
Mountain View, California

1956

Shockley Laboratories

- 1956—established by William Shockley
  – funded by Arnold Beckman
- Convinced silicon would replace germanium
- Created theoretical theory of solar cells
  – showing a maximum efficiency of 30%*
- Shockley as a manager…
  – outstanding in picking talent
  – over 20 years, 65 companies were founded by 1st or 2nd generation former Shockley Labs employees
  – horrific as a manager

* Solar cells >40% efficiency have been created

391 San Antonio Road,
Mountain View, California

391 San Antonio Road,
Mountain View, California

The Nobel Prize in Physics 1956

Photo from the Nobel Foundation archive.

William Bradford Shockley

Prize share: 1/3

John Bardeen

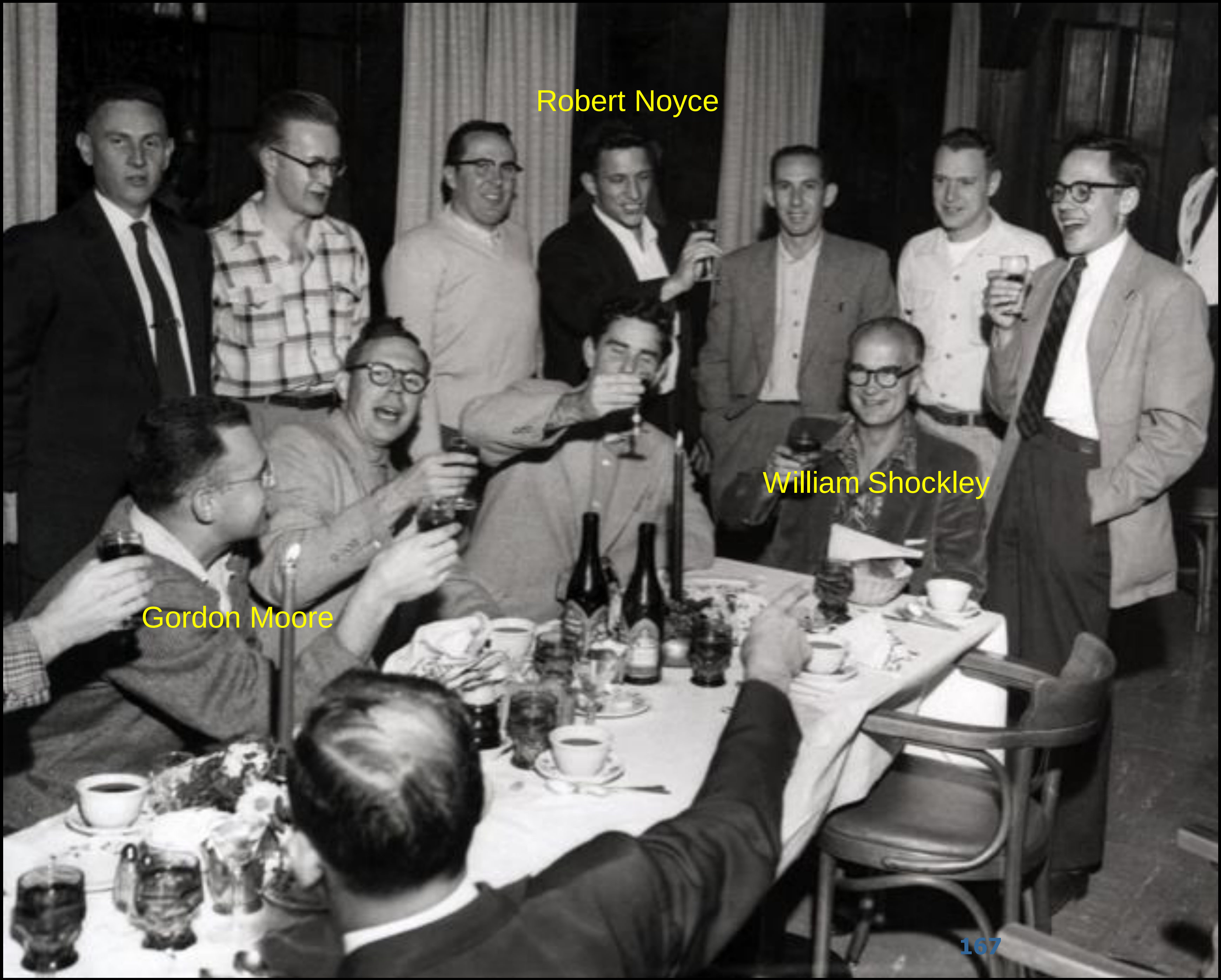
Prize share: 1/3

Photo from the Nobel Foundation archive.

Walter Houser Brattain

Prize share: 1/3

”…for their researches on semiconductors and their discovery of the transistor effect.”


Robert Noyce
William Shockley
Gordon Moore


URL
The "Traitorous Eight"
Gordon Moore
Julius Blank
Eugene Kleiner
Victor Grinich
Sheldon Roberts
Jean Hoerni
Jay Last
Robert Noyce

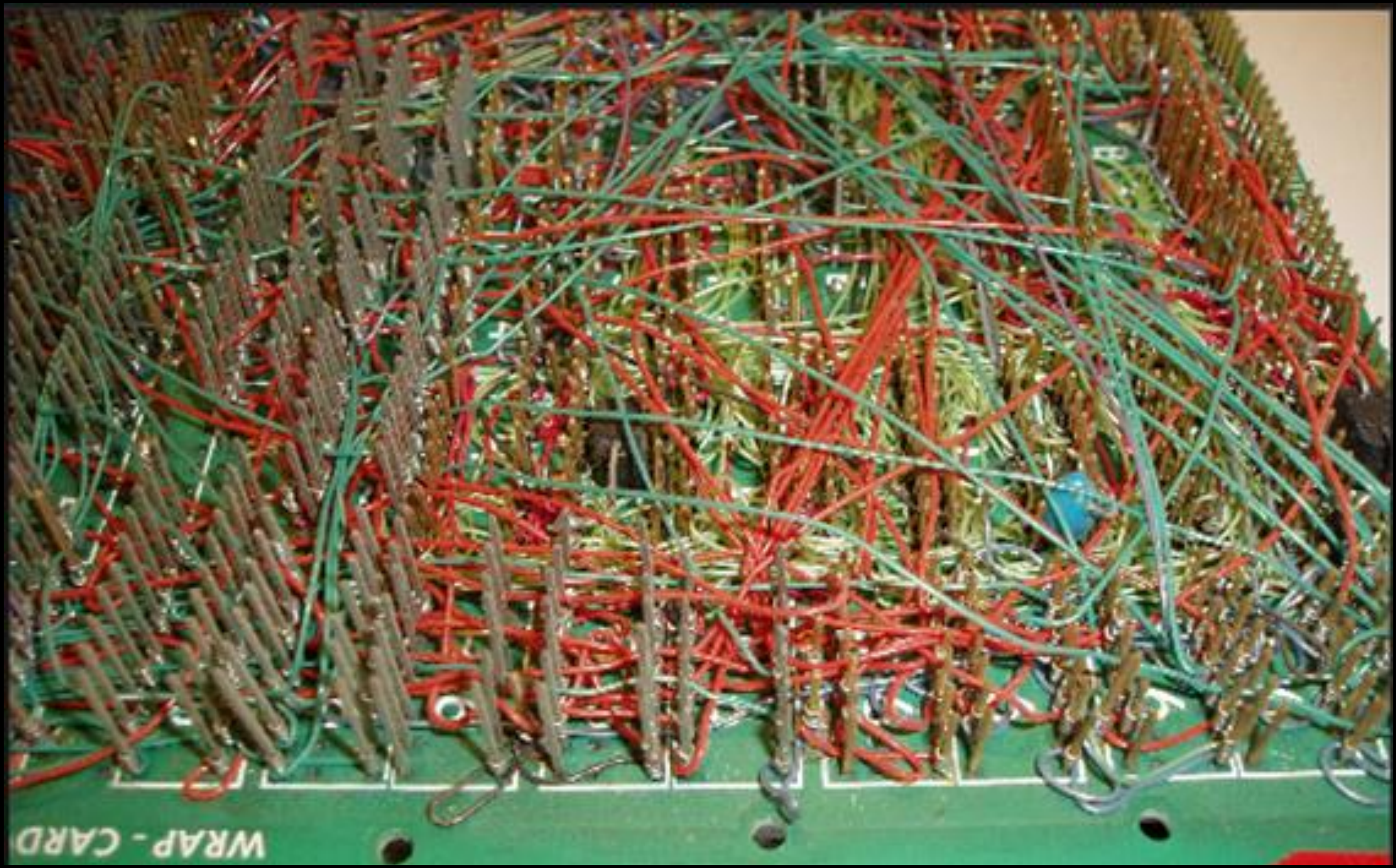
Fairchild Semiconductor International, Inc.*

- 1957—founded by the “traitorous eight”
  – a division of Fairchild Camera and Instruments
- Pioneer in manufacturing transistors and integrated circuits

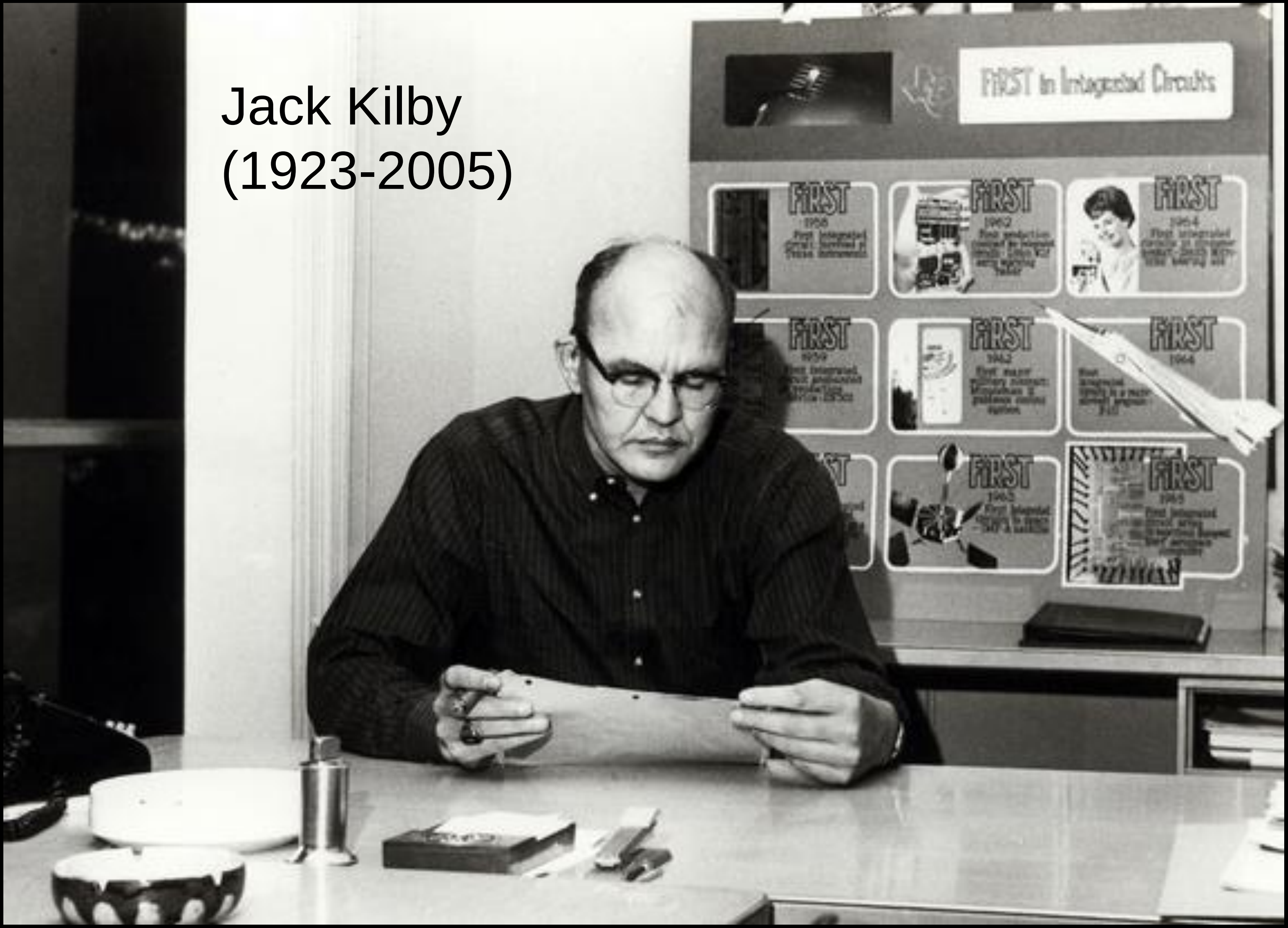
More about Robert Noyce and Gordon Moore shortly

* Since 2016 a subsidiary of ON Semiconductor

We have a problem…



Integrated Circuits

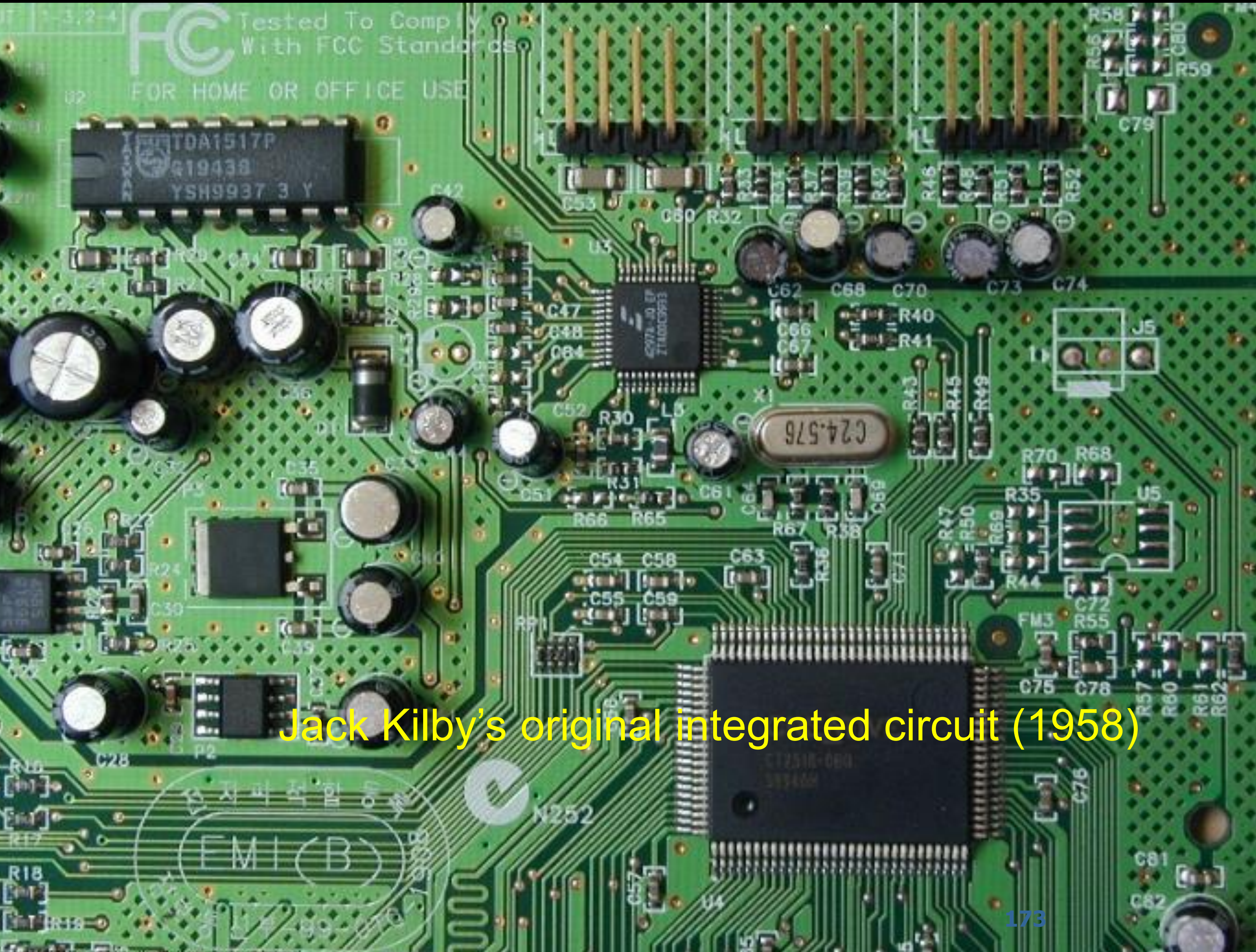


Jack Kilby
(1923-2005)

Jack Kilby

- Worked at Texas Instruments
- Patent filed February 6, 1959
  “Miniaturized Electronic Circuits”
- 2000—Nobel Prize in Physics with Zhores Alferov and Herbert Kroemer*
- Technology improved by Robert Noyce
  - Kilby used germanium
  - Noyce used silicon
  - Noyce eliminated wires
  - other enhancements

* Had Robert Noyce survived, he probably would have been included



Jack Kilby's original integrated circuit (1958)

1957—Fortran Developed

- Designed by John Backus & team at IBM
- General purpose language especially suited to numeric and scientific computing
- Used for:
  - Weather prediction
  - Computational fluid dynamics
  - Computational physics and chemistry
  - Crystallography
- Still in use today (legacy systems)

1959—Cobol

- Designed by CODASYL* for DoD
- Based on design work of FLOW-MATIC developed by Grace Hopper
- Widely used in business, finance, and administrative systems on mainframes
- Verbose, 300+ reserved words
- Largely used in legacy systems, **but**…
  - estimated 100 billion lines of COBOL still used today

* Conference/Committee on Data Systems Languages

DEC PDP-1 (1959)

DEC = <u>D</u>igital <u>E</u>quipment <u>C</u>ompany

PDP-1

- PDP = **P**rogrammed **D**ata **P**rocessor
- First minicomputer
- 2,700 transistors and 3,000 diodes
- 9 to 65 KB RAM
- 187 KHz clock speed*
- Seed of “hacker culture” at MIT
- “Spacewar”—first computer game, created by Steve Russell

*** 187 KHz = 0.000187 GHz**
This computer: 2.6 GHz

← Several comparisons to follow

1960s

IBM 7030 “Stretch” Supercomputer

IBM 7030 Supercomputer

- IBM's first transistorized computer (1961)
- Designed by Gene Amdahl
- World's fastest computer 1961-64
- Price—$8 million ($66.5 million today); only 9 sold
- 35 tons
- 64-bit processor
- Memory 2.048 MB
- Speed 1.2 MIPS

IBM System/360

IBM System/360

- In service 1965 to 1978
  - a family of 14 models of computers
- Designed by Gene Amdahl
- Commercial and scientific applications
- 256 KB to 8 MB memory
- **Backward compatibility**

Overview IBM Computers

Year	Model	Comments
1953	701	IBM's entry into large computers
1954	NORC	**N**aval **O**rdance **R**esearch **C**omputer
1958	SAGE AN/FSQ-7	North American Air Defense System at MIT
1959	1401	Popular enterprise system, high volume
1960-68	System/360	Dominant mainframe systems
1966	System/4Pi	9000 sold to DoD by the 1980s
1970	System/370	Replacement for System/360 mainframe family
1975	5100	"Portable" computer (50 lbs.)
1981	IBM PC	Industry standard. $1,565 and up (today $4,500 and up)
1983	System/36	Mid-range, office automation
1983	IBM PCjr	For the home market
1988	System/400	Medium size business computer family
1990	System/390	Replacement for System/370
1990	RISC System/6000	Workstations
1992	Thinkpad	Notebook computer
2001	eServer "Regatta"	Unix based
2003	eServer zSeries 990	Enterprise-class server
2005	System z9	Mainframe
2006	I5	Medium size business computer
2008	WebSphere line	Premises and application servers
2015	z13	Small mainframe, $75,000
2017	z14	Mainframe

IBM "Minnow" Floppy Disk Drive (1969)

IBM ”Minnow” Floppy Disk

- Developed in 1967
  - – marketed starting 1971
- 8-inch (200 mm) floppy disk
- 80 KB capacity

Types of Floppy Disks

8-inch
80 KB to
1.2 MB

5.25-inch
160 KB to
1.2 MB

3.5-inch
360 KB to
1.44 MB

CDC 6600 Supercomputer*

* **CDC** = **C**ontrol **D**ata **C**orporation

CDC 6600 Supercomputer

- World’s fastest 1964-69
- Designed by Seymour Cray
- $7 million (today $56 million)
- 6 tons
- CPU 10 MHz*
- RAM 982 KB
- Used FORTRAN
  – for scientific and engineering projects

*** 10 MHz = 0.01 GHz**
This computer: 2.6 GHz

"Mother of All Demos"

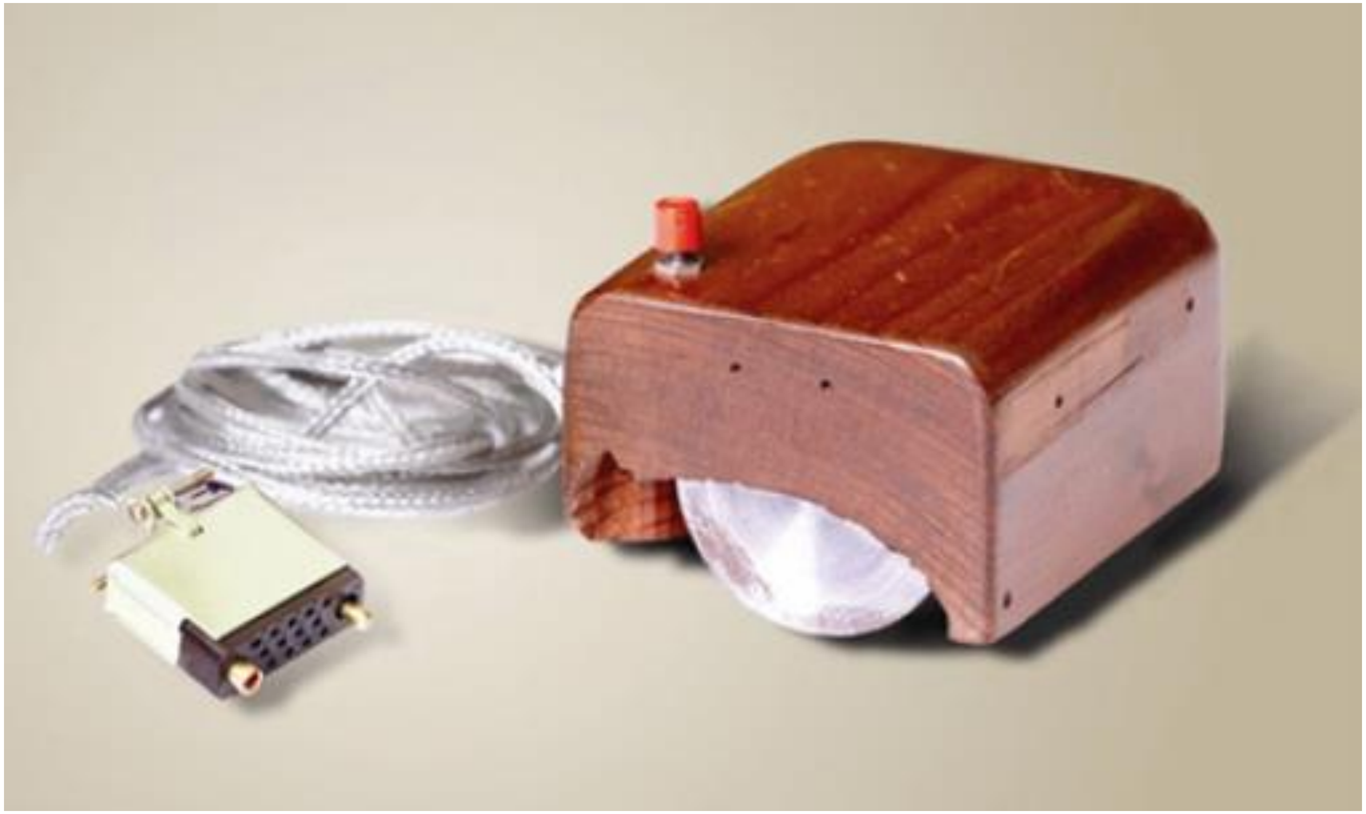
- ACM/IEEE Meeting in San Francisco, December 9, 1968; ~1,000 attendees
  - presented by Douglas Engelbart
- Live 90-minute demo of the "oN-Line System", aka NLS
- Telephone link to Menlo Park (30 miles away)
- On YouTube today
- The first public demonstration of the following on a single system…

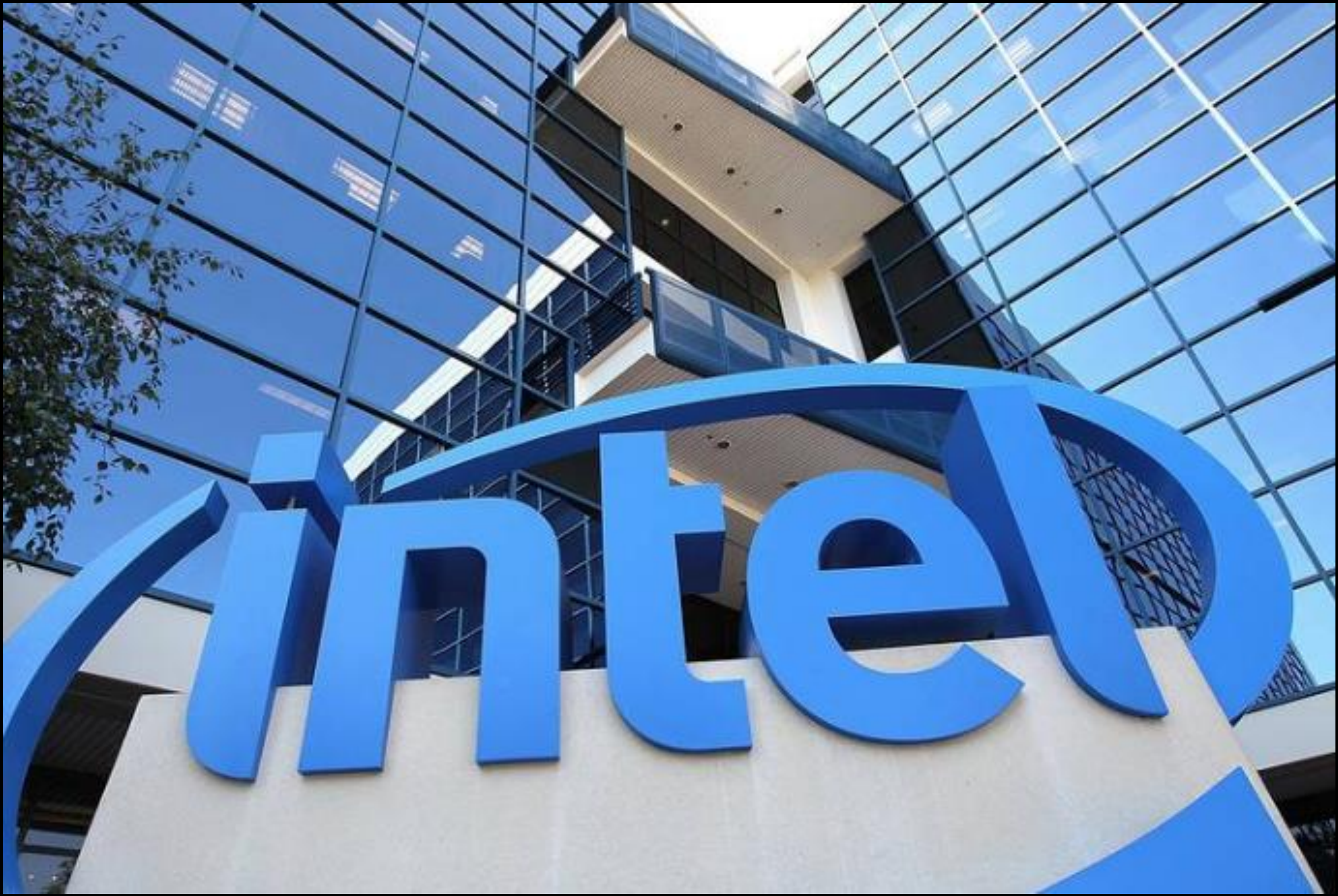
"Mother of All Demos" (cont.)

- Hypertext
- Graphics
- Windows
- Video conferencing
- Computer mouse
- Word processing
- Dynamic file linking
- Revision control
- A collaborative real-time editor
- Efficient navigation and command input

A panoramic view of the future

Engelbart's Mouse

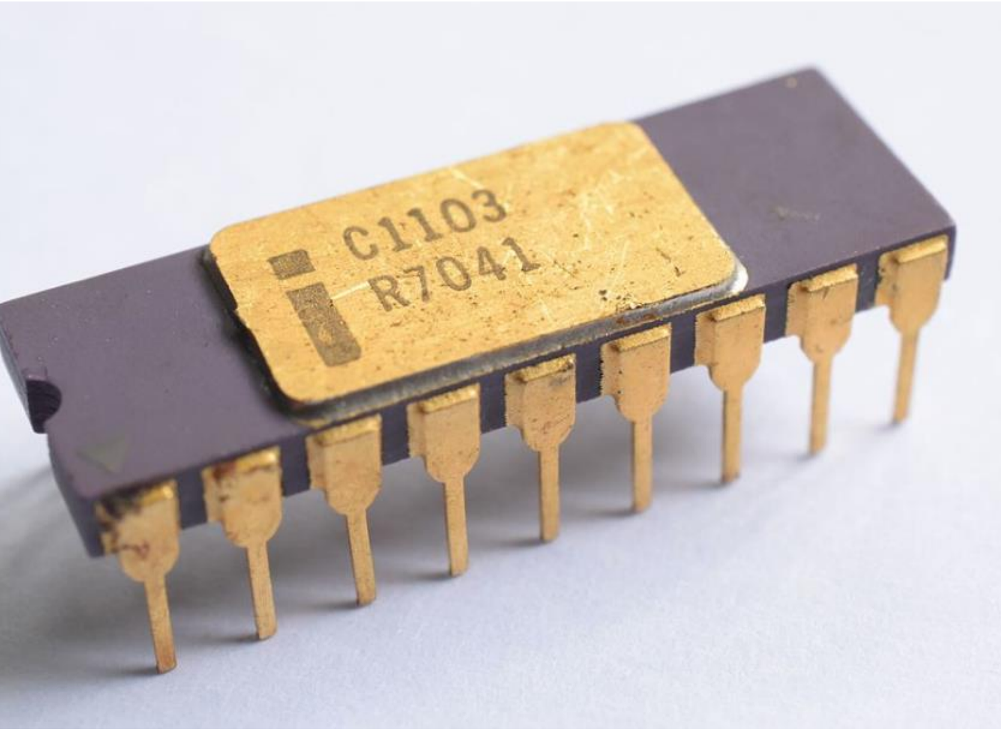



intel

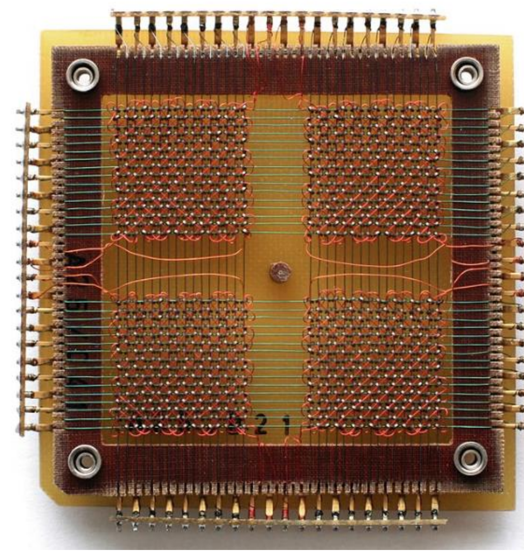
Intel

- 1968—founded by Robert Noyce and Gordon Moore… and Andrew (“Andy”) Grove
- Intel named from **int**egrated **el**ectronics
- Early developer of SRAM and DRAM memory chips
- Following success of the PC, microprocessors became their major products (x86 architecture)
- In competition with Microsoft for control of the direction of the PC industry
- In strong competition with AMD and others

Intel 1103 DRAM* Chip



- Released October 1970
- 1 KB capacity
- Replaced magnetic core type memory



* The traditional RAM in computers are DRAM (Dynamic Random Access Memory)

1970s

E-Mail Comes Along

- Created by Ray Tomlinson
  - computer engineer at MIT
  - 1971 sent first message to himself via ARPANET
  - known for “@” locator in email addresses

OR

- Created by Shiva Ayyadurai
  - developed as a high school student in late 1970

IBM 3850 Mass Storage System

WD 10,000 GB drive ↑

- Released in 1974; used through 1986
- Used thousands of cartridges (50 MB each)
- Whole system held 472 GB of data*

* This computer has 250 GB of SSD storage

Ted Hoff
(1937—)

- Ph.D. Elec. Eng. Stanford 1962
- Intel 1968-1989
- Atari 1984-1989
- Teklicon 1990-2007

Computer on a chip

United States Patent [19]

Hoff, Jr. et al.

[11] **3,821,715**

[45] **June 28, 1974**

[54] **MEMORY SYSTEM FOR A MULTI-CHIP DIGITAL COMPUTER**

[75] Inventors: **Marcian Edward Hoff, Jr.**, Santa Clara; **Stanley Mazor**, Sunnyvale; **Federico Faggin**, Cupertino, all of Calif.

[73] Assignee: **Intel Corporation**, Santa Clara, Calif.

[22] Filed: **Jan. 22, 1973**

[21] Appl. No.: **325,511**

[52] U.S. Cl. .... **340/172.5**, 340/173 R, 340/173 SP, 307/238

[51] **Int. Cl.** **G06f 13/00**, G11c 11/44

[58] **Field of Search** .... 340/172.5, 173 SP, 173 R; 307/238, 279

[56] **References Cited**

UNIT[illegible]TES PATENTS

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3,641,511	2/1[illegible]	Cricchi [illegible]	307[illegible]8 X
3,680,061	7/1[illegible]	Arbab et [illegible]	340[illegible]3 R
3,681,763	8/19[illegible]	M[illegible]e et [illegible]	340[illegible]3 R
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OTHER PUBLICATIONS

Schuenemann, "Computer Control" in IBM Technical Disclosure Bulletin, Vol. 14, No. 12, May 1972; pp. 3794–3795.

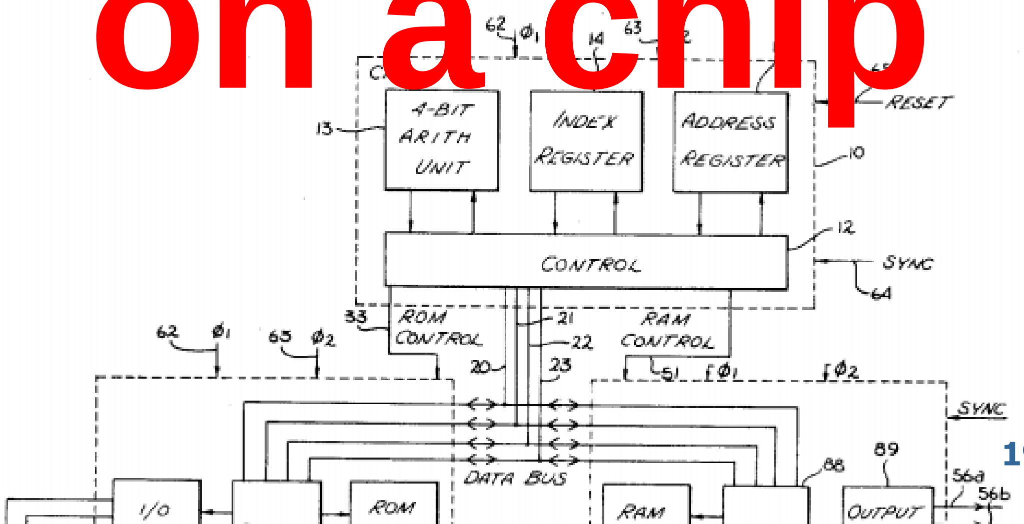
Primary Examiner—Paul J. Henon
Assistant Examiner—Melvin B. Chapnick
Attorney, Agent, or Firm—Spensley, Horn & Lubitz

[57] **ABSTRACT**

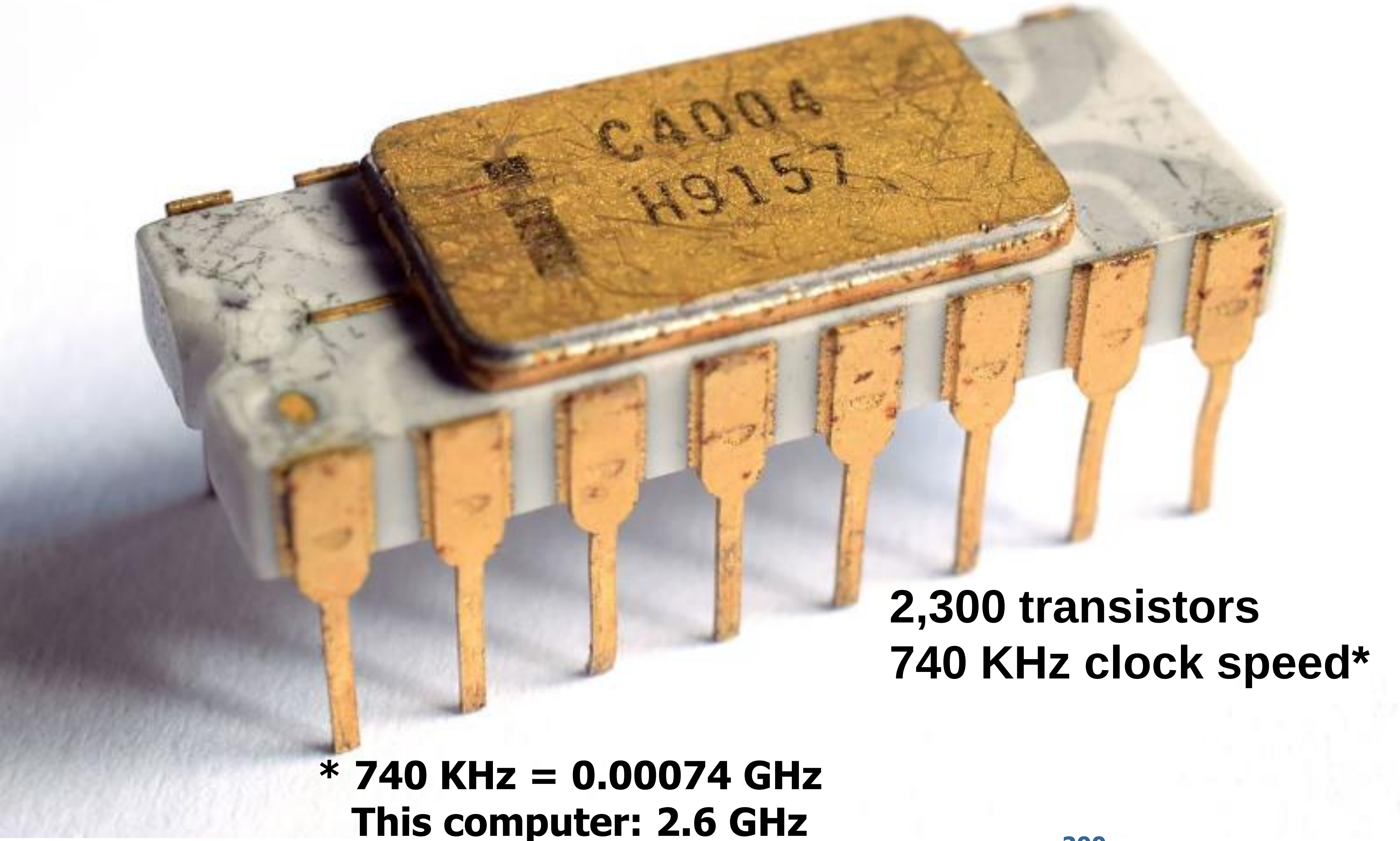
A general purpose digital computer which comprises a plurality of metal-oxide-semiconductor (MOS) chips. Random-access-memories (RAM) and read-only-memories (ROM) used as part of the computer are coupled to common bi-directional data buses to a central processing unit (CPU[illegible] with each memory includ[illegible]ing [illegible]ircu[illegible] [illegible]ich [illegible]the plu[illegible]ty o[illegible] [illegible]y ch[illegible] is [illegible]ing [illegible] the CPU. [illegible] co[illegible]ut[illegible] is f[illegible]ica[illegible] u[illegible] chips [illegible]unted on s[illegible] 16 p[illegible] in-[illegible]pa[illegible] all[illegible]ing additi[illegible]al memory chips to be added to the computer.

17 Claims, 5 Drawing Figures

← A general purpose digital computer



First to Market—Computer on a Chip (1971)
Intel 4004



2,300 transistors
740 KHz clock speed*

*** 740 KHz = 0.00074 GHz**
This computer: 2.6 GHz

Most Used Operating Systems

- Home computers:
  - Windows (75.47%)
  - macOS (12.33%)
  - Linux (1.61%)
  - Chrome OS (1.17%)*

- Smartphones—Android (Linux based)
- Tablets—iOS
- Linux in smart devices and IoT
- Linux in Web servers and supercomputers

* As of January 2019. 9.42% other or unknown; see

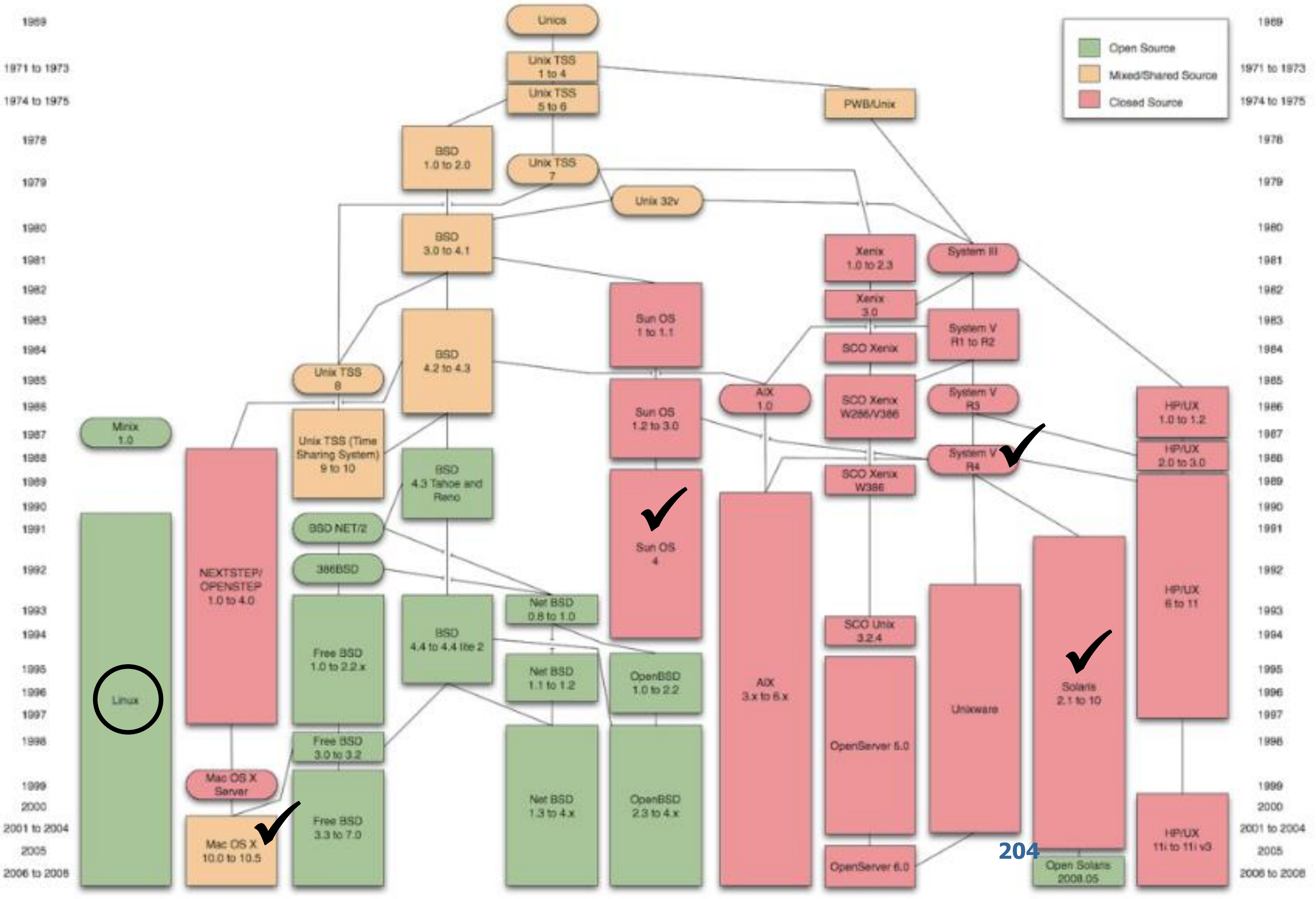
Unix

- Developed at Bell Labs (1969-70) by Ken Thompson and Dennis Ritchie
- A multi-user system
- Developed on DEC PDP 11/20
- Written in assembler language
- For word processing…
  - for patent applications
  - ***ed*** text editor and formatting with ***nroff***
- ***nroff*** quickly spawned ***troff*** the first electronic publishing system

Unix (cont.)

- 1972-73—the “C” programming language created by Dennis Ritchie
- 1973—Unix was re-written in ”C”
- 1973—Unix licensed to educational institutions

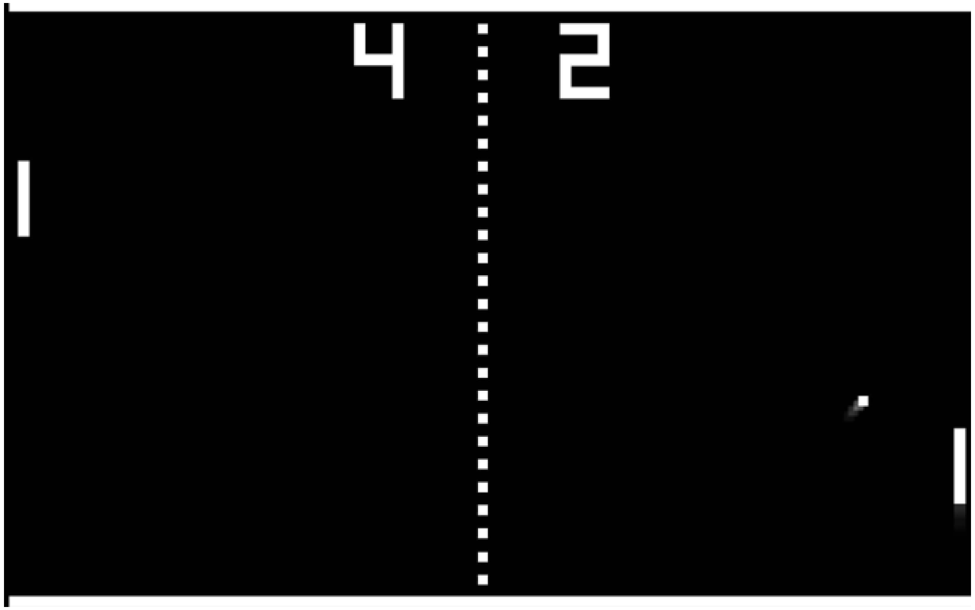
The Unix Family



HP-35 Scientific Calculator

- Released in 1972
- Marketed as “The new electronic slide rule”
- A slide rule killer!
- $395—$2,400 in today’s money

Pong



- 1972 Created by Alan Alcorn at Atari
- The first video game
- As a programming training exercise
- Became wildly popular
- Launched the electronic game industry

Honeywell vs. Sperry Rand

- 1964—Sperry Rand Corp granted a patent filed by Eckert and Mauchly for the ENIAC
- Sperry Rand sued Honeywell on claims of patent infringement
- Honeywell sued for monopolistic practices and fraud seeking to invalidate their patent
- Ruling (October 19, 1973):
  - court invalidated Sperry Rand’s patent
  - assigned invention of electronic digital computer to John V. Atanasoff
  - put invention of electronic digital computer in public domain

Xerox 9700 Laser Printer

- First commercial laser printer
  - released October 1977
- Developed by Gary Starkweather at PARC in early 1970s
- Used a PDP 11/34 for print controller and rasterizer
- 300 dpi
- 120 pages/minute
- Price $500,000 (?)

Xerox PARC Alto Computer

- 1973—first computer with graphics oriented OS
  - – decade before other GUI computers
- Mouse
- Late 1970s thousands in use at Xerox facilities
- ~500 at universities
- 1979 Steve Jobs visited PARC
- 1981—attempts to market for $100,000 ($289,000 today)

Cray 1 Supercomputer URL URL

Cray 1 Supercomputer

- 1976—first installed Los Alamos National Laboratory
- 64-bit processor; 80 MHz*
- 8.39 MB RAM
- Storage 303 MB
- Price $7.9 million ($36 million today)
- Eventually >100 sold
- Ten times faster than closest competitor
- One of most successful supercomputers in history

*** 80 MHz = 0.08 GHz**
This computer: 2.6 GHz

Manufacturing Computer Chips URL URL URL URL

10-minute video URL

The Internet

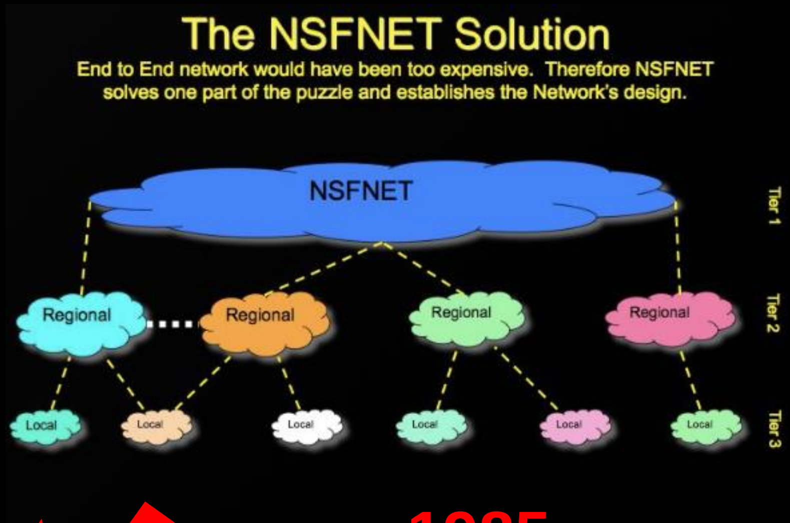
2004 Stamp of Azerbaijan
35 Years of the Internet, 1969–2004

Pre-Internet Thoughts

- Early 1900s-–Nikola Tesla imagines a “world wireless system”
- 1930s & 40s—Paul Otlet and Vannevar Bush conceive searchable storage system for books and other media
- Early 1960s—J.C.R. Licklider popularized idea of an “Intergalactic Network”
- 1965—Ted Nelson published article about hypertext

Internet History in a Nutshell

1969



1985

1991

The Internet

- 1969—DoD created ARPANET*
  - – linking UCLA, UC Santa Barbara, Stanford (SRI), and University of Utah
  - – first message “LO” for ”LOGIN”…

    … then Stanford’s computer crashed
  - – system recovered “LOGIN” sent
- 1974—Vinton Cerf and Bob Kahn published “A protocol for Packet Network Interconnection”—describing TCP

* **A**dvanced **R**esearch **P**rojects **A**gency **N**etwork

The Internet (cont.)

- 1974—first ISP (Telenet) established; commercial version of ARPANET
- 1981—NSF provided a grant to establish Computer Science Network (CSNET)
  - providing networking services to university computer scientists (an ISP)
- 1983—ARPANET adopted TCP/IP
- 1983—DNS established (.com, .edu, .gov)
- 1985—Symbolics Computer Corp became the first registered domain “Symbolics.com”

The Internet (cont.)

- 1985—NSFNET established
- 1986—both NSFNET and ARPANET quickly expanded across U.S.
- 1987—20,000 hosts on the Internet
- 1987—Cisco shipped first router
- 1990—Tim Berners-Lee developed World Wide Web at CERN (released 1991)

The Internet (cont.)

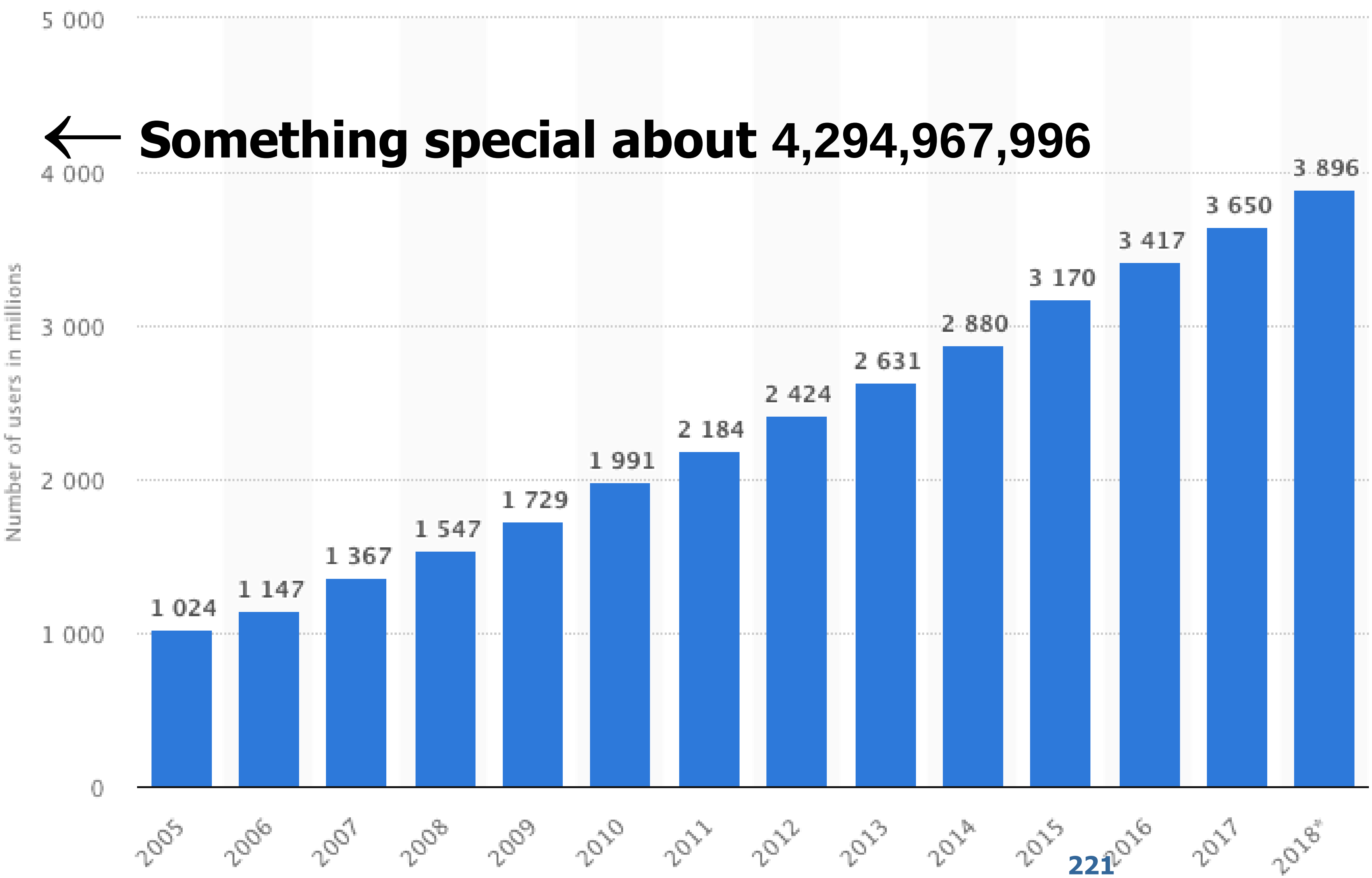
- **1991—NSF opened the Internet to commerce**
- 1993-–Marc Andreessen announced the Mosaic Web browser (numerous other browsers see)
- 1994—Justin Hall developed the “blog”
- **1995—NSF turned over Internet backbone to private industry (NSFNET discontinued)**
- Was the Internet designed for survival of communications in the event of nuclear war?
  - **Yes—**DoD, who funded its development
  - **No—**academics who did much of the design and development

Guardian of The Internet

- **1998-–established as international not-for-profit**
- **Assigns, manages and controls the domain name system (DNS)**
- **Example domain name:**
  - **gmu.edu**
  - **129.174.1.59**
- **<u>Does not control Internet content</u>**

Internet Users 2005-2018

← Something special about 4,294,967,296



"Crowded Internet Problem"

- Each user on the Internet requires an IP address, example 192.168.40.88
- At present IP addresses (IPv4) use 32 bits (4 bytes) which accommodates 2^{32} users, i.e., 4,294,967,996
- Remember the "Year 2000" problem?

Solution…

- IPv6, using 128 bits, is being deployed
  - $2^{128} = 3.4028 \times 10^{38}$ addresses

IBM 5100

Back to the 1970s

IBM 5100

- 1975—introduced on the market
- First (?) “portable” computer, 53 lbs
- IBM Palm CPU, 1.9 MHz*
- Price $9,000 to $20,000 ($42,500 to $94,500 today)

*** 1.9 MHz = 0.0019 GHz**
This computer: 2.6 GHz

Personal Computer Timeline

- 1975—IBM launches IBM 5100, first to look like a modern desktop PC
- 1975—Microsoft founded by Bill Gates and Paul Allen
- 1976—Apple founded by Steve Jobs and Steve Wozniak
- 1976—Apple sold 200 Apple 1 computers

Apple Computer Manufacturing Facility

Personal Computer Timeline (cont.)

- 1977—Radio Shack introduced TRS-80
- 1977—Commodore PET introduced
- 1981—IBM launched PC with licensed Microsoft's DOS
- 1981—Osborne 1; $1,800* (23.5 lbs) (CP/M)
- 1983—Compaq Portable, IBM PC compatible (Microsoft DOS), $3,590**, 28 lbs.
- 1984—Dell Computer Corporation launched

* $5,000 in 2019 dollars

** $9,590 in 2019 dollars

Personal Computer Timeline (cont.)

- 1984—Apple launched the Macintosh
- 1985—Microsoft introduced Windows OS
- 1980s-90s—Numerous advances in Windows PCs and Apple computers
- 2002—one billionth PC sold
- 2008—laptop shipments overtook desktop computer sales
- 2007-2019—smartphones

Homebrew Computer Club

- March 1975—first meeting in Gordon French's garage in Menlo Park, California
- Hobbyists, engineers, programmers
- After one year ~750 members
- Three notable members:
  - Steve Jobs
  - Adam Osborne
  - Steve Wozniak
- At least 23 tech companies got their start at Homebrew

NEWSLETTER

Homebrew Computer Club

Robert Reiling, Editor □ Post Office Box 626, Mountain View, CA 94042 □ **Joel Miller**, Staff Writer

Typesetting, graphics and editorial services donated by **Laurel Publications**, 17235 Laurel Rd., Los Gatos, CA 95030 (408) 353-3609

RANDOM DATA

By Robert Reiling

Computer clubs continue to form around the country...E. Brooner would like to have material to help him get started with the "Flathead Computer Society" in the Kalispell area. His Address is P.O. Box 236, Lakeside, Montana 59922.

Did you see the SOL terminal demonstrated by Bob Marsh at the Sept. 1st meeting? An excellent design that will interest hobbyists and commercial users alike. It's available from Processor Technology, 6200 Hollis St., Emeryville, CA 94608. Write them for prices and specifications.

The OSI Systems Journal has been sent to all OSI customers (free—at least for the time being). It's a bi-monthly magazine with plans to go monthly in the future. There are 28 pages in the first issue (August 1976, Vol. 1, No. 1) with a hardware feature covering the OSI 440 Video Graphics System and software, features concerning Tiny BASIC for the 6800 and a Graphics Editor for the 6502. It also includes OSI product and software catalog data. The BASIC is, of course, the 2K Tiny BASIC developed by Tom Pittman. Many of you have met Tom at the Homebrew computer Club meetings. The OSI Systems Journal is a good way to learn more about the OSI computer hardware and software along with helpful user information. The contact address is: The OSI Systems Journal, P.O. Box 134, Hiram, Ohio 44234.

KIM-1 users now have a newsletter. Eric Rehnke is producing the newsletter every 5-8 weeks, MOS Technology, Inc. helped get it started by sending copies to all known KIM owners. The user group, however, is independent of MOS Technology, Inc. The newsletter is devoted to KIM-1 support. Subscriptions are $5.00 for the next six issues. Contact "KIM-1 User Notes," c/o Eric C. Rehnke, Apt. 207, 7656 Broadview Rd., Parma, Ohio 44134.

The BAMUG club has a new contact address. It is BAMUG, c/o Timothy O'Hare, 1211 Santa Clara Ave., Alameda, CA 94501. Write Timothy for club information. I suggest you include a stamped, self-addressed envelope.

Beware of board snatchers! Glenn Ewing reports 11 boards were taken out of his IMSAI computer. The boards are: MPU, 4 RAM-4's, SIO-2, P10-4, PIC-8, PROM-4, IFM and FIB. Glenn suggests you consider providing good security for your computer and associated equipment. In his case the computer was in a locked office which was burglarized. In the event you have information on the above boards, write Lt. Glenn Ewing, Code 62EI, Naval Post Graduate School, Monterey, CA 93940.

For family and friends of people who always wanted to know about computers, but didn't want to ask them, four easy-going classes are available starting Oct. 19th on Tuesdays from 7 to 9 p.m. You can learn how computers work and what they can and can't do. You will also have some of the jargon deciphered, see what you can do with a computer, play some games and learn to program. The cost is $25. Contact the Community Computer Center, 1919 Menalto Ave., Menlo Park, CA 94025, phone (415) 325-4444.

A call for papers in personal computing has been issued by the 1977 National Computer Conference. The conference is scheduled for June 13-16, 1977. I have a few copies of the guidlines if you would like to submit a paper.

The First West Coast Computer Faire will be held April 16 and 17, 1977 at the San Francisco Civic Auditorium. This faire is shaping up rapidly. If you would like to lead a conference or participate in a conference session, please contact me. More information about the Faire is in the accompanying article.□

THE FIRST WEST COAST COMPUTER FAIRE

A Call For Papers And Participation

The San Francisco Bay Area is finally going to have a major conference and exhibition exclusively concerned with personal and home computing—The First West Coast Computer Faire. And, it promises to be a massive one! It will take place in the largest convention facility in Northern California: The Civic Auditorium in San Francisco. It will be a two-and-a-half day affair, starting on Friday evening and running through Sunday evening, April 15-17.

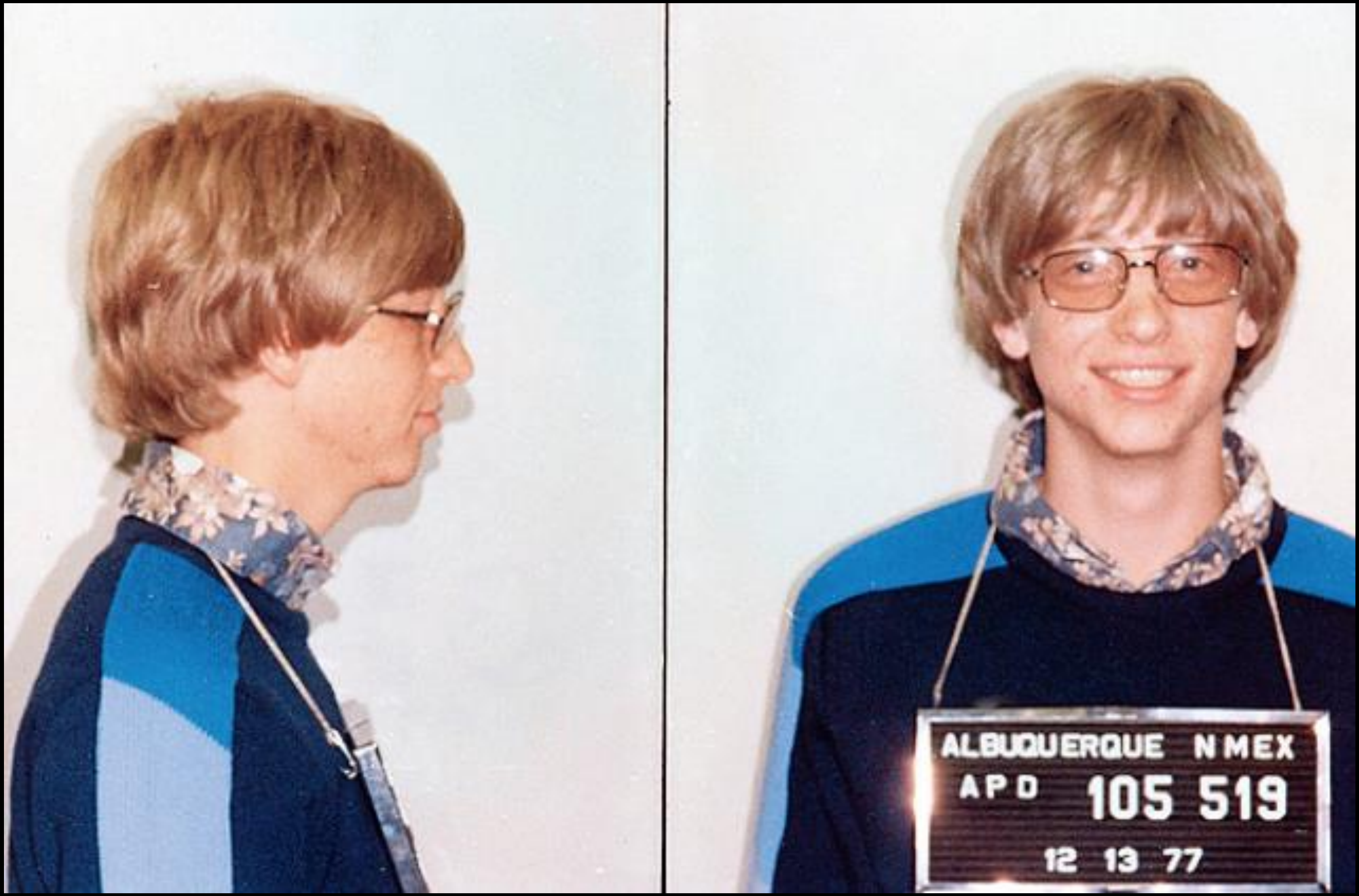
It is being sponsored by a number of local and regional hobbyist clubs, educational organizations and professional groups. These include:

- The two largest amateur computer organizations in the United States—the Homebrew Computer Club and the Southern California Computer Society
- Both of the Bay Area chapters of the Association Of Computing Machinery—the San Francisco Chapter and the Golden Gate Chapter
- Stanford University's Electrical Engineering Department


HOW TO "READ" FM TUNER SPECIFICATIONS
Popular Electronics
WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE JANUARY 1975/75¢
PROJECT BREAKTHROUGH!
World's First Minicomputer Kit to Rival Commercial Models...
"ALTAIR 8800" SAVE OVER $1000
ALTAIR 8800
ALSO IN THIS ISSUE:
• An Under-$90 Scientific Calculator Project
• CCD's—TV Camera Tube Successor?
• Thyristor-Controlled Photoflashers
TEST REPORTS:
Technics 200 Speaker System
Pioneer RT-1011 Open-Reel Recorder
Tram Diamond-
Edmund Scienti
Hewlett-Packar

1

Guess Who?



Bill Gates' open letter to Homebrew Newsletter…

…decrying theft of software by hobbyists passing on Microsoft's Altair BASIC

February 3, 1976

An Open Letter to Hobbyists

To me, the most critical thing in the hobby market right now is the lack of good software courses, books and software itself. Without good software and an owner who understands programming, a hobby computer is wasted. Will quality software be written for the hobby market?

Almost a year ago, Paul Allen and myself, expecting the hobby market to expand, hired Monte Davidoff and developed Altair BASIC. Though the initial work took only two months, the three of us have spent most of the last year documenting, improving and adding features to BASIC. Now we have 4K, 8K, EXTENDED, ROM and DISK BASIC. The value of the computer time we have used exceeds $40,000.

The feedback we have gotten from the hundreds of people who say they are using BASIC has all been positive. Two surprising things are apparent, however. 1) Most of these "users" never bought BASIC (less than 10% of all Altair owners have bought BASIC), and 2) The amount of royalties we have received from sales to hobbyists makes the time spent of Altair BASIC worth less than $2 an hour.

Why is this? As the majority of hobbyists must be aware, most of you steal your software. Hardware must be paid for, but software is something to share. Who cares if the people who worked on it get paid?

Is this fair? One thing you don't do by stealing software is get back at MITS for some problem you may have had. MITS doesn't make money selling software. The royalty paid to us, the manual, the tape and the overhead make it a break-even operation. One thing you do do is prevent good software from being written. Who can afford to do professional work for nothing? What hobbyist can put 3-man years into programming, finding all bugs, documenting his product and distribute for free? The fact is, no one besides us has invested a lot of money in hobby software. We have written 6800 BASIC, and are writing 8080 APL and 6800 APL, but there is very little incentive to make this software available to hobbyists. Most directly, the thing you do is theft.

What about the guys who re-sell Altair BASIC, aren't they making money on hobby software? Yes, but those who have been reported to us may lose in the end. They are the ones who give hobbyists a bad name, and should be kicked out of any club meeting they show up at.

I would appreciate letters from any one who wants to pay up, or has a suggestion or comment. Just write me at 1180 Alvarado SE, #114, Albuquerque, New Mexico, 87108. Nothing would please me more than being able to hire ten programmers and deluge the hobby market with good software.

Bill Gates

Bill Gates
General Partner, Micro-Soft

Bill Gates
(1955-)

Paul Allen
(1953-2018)

Microsoft

- 1975—founded by Bill Gates and Paul Allen
  - to develop and sell BASIC for Altair 8800
- Products:
  - **1980—MS-DOS (licensed to IBM)**
  - 1985—Microsoft Windows
  - 1990—Microsoft Office
  - 2001—Xbox
  - **2008-–Azure Services (Cloud computing)**
  - **2011—Office 365**
  - 2012—The Surface laptops
- 2019—Market capitalization $1.07 trillion URL

Guess Who?

1973—visited the guru Maharaj-ji in India

Steve Jobs
(1955-2011)

Steve Wozniak
(1950-)

Who was the third founder of Apple?

Apple, Inc.

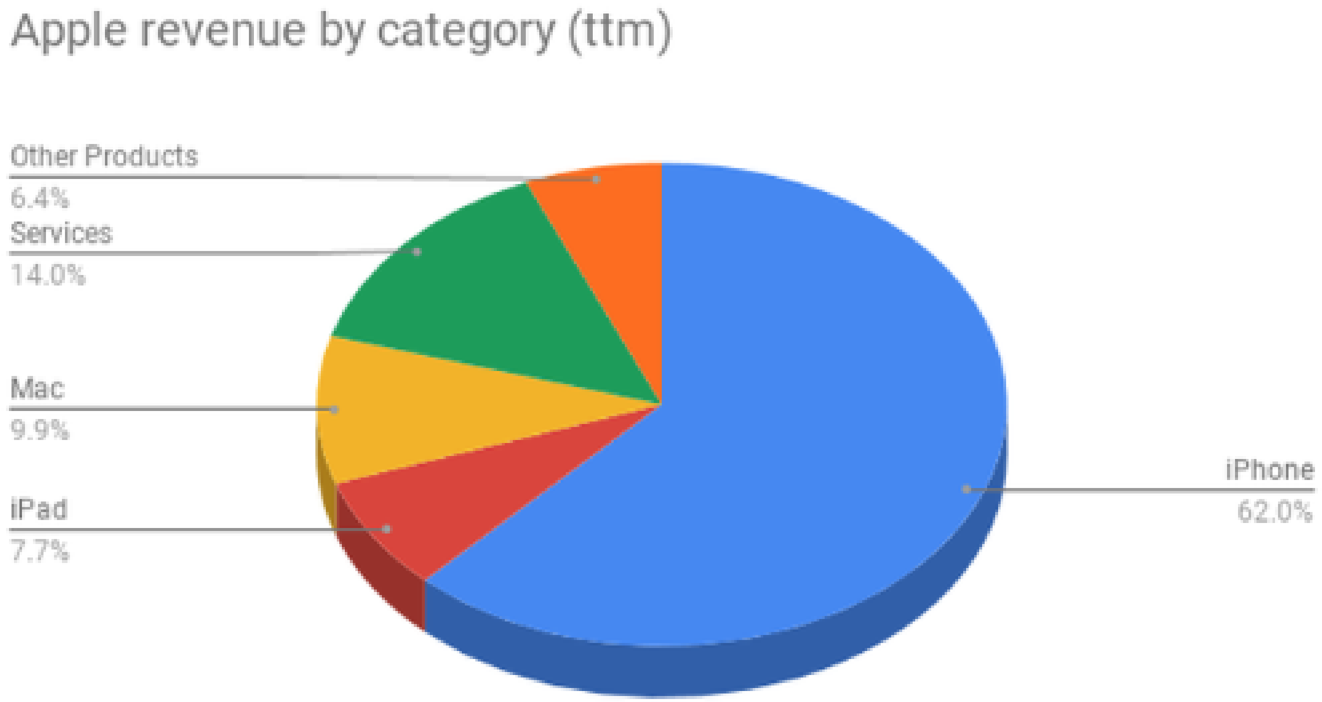
- 1976—founded by Steve Jobs, Steve Wozniak and Ronald Wayne*
- Products:
  - **1970s—computers**
  - 2001—iTunes
  - 2001—iPod
  - 2007—Apple TV
  - **2007—iPhone**
  - 2012—iPad
  - 2014—Apple Pay
  - 2015—Apple Music
  - 2016—Apple Watch
  - 2019—Credit card & entertainment (streaming, games, etc)
- 2019—market capitalization $962 billion

* In 1976 sold his 10% share in Apple for $800

Apple, Inc.

~~The Computer Company~~

The Smartphone Company



2018 revenue from computer sales $25.3 billion
Profit margin of ~30% = $7.59 billion profit

80 Years of Computer History

Lorrin R. Garson

Lifetime Learning Institute

of Northern Virginia

Summer 2019

Lecture 3 of 3

September 5, 2019

Apple, Inc.

~~The Computer Company~~

The Smartphone Company

Here is where we left off…

2018 revenue from computer sales $25.3 billion
Profit margin of ~30% = $7.59 billion profit

1980s

Seagate ST-506

- 1980—first HDD for PC (5.25-in)
- 5 MB capacity
- $1,500 ($4,800 today’s money)

Sun 1 Workstation

- 1982—designed by graduate students at Stanford University
- SunOS (derived from Unix 7)
- Motorola 68000 CPU,10 MHz*
- 256 KB to 2 MB RAM
- No windows system (later X Window)
- 2010—Sun Microsystems purchased by Oracle Corp.

*** 10 MHz = 0.01 GHz**
This computer: 2.6 GHz

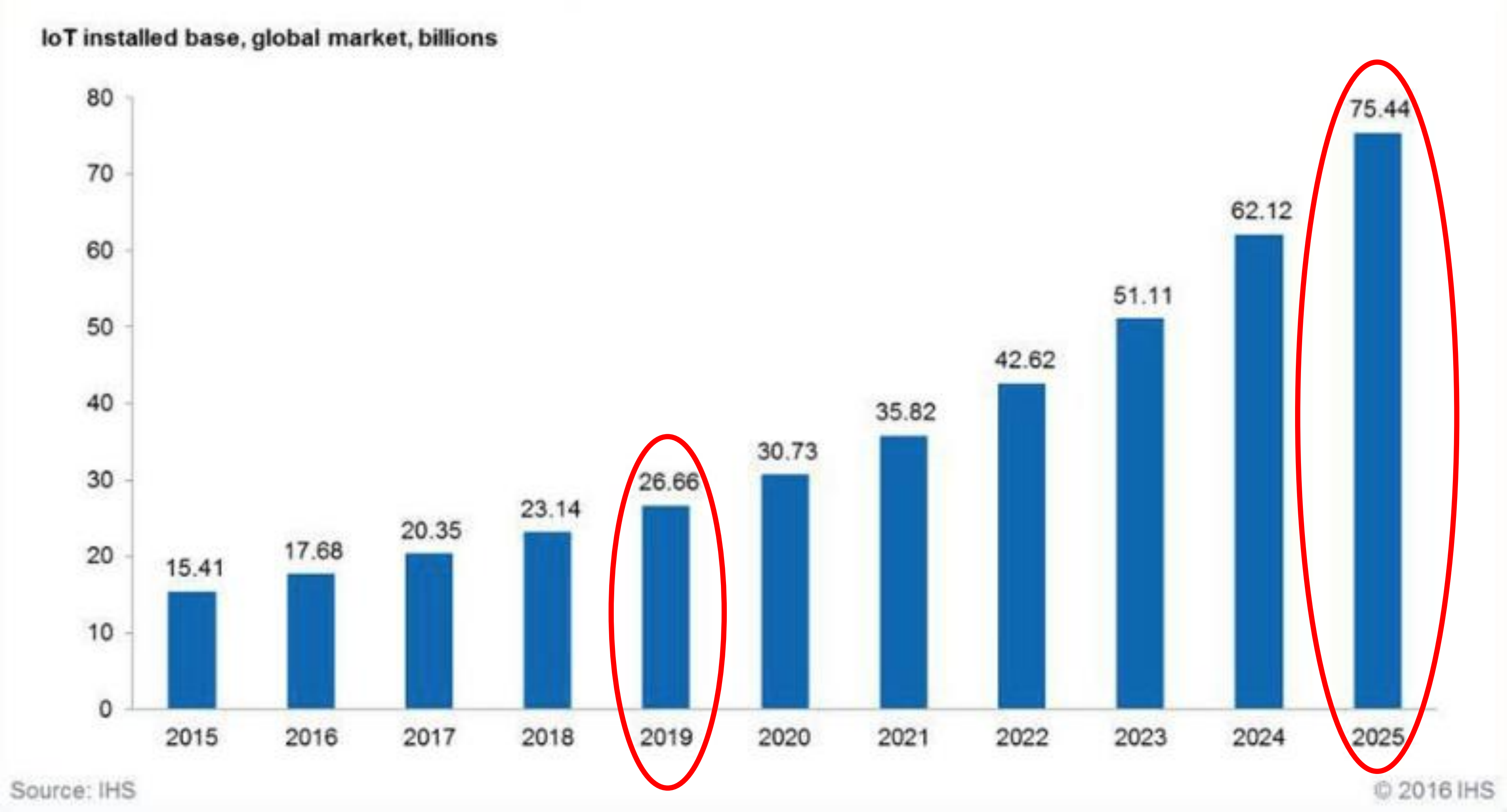
The First "Internet of Things*"

- 1982—Coke vending machine at Carnegie Mellon University
- "Called home" to report:
  - inventory
  - temperature of drinks

* aka IoT

Growth: Internet of Things

(number devices—billions)



Smart Speakers

Amazon Echo*
2^{nd} Gen

Google Home

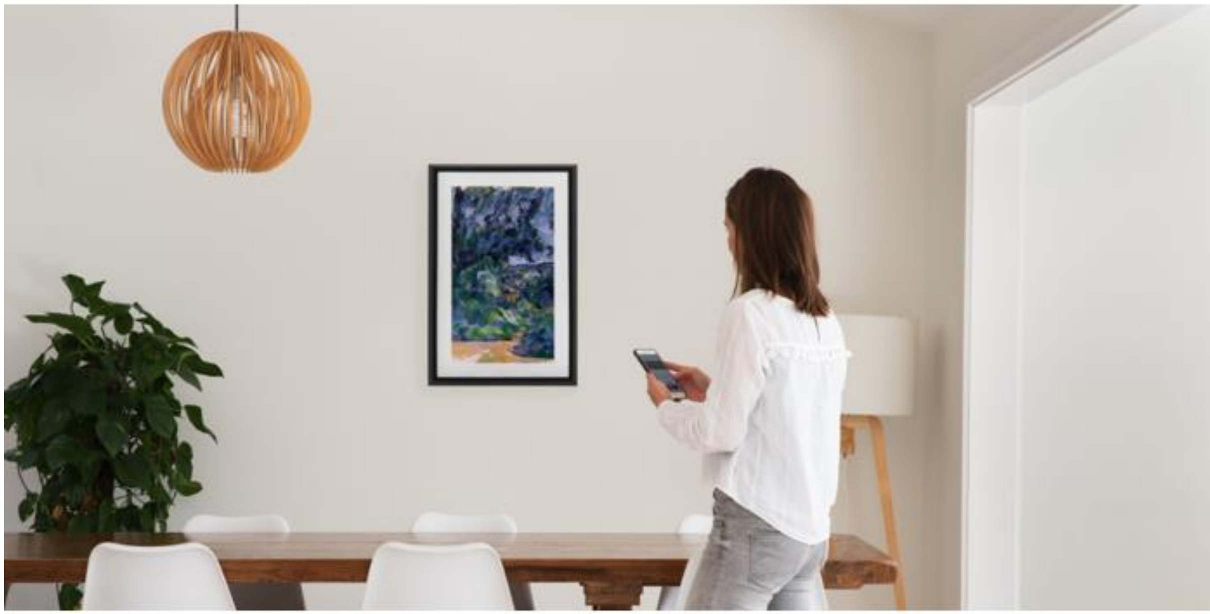
Apple HomePod

* The Amazon Echo first came out on November 6, 2014

Internet of Things

Meet Meural (2015)

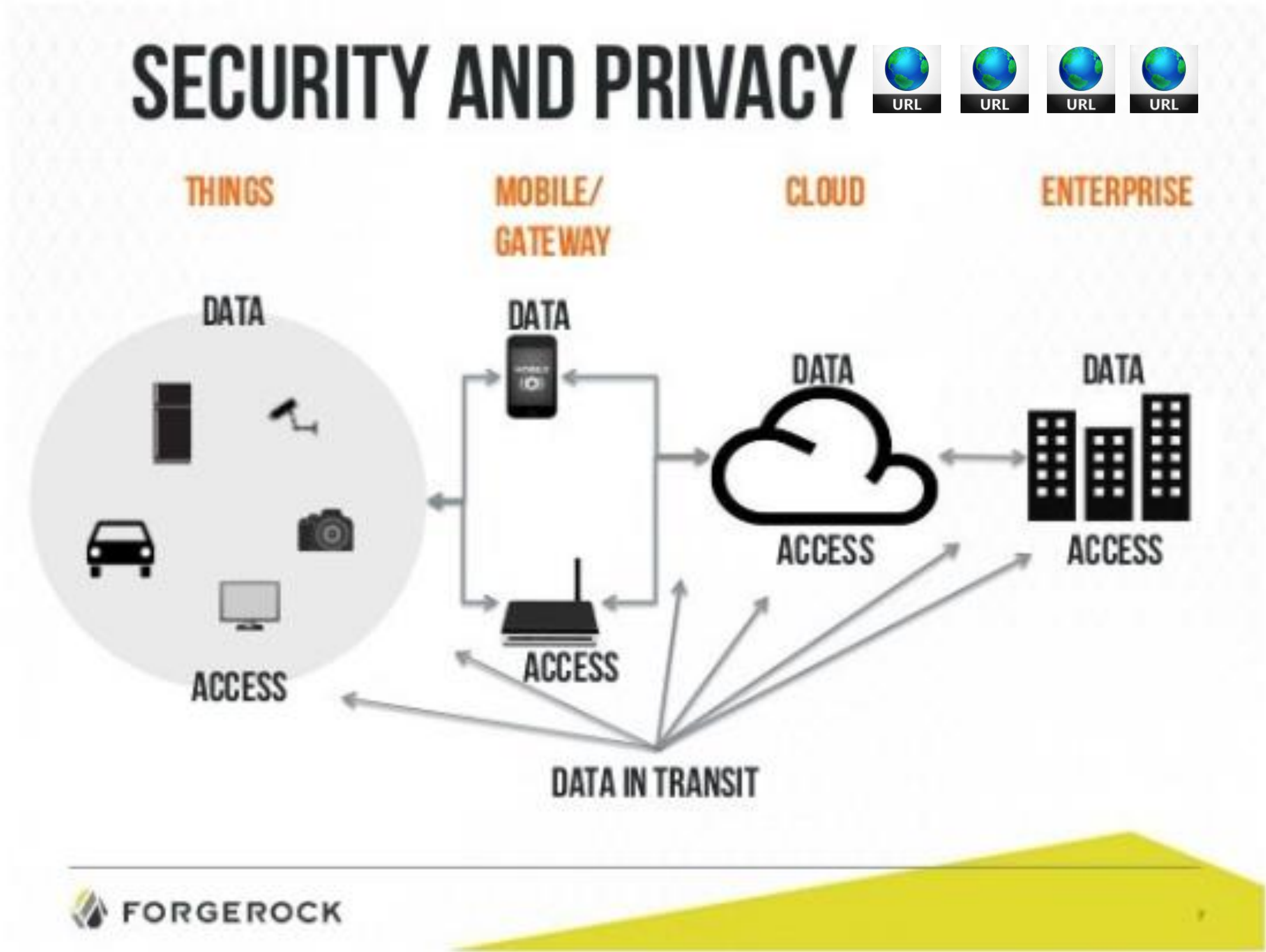
Experience the world of art at your fingertips



The Meural Canvas is a smart art frame that renders images as lifelike and textured as museum originals. Each Meural Canvas combines state-of-the-art tech with artful design:

- With *TrueArt* technology, you can see each and every brushstroke
- It's easy to upload your own images
- Works with Alexa for voice control
- Three ways to control: the wave of your hand, our app, and our online dashboard
- Hang in vertical or horizontal—the frame automatically detects its orientation

Internet of Things


SECURITY AND PRIVACY
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URL
URL
URL
THINGS
MOBILE/
GATEWAY
CLOUD
ENTERPRISE
DATA
ACCESS
DATA
ACCESS
DATA
ACCESS
DATA
ACCESS
DATA IN TRANSIT
FORGEROCK

CD-ROMs* and DVDs

- 1984—*Grollier's Electronic Encyclopedia* (12% of capacity)
- Standard CD-ROM 120 mm holds 550-737 MB
- 1997—DVDs available
  - 15 types
  - 3.95 to 9.39 GB capacity

* Introduced by Denon and Sony at a computer show in Japan in 1984

Richard Stallman (1953-)

Richard Stallman

Open Source Software

Name	Year Established	URL
GNU Project	1983	
Free Software Foundation	1985	
Open Source Initiative	1998	
Apache Software Foundation	1999	
Linux Foundation	2000	
Gnome Foundation	2000	
Python Software Foundation	2001	
Eclipse Foundation	2004	
Software Freedom Law Center	2005	
OW2 Consortium	2007	

Free Office Automation Software

Name	URL	Comments
Google Docs		Web-based, works with any browser
iWork		macOS
LibreOffice		Window, macOS, Linux
NeoOffice		macOS
Polaris Office		Windows, macOS, iOS, Android
SoftMaker FreeOffice		Windows, macOS, Linux
WPS Office		Windows, Linux, iOS, Android

Not Free

- Microsoft Office—Office 365 is now dominant
- Google’s G Suite

Microsoft Word

- Introduced in 1983 under the name “Multi-Tool Word” for Xenix computer
- 1983—for IBM PCs and Apple OS
- 1985—AT&T Unix PC and Atari ST (Tramiel OS)
- 1989—Microsoft Windows and SCO Unix
- 1988—Microsoft Office (Windows and macOS)
  – Word
  – Excel
  – PowerPoint
  – Outlook (1997)
  – OneNote
  – Publisher and Access (Windows only)

Famous Apple Commercial

- 1995—Clio Awards Hall of Fame
- 1995—Advertising Age, Greatest Commercial
- 1999—TV Guide, Greatest Commercial of All Time
- 2003—Hall of Fame Award
- 2007—Best Super Bowl Spot
- Others…
- Available on YouTube

Sa !

NeXT Inc.

- 1985—founded by Steve Jobs
- Created three generations of the NeXT computers (a workstation for the academic market)
- Created the Unix-like NeXTSTEP operating system
- 1990s—used at George Mason University
- 1990s—used by Tim Berners-Lee to create WWW
- 1997—Apple purchased NeXT Inc. to acquire
  – Steve Jobs
  – NeXTSTEP OS

The Morris Worm

- 1988—Robert Morris, age 23, released an Internet worm, aka “The Great Worm”
  - caused major problems for days infecting 1000s of Unix computers
  - a denial of service attack
  - first person convicted under “Computer Fraud and Abuse Act”
- Son of a computer security expert at NSA
- Robert Morris became tenured professor at MIT in 2006

Computer Defeats Master Chess Players

- 1989—IBM Computer “Deep Thought” defeated David Levy
- 1996—IBM “Deep Blue” defeated Garry Kasparov*; 4 to 2 games
- 1997–rematch, computer wins again 3.5 to 2.5 games

* Reigning world champion and Grand Master

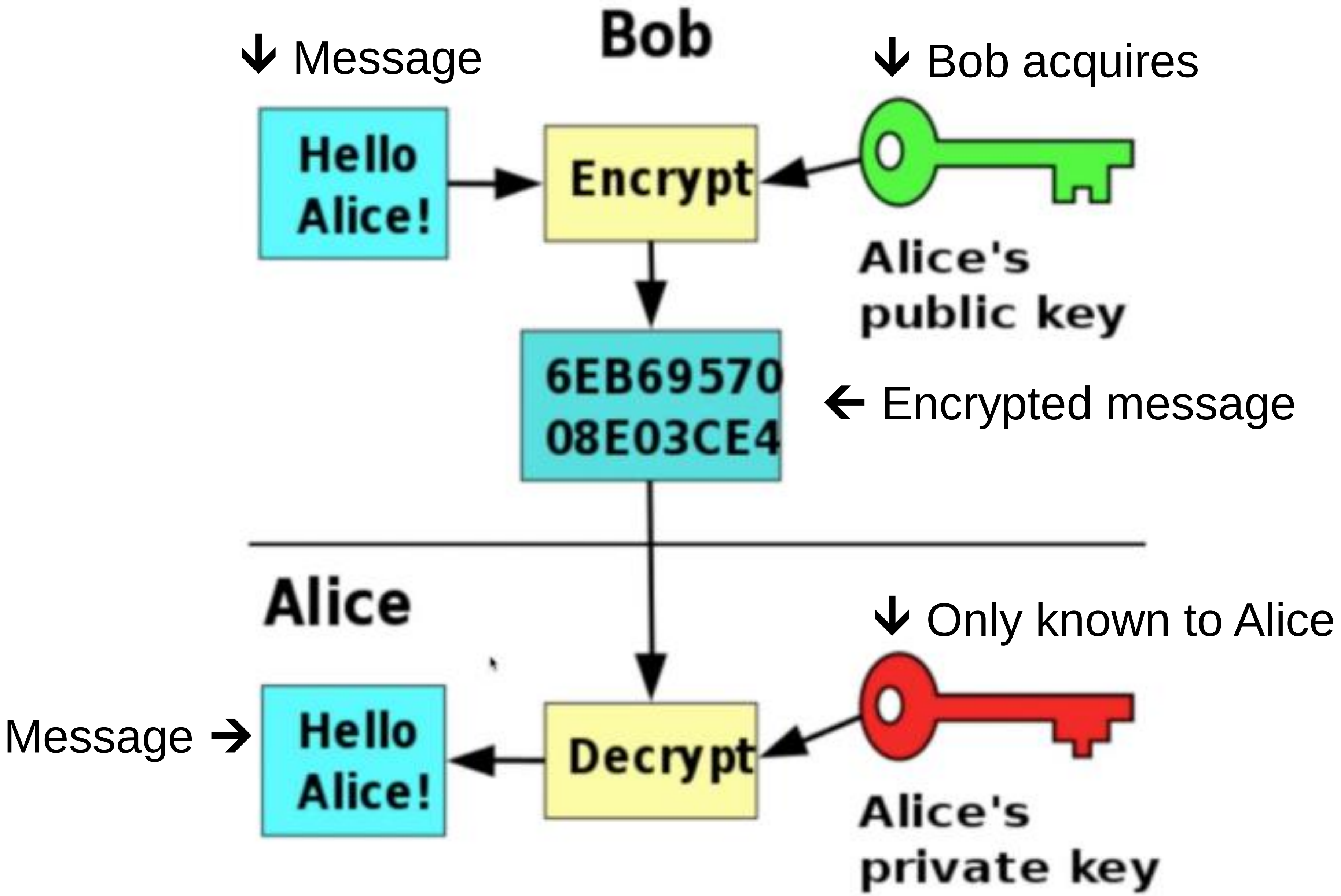
1990s

PGP Software

- 1991—PGP* encryption software created by Phil Zimmermann
  – uses an exchange of public and private keys
- Used for encryption of e-mail, files, directories, disk partitions, etc.
- 1993—U.S. government started a criminal investigation; dropped case in 1996
- 2002—PGP, Inc. formed
- 2010—Symantec acquired PGP, Inc.

* **P**retty **G**ood **P**rivacy

Encrypted Communications



Google

Larry Page (left) and Sergey Brin in garage in Menlo Park
(Garage belonged to Susan Wojcicki, now CEO of YouTube)

Google

- 1998—Google, Inc. founded
- 1998—had an index of ~ 60 million Web pages
  - crawling the Web, indexing & ranking
- 1998—widely recognized as best search engine
- Unofficial Google moto “Don’t be evil”
- 2000—started selling ads based on:
  - price bid
  - click-throughs (average $1 to $2/click)
- 2004—Google went public

Google (cont.)

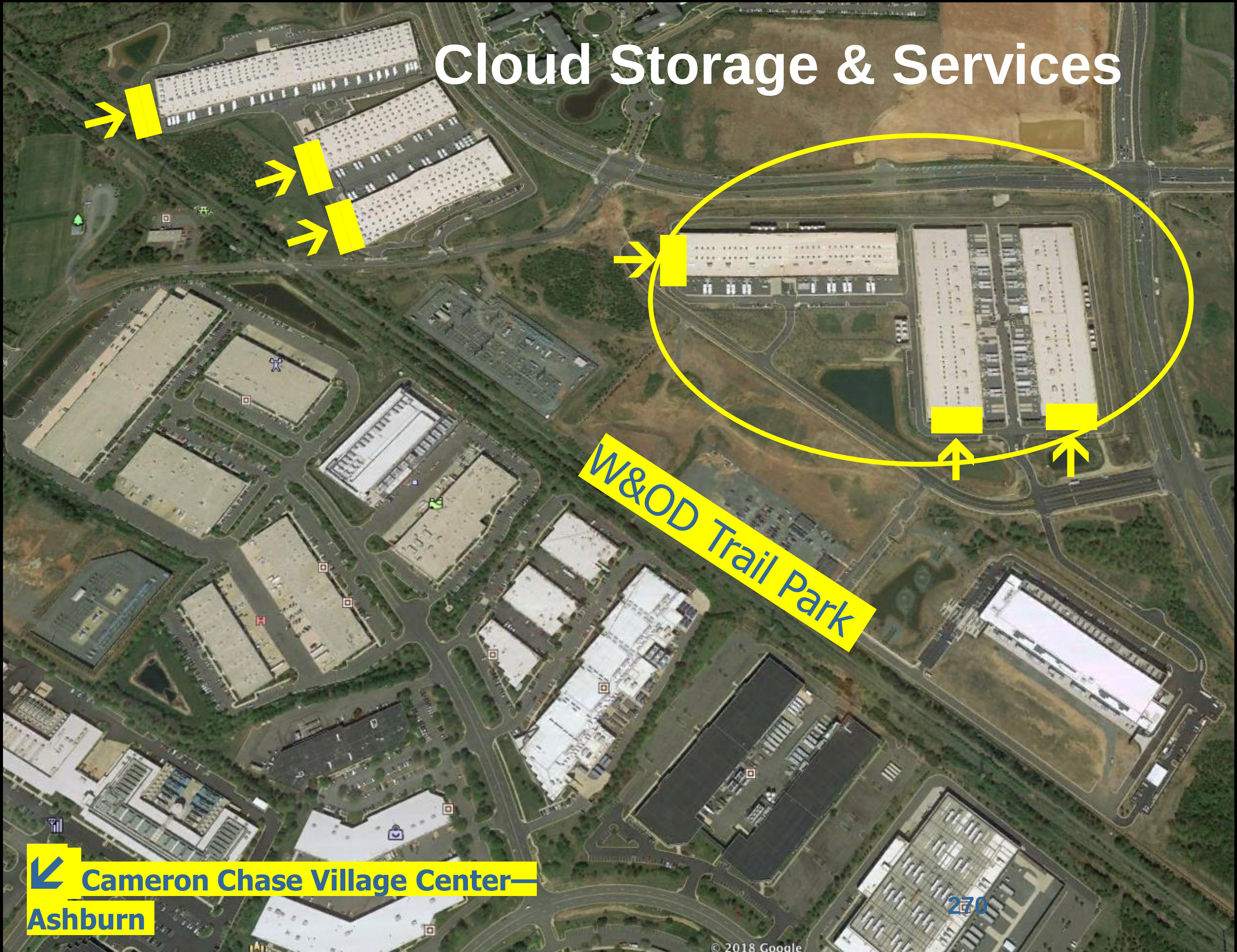
- 2015—reorganized as Alphabet, a holding company
- 70 offices in 50 countries (?)
- 2019—market capitalization (Alphabet, Inc.) $835 billion

Amazon

- 1994—established, selling books online
  - software, video games, apparel, jewelry, etc.
- 2005—**Web Services started (Cloud storage)**
- 2007—Amazon Fresh
- 2007—Amazon Kindle
- 2010—**Sales of Kindle books > hardcopies**
- 2014—Amazon Echo
- 2015—Amazon Restaurants
- 2017—Whole Foods acquired
- 2019—market capitalization $904 billion

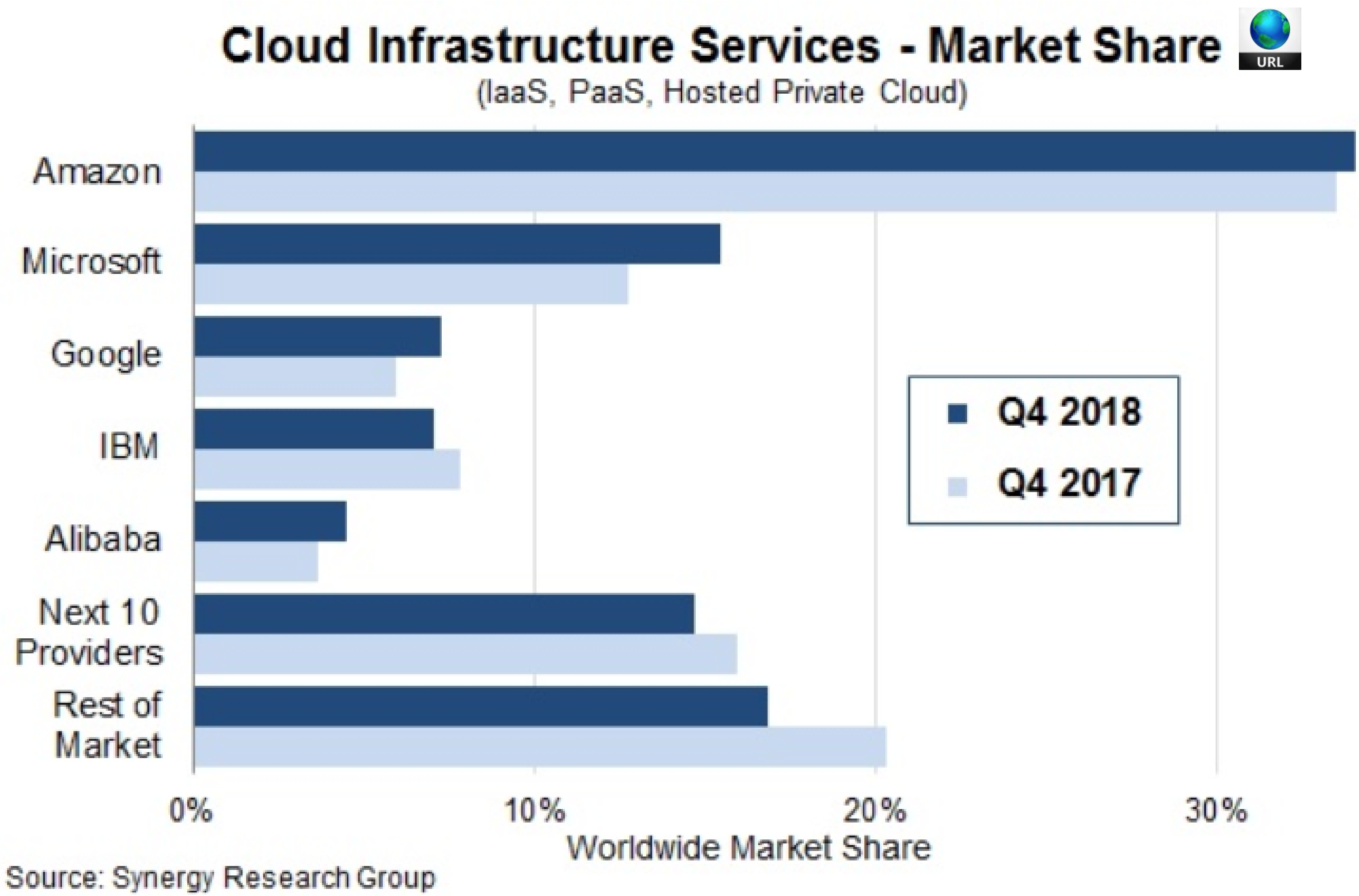
Cloud Storage and Services

Your backup isn't here


Cloud Storage & Services
W&OD Trail Park
Cameron Chase Village Center—
Ashburn
© 2018 Google


624 ft
185 ft
210 ft

Cloud Storage & Services



Linus Torvalds

(1969-)

Linux

- 1991—Torvalds released the Linux kernel*
- 1992—Kernel became open source
- Kernel included in all Linux distributions (“distros”), i.e., Debian, Fedora, Ubuntu…
- Used in <2% of desktop computers
- Linux leading OS in servers & supercomputers
- Used in TVs, routers, cars… and lots of IoT

* Kernel—lowest level of software that interfaces hardware with applications

- 324 million lines of code (2009)
- 1000s developers
- $8-$19 billion to develop by conventional means

debian

The Dark Web*

- 1990s—created by U.S. government to exchange information anonymously
  - known as the TOR project
  - accessed using the Tor Browser
- Widely distributed systems
- Uses:
  - Secret/anonymous communications
  - Sale of drugs, arms, prostitution, etc.
  - Used by criminal groups

* Not to be confused with the "Deep Web"

Silk Road

- 2011—Launched by Ross Ulbricht, aka "Dread Pirate Roberts"
- First (?) "darknet" black market, selling:
  - drugs
  - arms
  - forged documents
  - murder-for-hire (?)
- 2013—shut down by FBI
- 2015—Ulbricht convicted of numerous crimes and sentenced to life plus 40 years without parole

WiFi

CALLING

WiFi

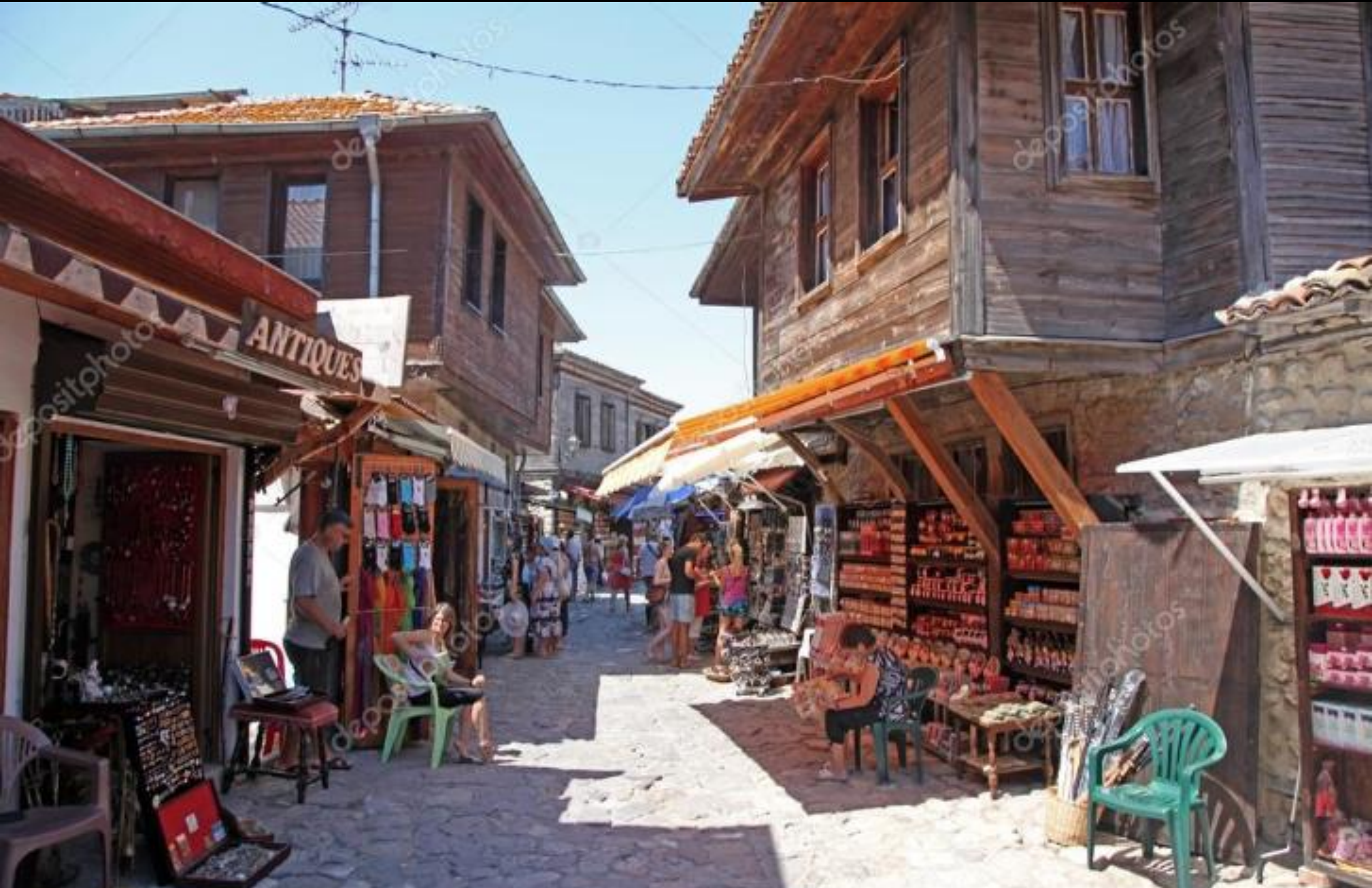
- Introduced in 1997
- 2.4 GHz, frequency…
  - multiple channels
  - range 150 feet indoors
  - range 300 feet outdoors
- 5 GHz frequency…
  - multiple channels
  - ~⅓ the range of 2.4 GHz but higher speed
- 7 frequencies each with multiple channels
- A tortured history of numerous lawsuits between patent holders

WiFi Standards

WiFi Standard	Networks
WiFi 1	802.11b
WiFi 2	802.11a
WiFi 3	802.11g
WiFi 4	802.11n
WiFi 5	802.11ac

WiFi 6 (802.11ax) coming 3rd Q 2019

Nessebar, Bulgaria




FREE
WiFE
ZONE

Harald Gormsson

King of Denmark 940-981

←Harald "Bluetooth" Gormsson
Liked to snack on blueberries

Bluetooth

- 1994—invented by Jaap Haartsen
  - released 1998
- Peer-to-peer communication technology
- Range…
  - Initally: <33 feet
  - Bluetooth 5.0: 100 to 1,000 feet
- Installed in billions of devices each year

2000s

WEEKLY WORLD NEWS

THE COMPUTER CRASH OF THE MILLENNIUM!

JANUARY 1, 2000

THE DAY THE EARTH WILL STAND

ALL BANKS WILL FAIL!

FOOD SUPPLIES WILL BE DEPLETED!

ELECTRICITY WILL BE CUT OFF!

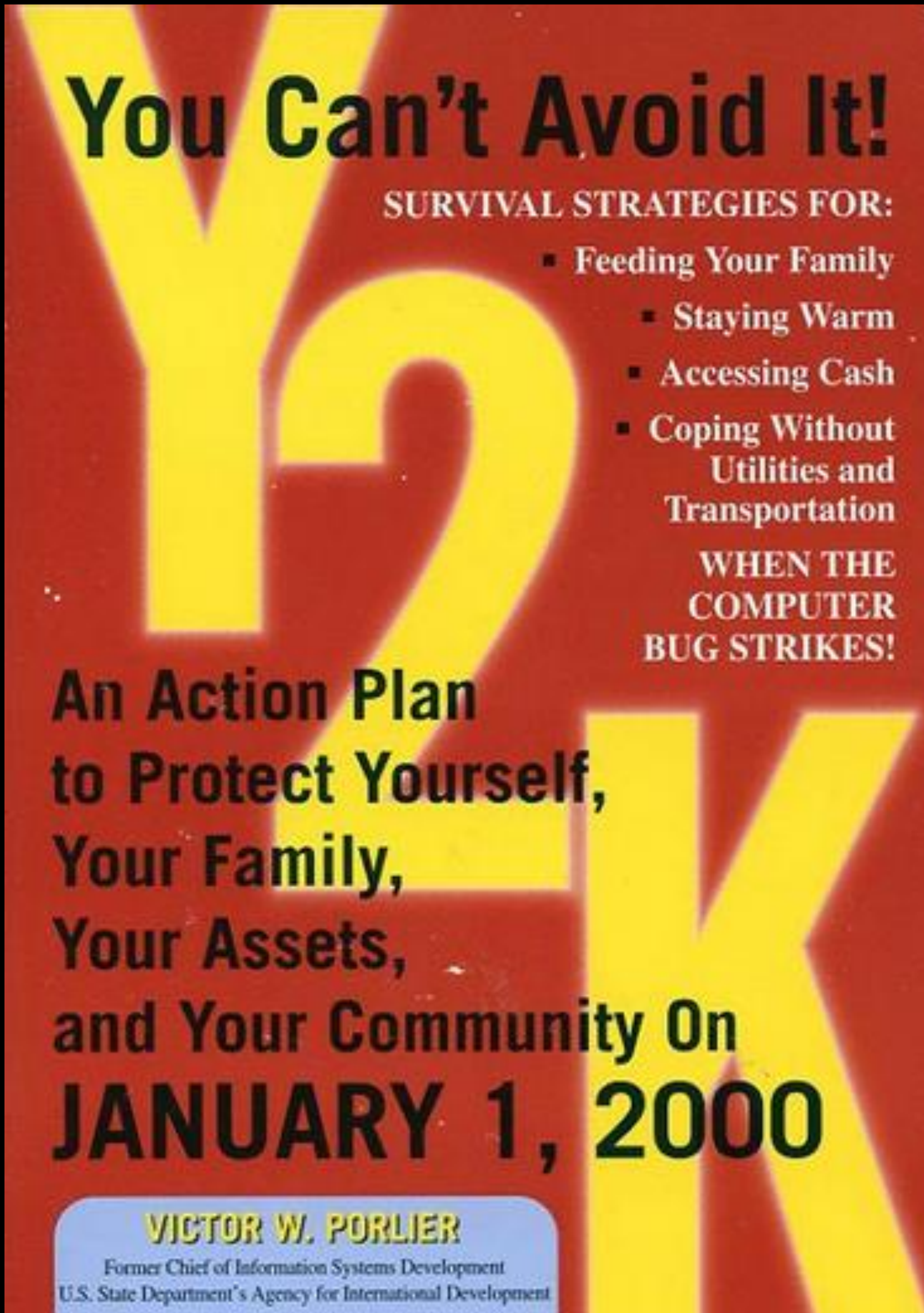
THE STOCK MARKET WILL CRASH!

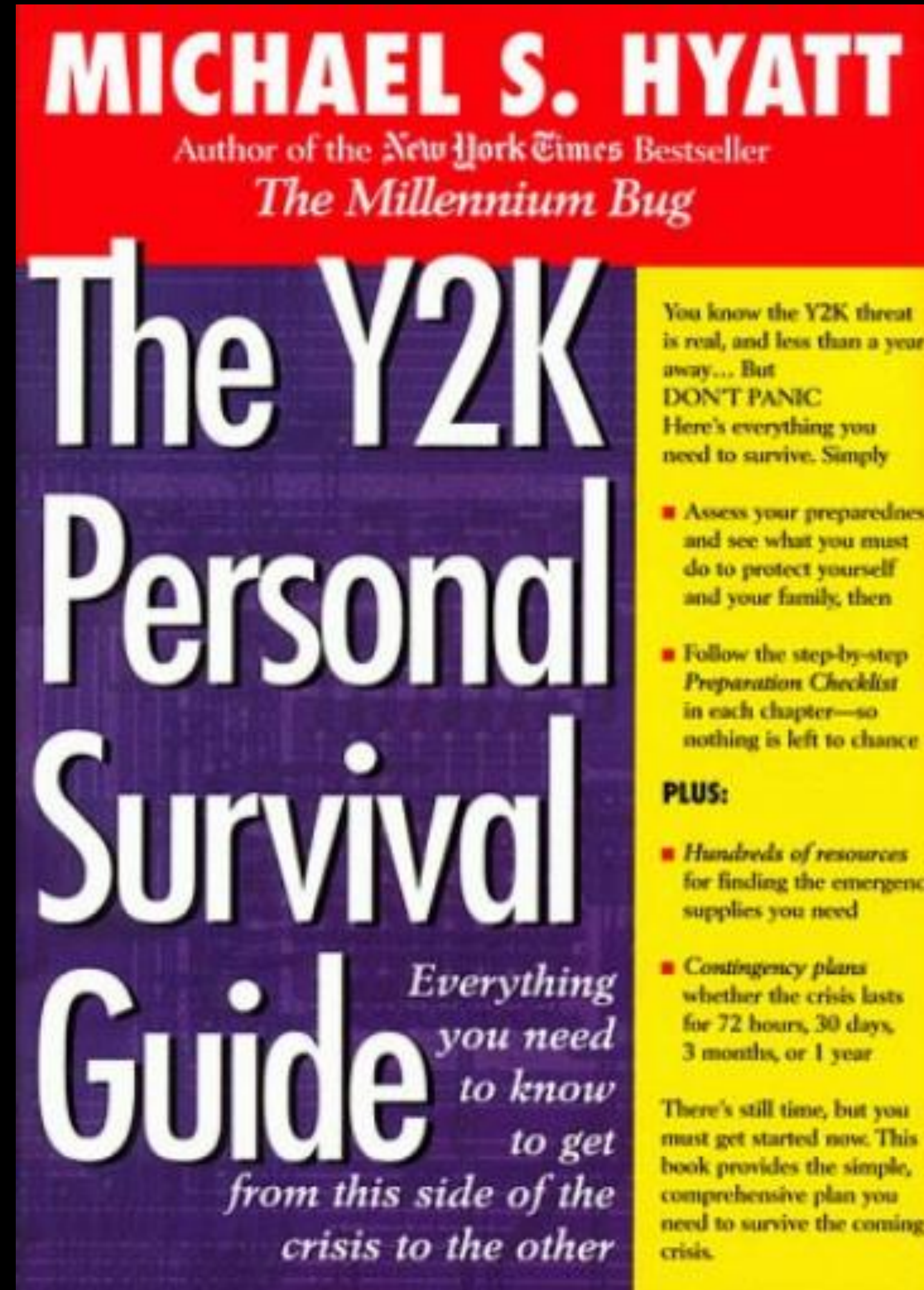
VEHICLES USING COMPUTER CHIPS WILL STOP DEAD!

TELEPHONES WILL CEASE TO FUNCTION!

DOMINO EFFECT WILL CAUSE

Year 2000 Fiasco


You Can't Avoid It!
SURVIVAL STRATEGIES FOR:
▪ Feeding Your Family
▪ Staying Warm
▪ Accessing Cash
▪ Coping Without Utilities and Transportation
WHEN THE COMPUTER BUG STRIKES!
Y2K
An Action Plan to Protect Yourself, Your Family, Your Assets, and Your Community On JANUARY 1, 2000
VICTOR W. PORLIER
Former Chief of Information Systems Development
U.S. State Department's Agency for International Development


MICHAEL S. HYATT
Author of the New York Times Bestseller
The Millennium Bug
The Y2K Personal Survival Guide
Everything you need to know to get from this side of the crisis to the other
You know the Y2K threat is real, and less than a year away… But DON'T PANIC
Here's everything you need to survive. Simply
▪ Assess your preparednes and see what you must do to protect yourself and your family, then
▪ Follow the step-by-step Preparation Checklist in each chapter—so nothing is left to chance
PLUS:
▪ Hundreds of resources for finding the emergenc supplies you need
▪ Contingency plans whether the crisis lasts for 72 hours, 30 days, 3 months, or 1 year
There's still time, but you must get started now. This book provides the simple, comprehensive plan you need to survive the coming crisis.


BIENVENUE A
L'ECOLE CENTRALE
DE NANTES
12 HEURES 09
3 JANVIER 1900

Y2K Problem

- Dates stored in 2 bytes (string variable): “60” for 1960, “99" for 1999
  - ✓ 99 – 60 = 39 (no problem)
- When year 2000 arrived “00”…
  - ✓ 00 – 60 = – 60 (**a problem**)
- If dates had been stored as 2 byte integers, dates up to 65,536 (2^{16}) could have been accommodated
  - ✓ $2000_{int} - 1960_{int} = 40$ (no problem)

The 2038 Problem

On Tuesday, January 19, 2038 [at 03:14:07 (UTC)]

Some computers' time will revert to…

Friday, December 13, 1901 [at 20:45:52 (UTC)]

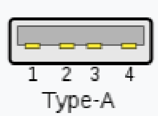
Worry-warts enjoy the angst!

2000 (?)—“First” Thumb Drive (IBM)*

* “First” to mass market in the U.S.

Thumb Drives

- 2000—sold by IBM, 8 MB capacity
- Capacity today: 4 GB to 1 TB
- Longevity: 3,000 to 100,000 writes

Connectors	USB 1.0 1996	USB 2.0 2001	USB 2.0 Revised	USB 3.0 2011	USB 3.1 & 3.2 2014 & 2017
Data rate	187.5 kB/s (*Low Speed*)	60 MB/s	60 MB/s	625 MB/s (*SuperSpeed*)	1.25 GB/s
	1.5 MB/s (*Full Speed*)				2.5 GB/s (*SuperSpeed+*)
	Type A 			Type A 	

Unusual Thumb Drives

2000—Sony's Playstation 2

Playstation 2

- Priced at $299 ($441 today)
- Best selling home game console of all time; 155 million units sold
- ~4,000 games available; 1.5 billion copies sold
- Production ceased in 2013
- Current model Playstation 4 ($300-$400)

WIKIPEDIA

The Free Encyclopedia

Wikipedia

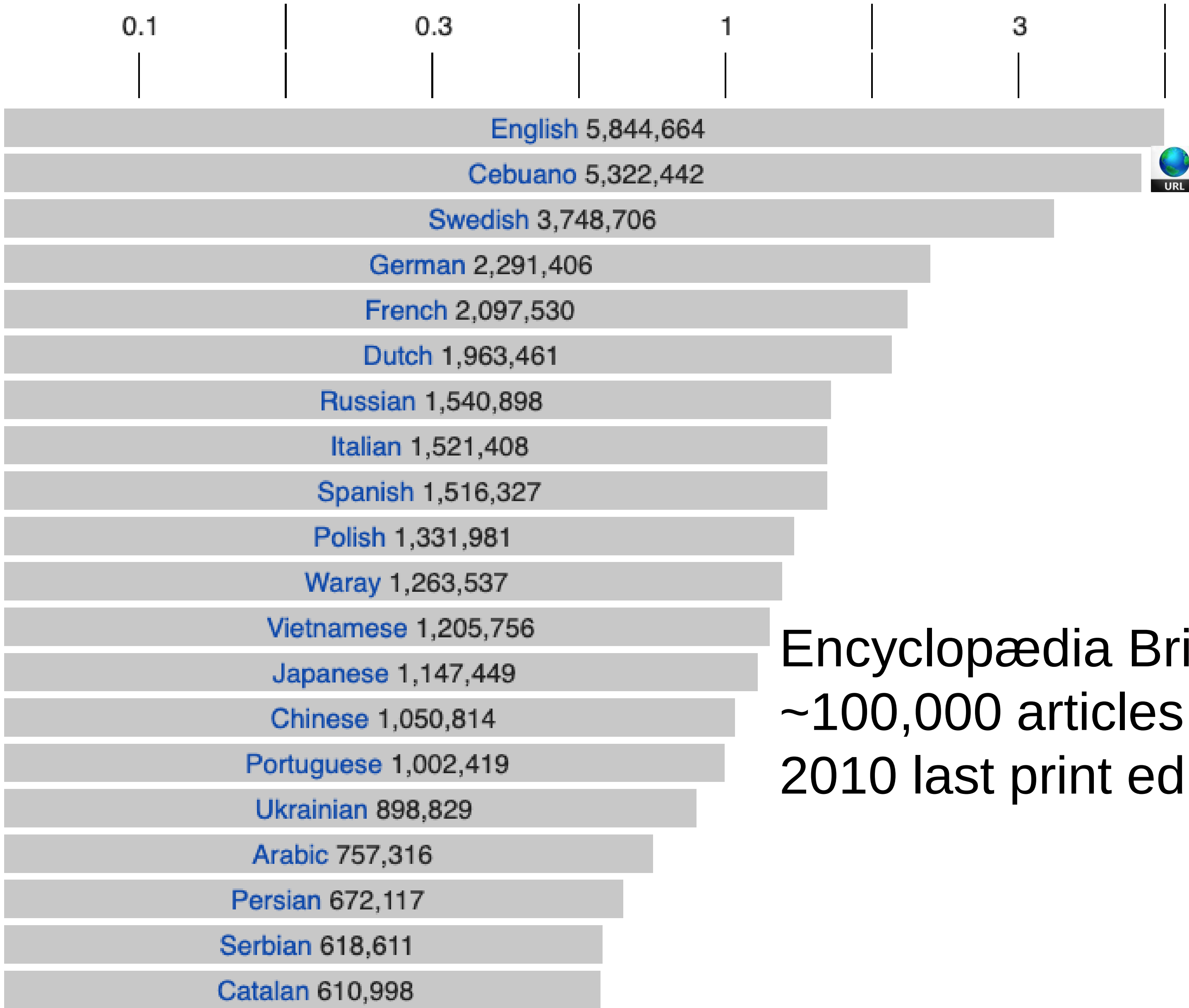
- Created by Jimmy Wales & Larry Sanger
  - – released January 15, 2001
- Owned by the Wikimedia Foundation*
- Funded by donations
- Many millions of articles in 301 languages
- Articles community posted and edited
- Criticisms—read all about it in Wikipedia
  - – and other sources

* A not-for-profit organization in San Francisco

Logarithmic graph of the 20 largest language editions of Wikipedia

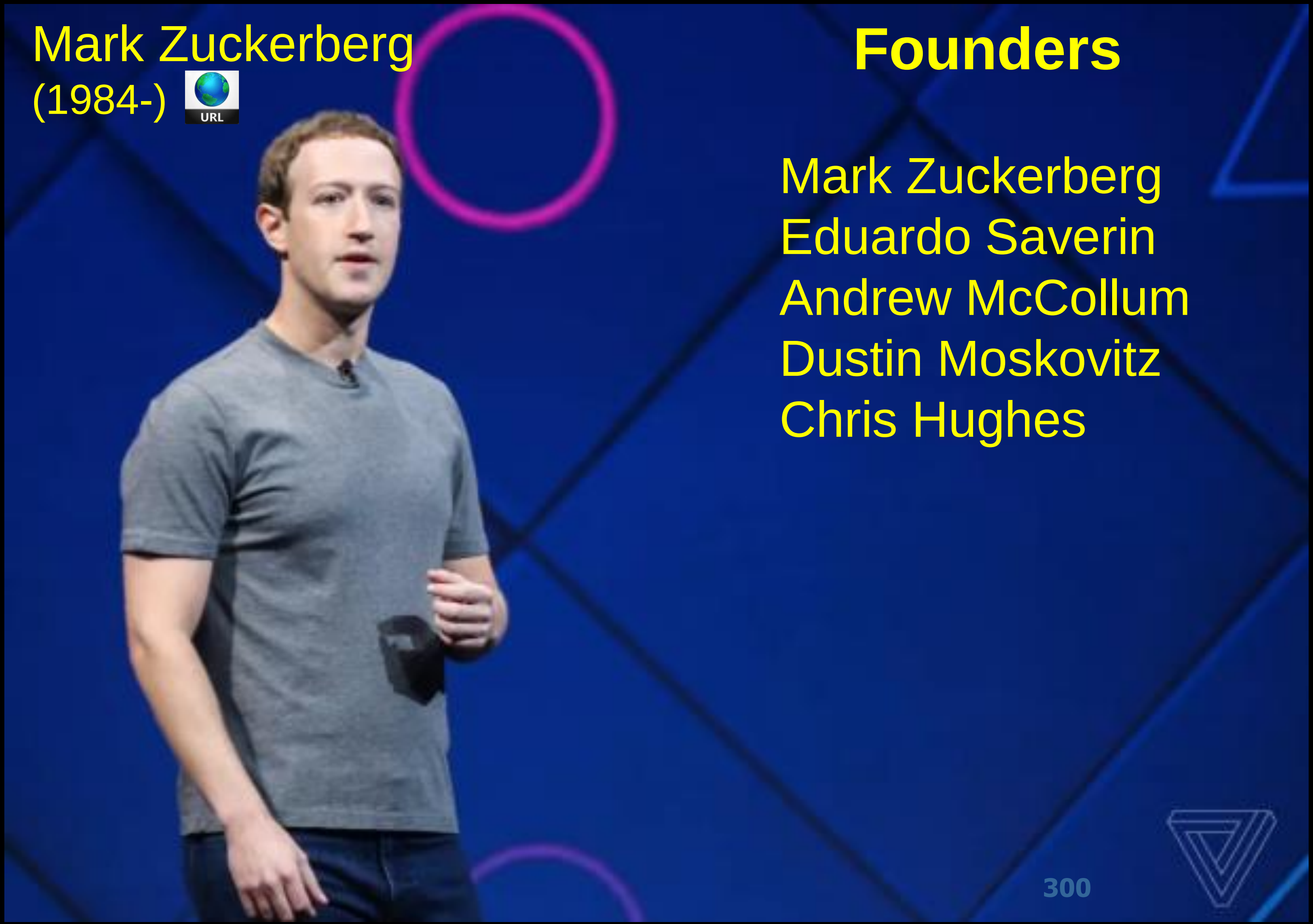
(as of 18 April 2019)[132]

(millions of articles)



Encyclopædia Britannica
~100,000 articles (online)
2010 last print edition

Facebook



Mark Zuckerberg
(1984-)

Founders

Mark Zuckerberg
Eduardo Saverin
Andrew McCollum
Dustin Moskovitz
Chris Hughes

Facebook

- 2004—established at Harvard University as online student directory with pictures
- 2004—most universities in U.S. & Canada
- 2004—numerous lawsuits (settled in 2008)
- 2006—open to anyone at least 13 years old
- Evolved into a broad social network service
- 2012—IPO, largest initial valuation to date in 2012 ($104 billion)
- 2018—2.2 billion active monthly users
- 2019—market capitalization $543 billion

Facebook

- Controversies:
  - Privacy
  - Censorship
  - Objectionable content
  - Adverse psychological effects on young users
  - Inadequate computer security
    - ✓100s of millions passwords stored as plain text
    - ✓September 2019—millions of customers private data stolen

2005 DARPA Grand Challenge

Defense **A**dvanced **R**esearch **P**rojects **A**gency

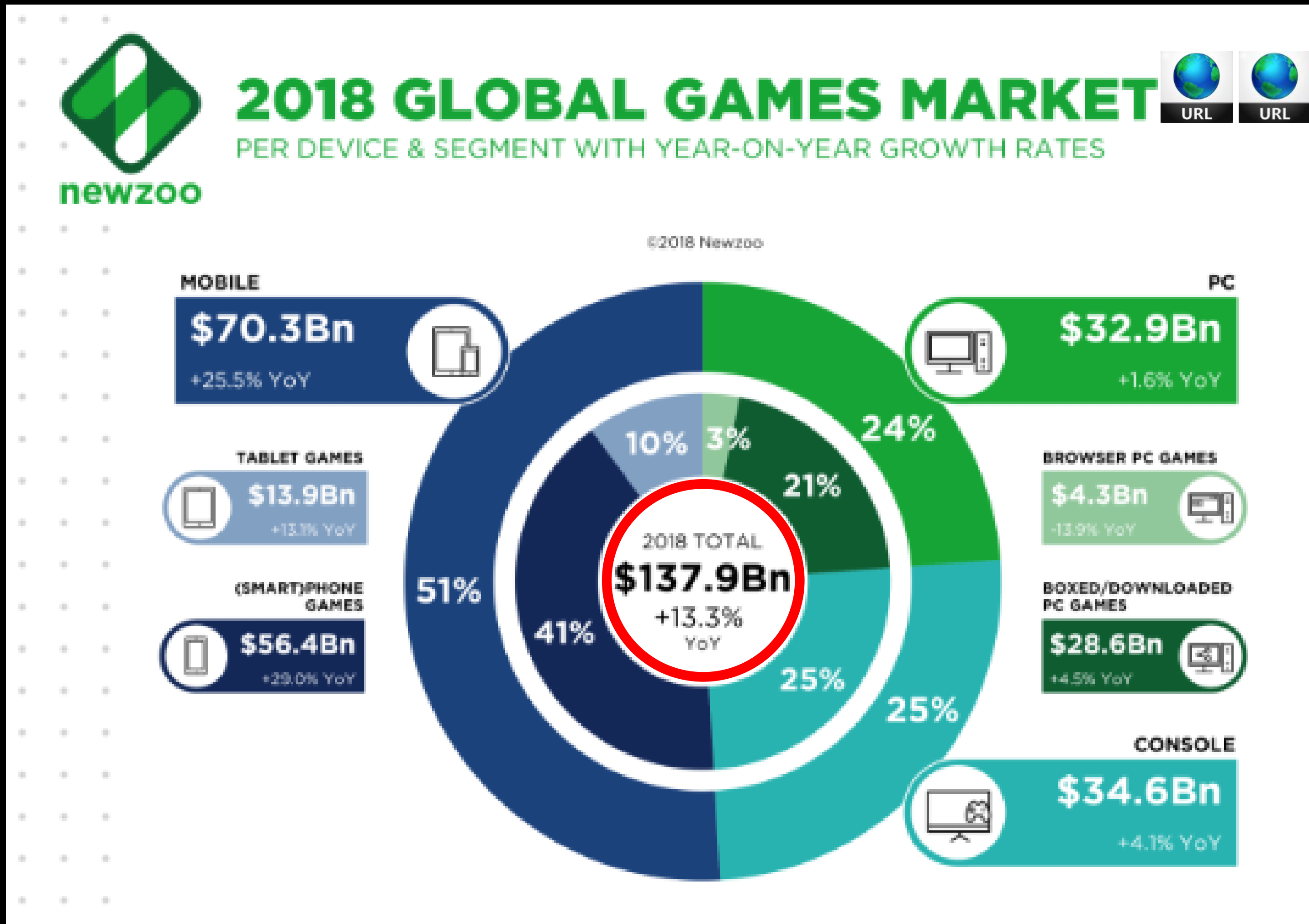
DARPA Grand Challenge

- Driverless car competition (2005)
- 113 miles alongside of Interstate 15, Barstow, California to Primm, Nevada
- 23 vehicles in the race—5 completed course
- Winning car “Stanley” in 6 hr, 54 min (16 mph)
  - Stanford University
  - VW Electronics Research Laboratory
- $2 million prize

2006—Nintendo Wii

Nintendo Wii

- 2006—7th generation released, price: $249.99 (today $316)
- 2006—first quarter 101 million units sold **($31.9 billion** revenue today's money)
- 2013—product discontinued
- Current product Nintendo Switch (~$300)
- 2019—Nintendo still very active
  - founded 1889 (playing cards)
  - about 6,000 employees



Global movie industry (2018) $41.1 billion URL

Bitcoin

Established January 9, 2009

Bitcoin*

- Created by Satoshi Nakamoto (a pseudonym)
- A **traceless**, electronic cash payment system
  - distributed on many computers
  - a public ledger recording who owns each unit of available Bitcoin (blockchain technology)
  - money transfer: debit one owner and credit another owner
- Owners are registered as an alias string of characters (public address)
- Proof of ID/ownership accomplished by public/private key cryptography

* aka a cryptocurrency

Bitcoin (cont.)

- Potential maximum of 21 million Bitcoins in existence (think world's gold supply)
- Increasing the Bitcoin supply is complex and unlikely to occur in the foreseeable future
- 4.3 million Bitcoins remain to be identified
- Bitcoin identification is called "mining"
- There are rules limiting the number of Bitcoins that can be annually "mined"

Bitcoin Mining

- Successful identification accrues a Bitcoin reward
- Mining requires:
  - considerable computer resources
  - large quantities of electricity consumed for computing and cooling
    - ✓world-wide electricity consumption for mining equal to 1.1% of U.S. annual electricity production
    - ✓~50 TWh (50 billion kWh)
    - ✓at a cost of $6.25 billion

Bitcoin Criticisms

- High electricity consumption from mining
- Illegal transactions by criminals
- Price volatility of Bitcoin
- Considerable speculation
- Thefts from exchanges*
- Threat of an economic bubble

*** CNN reported May 8, 2019 that hackers had stolen $40 million worth of Bitcoin**

Value of Bitcoin in U.S. Dollars

(April 2017 to April 2019)

California Gold Rush of 1849

Bitcoin Rush of 2017-18

An Unintended Consequence

GPU—Nvidia GeForce GTX 1070

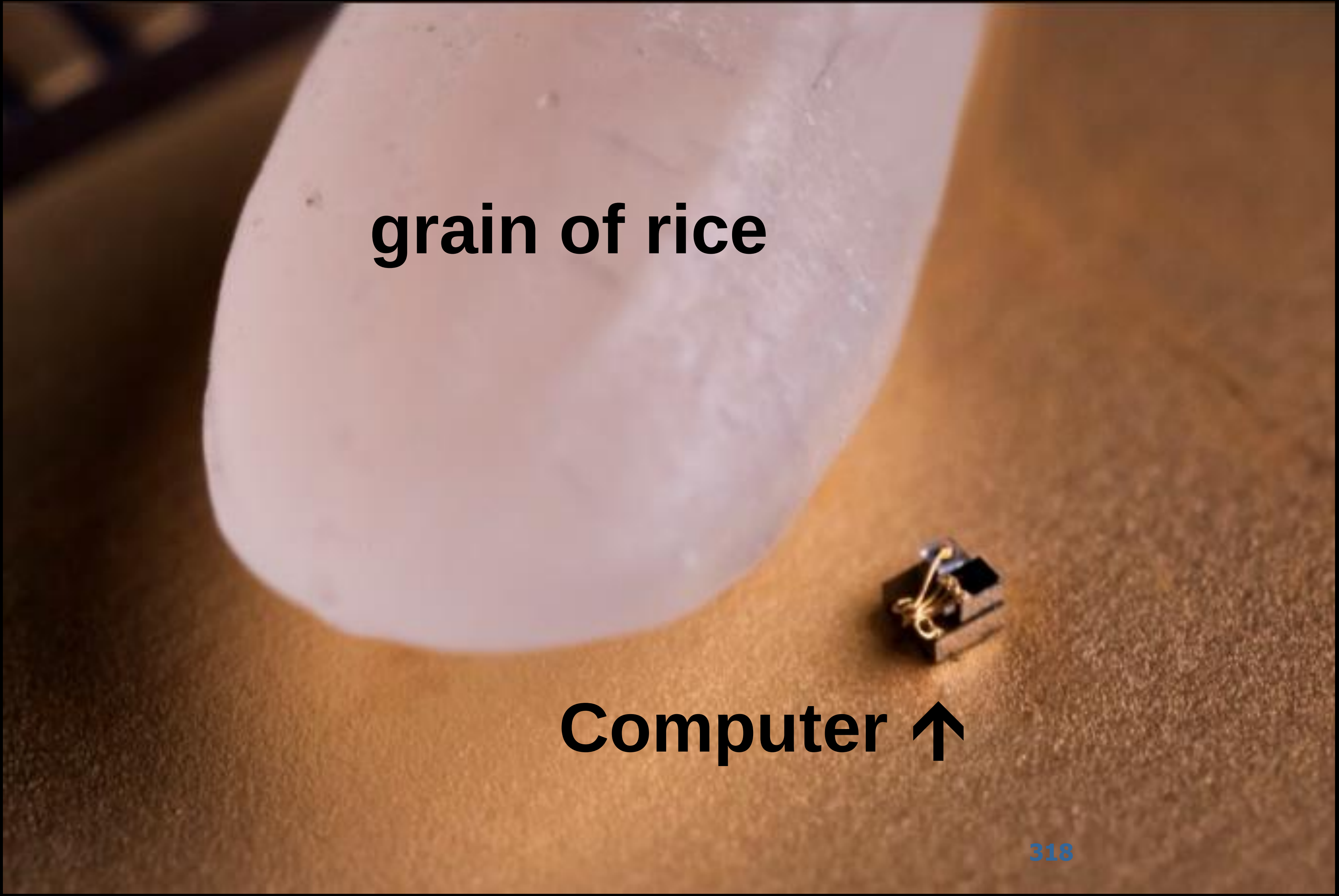
January 2018
MSRP $380

2018 Price $700
Current Price $279

Bitcoin miners caused worldwide shortage of GPUs

2010s

World's Smallest Computer



The Michigan Micro Mote

- Created at the University of Michigan in 2015
- 0.3 mm on a side
- All data and programs lost when turned off
- CPU—Phoenix processor
- RAM (amount?)
- Solar cells
- Wireless transmitter

Some Gloomy Stuff…

The Stuxnet Worm

- Some uncertainty “whodunit”
- Probably created and released by U.S. and Israel governments
- 2010—discovered by Sergey Ulasen at Kaspersky Labs in Moscow
- Worm targeted Siemens industrial control systems used in uranium enrichment processes
- Probably destroyed ~1000 centrifuges used to enrich U^{235} in UF_6

The Stuxnet Worm

Uranium enrichment facilities, Natanz, Iran

Heartbleed Attack

Heartbleed Attack

- Discovered in 2014
- Operates against protocols used to communicate between servers
  - – one part of which is called “Heartbeat”
- The malware allowed usernames and passwords, e-mails, documents and other sensitive information to be compromised
- ~ 500,000 Web servers affected


SONY
PICTURES
HACKED

The Sony Hack

- Discovered November 24, 2014
  - – duration unknown, at least two months
- Attacker “Guardians of Peace”, probably North Korean government
- In retaliation against the anti-North Korean movie “The Interview” (a comedy)

The Sony Hack (cont.)

- About 100 TB of data stolen
  - E-mails
  - Salary of executives
  - Financial information
  - Social Security numbers
  - Medical information
  - **Celebrity gossip**
  - Several unreleased movies
- 2015—about 30,000 documents released to Wikileaks

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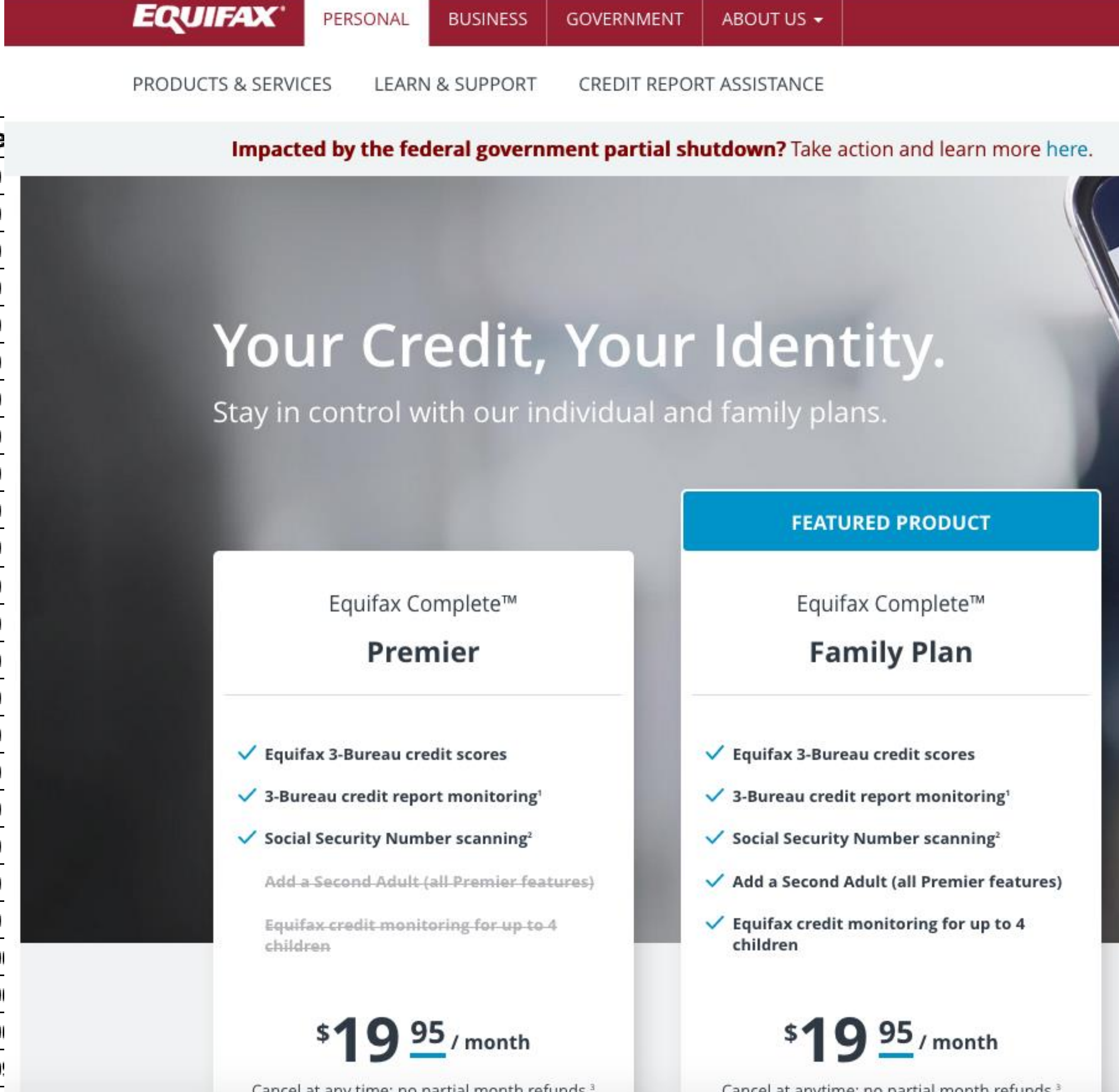



EXTRA! EXTRA!
READ ALL ABOUT IT!
GOOD NEWS!!

Supercomputers

One more slide

Year	Supercomputer	Peak speed (Rmax)	Location
1993	Fujitsu Numerical Wind Tunnel	124.50 GFLOPS	← 124.5×10^9 — 124 billion/sec
1993	Intel Paragon XP/S 140	143.40 GFLOPS	DoE-Sandia National Laboratories, New Mexico, USA
1994	Fujitsu Numerical Wind Tunnel	170.40 GFLOPS	National Aerospace Laboratory, Tokyo, Japan
1996	Hitachi SR2201/1024	220.4 GFLOPS	University of Tokyo, Japan
	Hitachi CP-PACS/2048	368.2 GFLOPS	University of Tsukuba, Tsukuba, Japan
1997	Intel ASCI Red/9152	1.338 TFLOPS	DoE-Sandia National Laboratories, New Mexico, USA
1999	Intel ASCI Red/9632	2.3796 TFLOPS	
2000	IBM ASCI White	7.226 TFLOPS	DoE-Lawrence Livermore National Laboratory, California, USA
2002	NEC Earth Simulator	35.86 TFLOPS	Earth Simulator Center, Yokohama, Japan
2004	IBM Blue Gene/L	70.72 TFLOPS	DoE/IBM Rochester, Minnesota, USA
2005		136.8 TFLOPS	DoE/U.S. National Nuclear Security Administration, Lawrence Livermore National Laboratory, California, USA
		280.6 TFLOPS	
2007		478.2 TFLOPS	
2008	IBM Roadrunner	1.026 PFLOPS	DoE-Los Alamos National Laboratory, New Mexico, USA
		1.105 PFLOPS	
2009	Cray Jaguar	1.759 PFLOPS	DoE-Oak Ridge National Laboratory, Tennessee, USA
2010	Tianhe-IA	2.566 PFLOPS	National Supercomputing Center, Tianjin, China
2011	Fujitsu K computer	10.51 PFLOPS	RIKEN, Kobe, Japan
2012	IBM Sequoia	16.32 PFLOPS	Lawrence Livermore National Laboratory, California, USA
2012	Cray Titan	17.59 PFLOPS	Oak Ridge National Laboratory, Tennessee, USA
2013	NUDT Tianhe-2	33.86 PFLOPS	Guangzhou, China
2016	Sunway TaihuLight	93.01 PFLOPS	Wuxi, China
2018	IBM Summit	122.3 PFLOPS	122.3×10^{15} — 122 million billion/sec

Factors Affecting CPU Performance

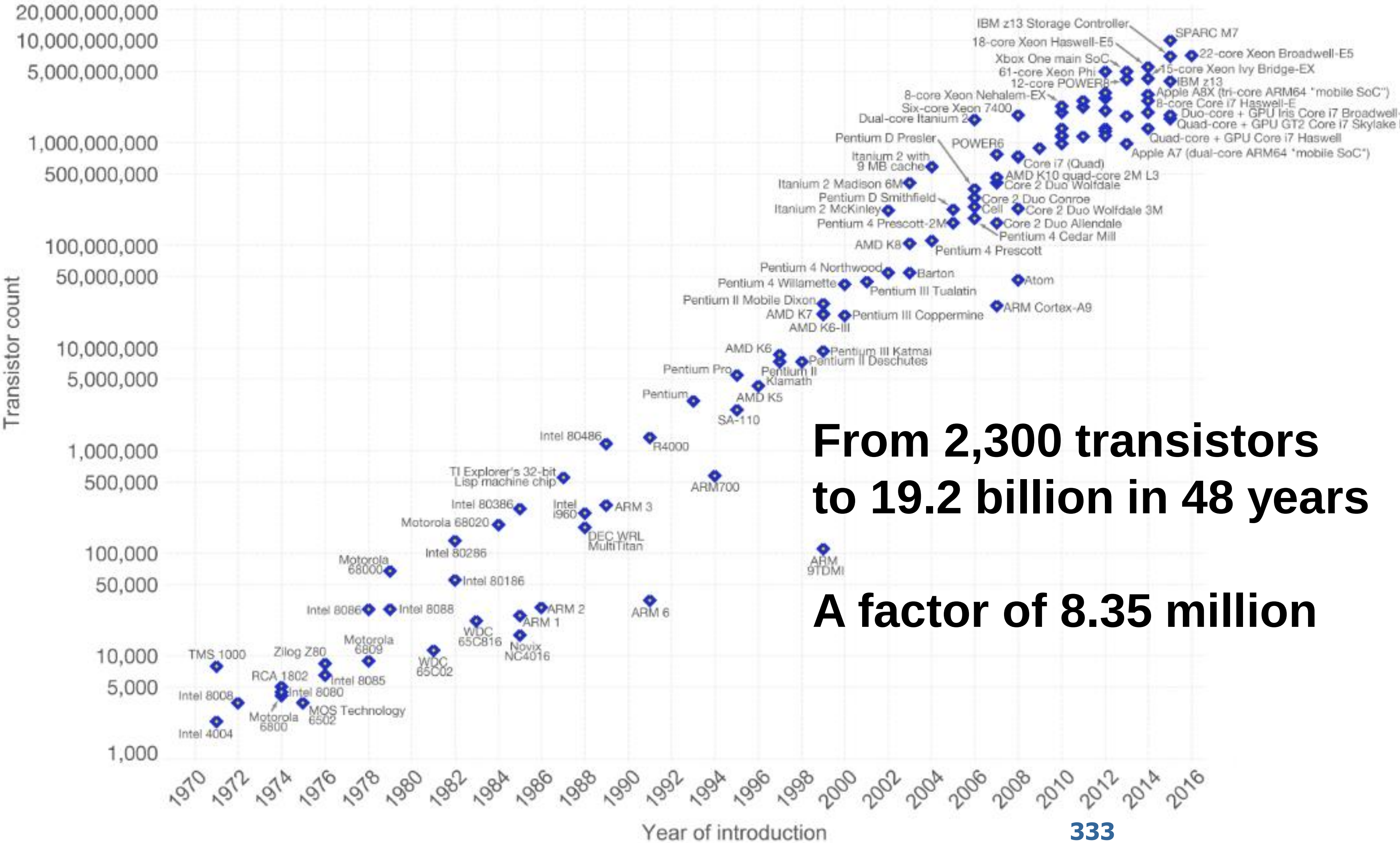
- Clock speed
- Number of transistors
- Cache memory (L1, L2, L3…)
- Number cores
- Lithographic scale*
- Other factors…

* For silicon, at approximately 2 nm, quantum tunneling becomes an issue

Moore's Law – The number of transistors on integrated circuit chips (1971-2016)

Our World in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore's law.



From 2,300 transistors to 19.2 billion in 48 years

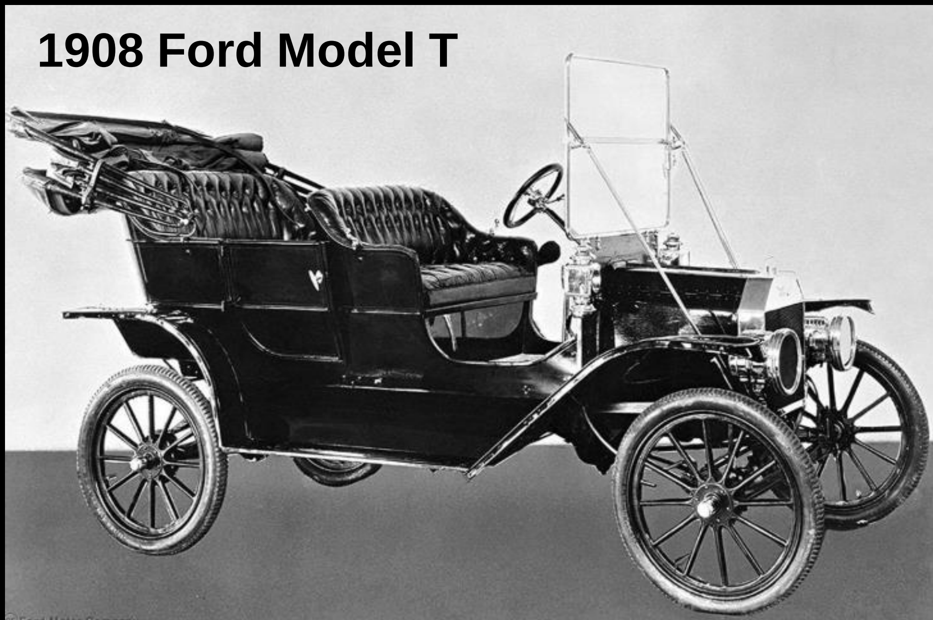
A factor of 8.35 million

Advances in CPUs

CPU Model	Year	Cores	Threads	Clock Speed	Number Transistors	Price
Intel 4004	1971					
Intel Core i9-9900K	2018					

- The Core i9-9900K is an upper-end CPU used in desktop computers
- By-the-way, the AMD Ryzen Epyc has 19.2 billion transistors—largest number on a single CPU chip

Change in Prices of Cars?

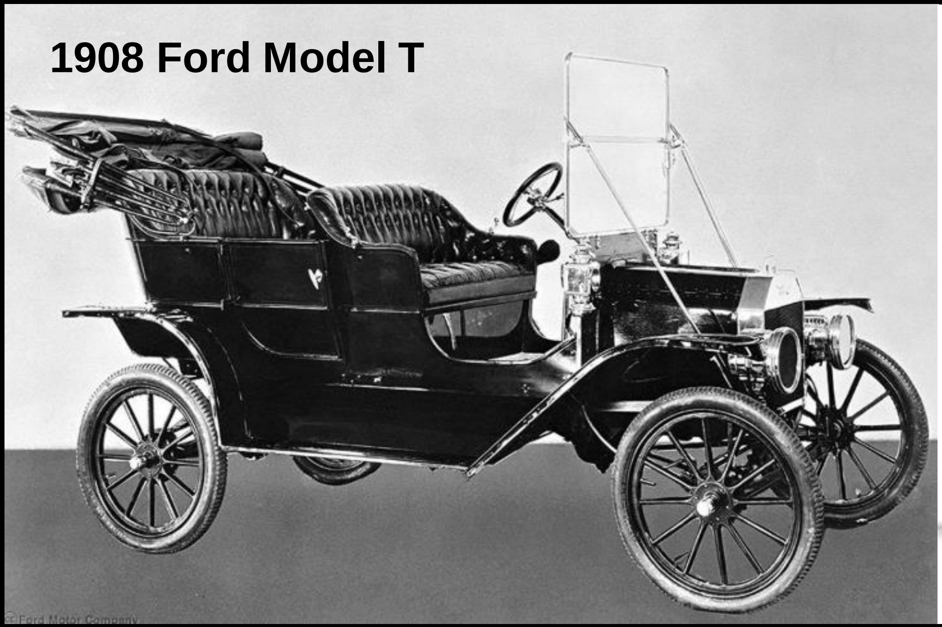


Price $850

Price $22,840

$24,000 in 2019 dollars

Change in Prices of Disk Drives?



2019

Price of Storage in 1979

75 MB hard disk drive

$12,500 (1979)

$43,200 in today's money

4 TB HDD in 2019

$69.95

Price per Terabyte

75 MB HDD in 1979

$576,000,000/TB
in today’s money

4 TB HDD in 2019

$17.50/TB

Imagine

If the price of cars had paralleled the price of disk drives…

If Car Prices Paralleled HDD Prices

Price ~$4,000

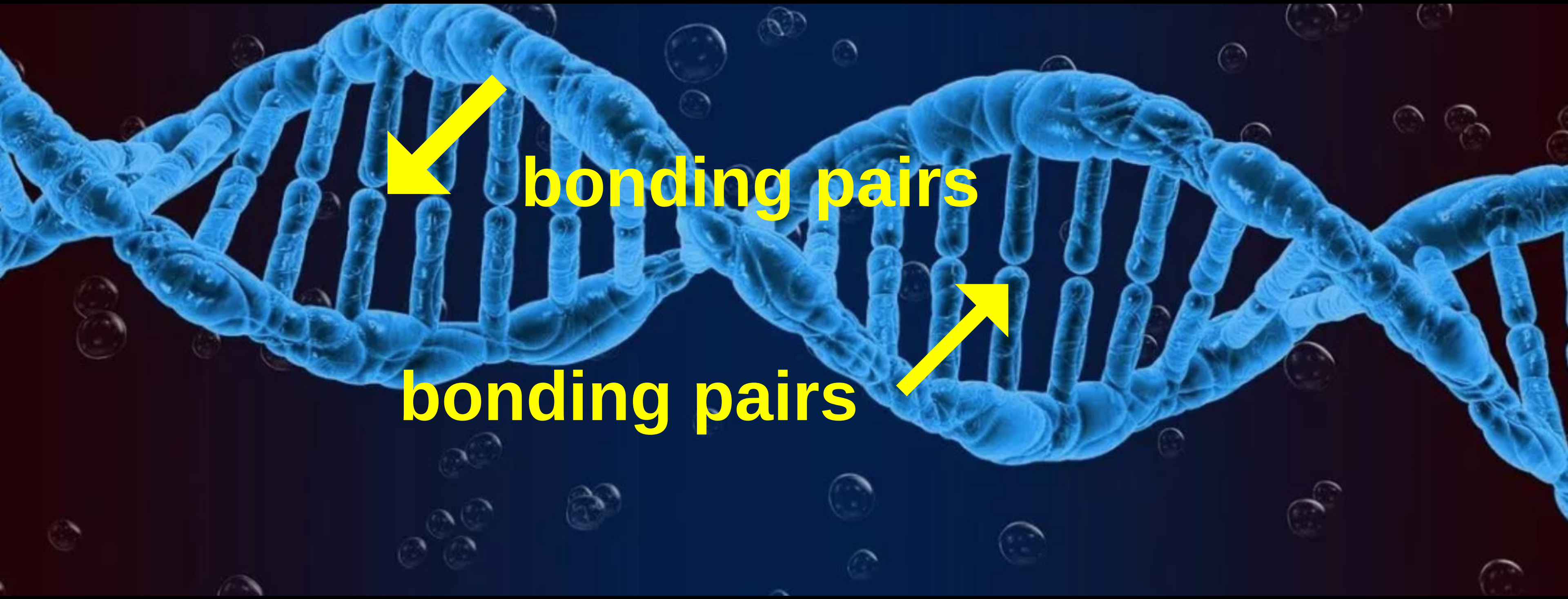
$14,900 in 2019 dollars

$0.000450

2,223 cars/$

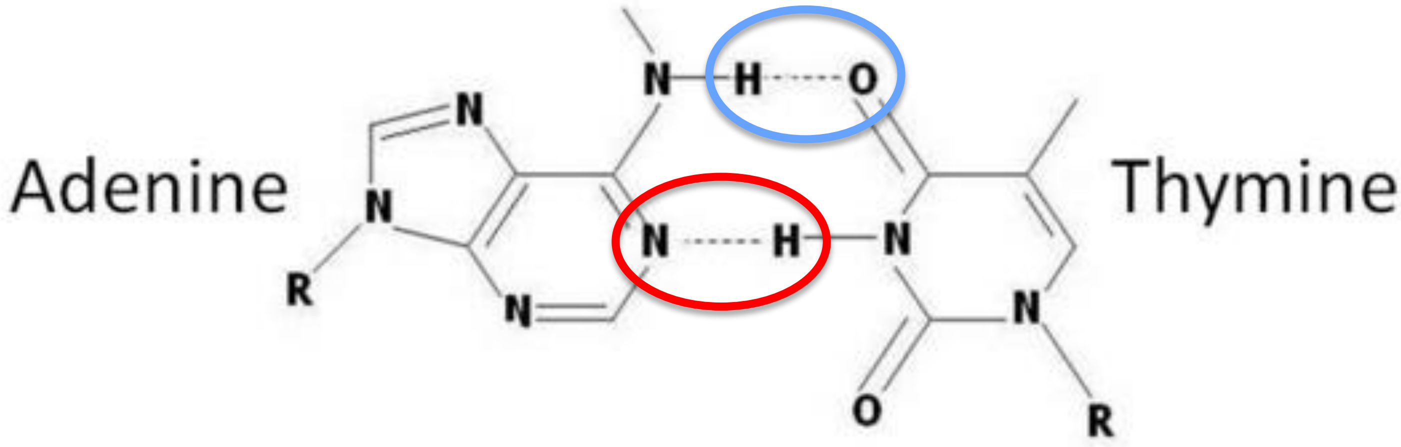
A Peek Into the Future

Be patient—this is relevant to computers!



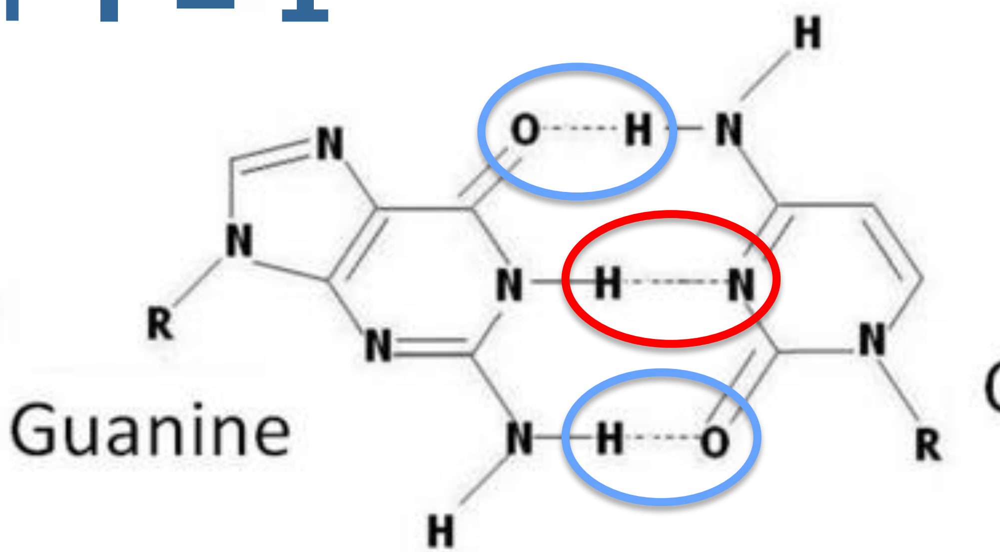
Deoxyribonucleic Acid… aka DNA

DNA Nucleotide Pairing



A + T = 1

Adenine ≠ Cytosine
Guanine ≠ Thymine



Cytosine

G + C = 0

What Has Been Stored in Synthetic DNA?

- The word “hello”
- A movie (22 MB)
- Tolstoy’s *War and Peace*
- A computer operating system
- All of Wikipedia in English (16 GB)
- Various bits and pieces...

Useful Properties of DNA

- Massive storage capacity: ~200,000 TB in 1 gram of DNA
- Durable for thousands of years
- Challenges:
  - Very expensive
  - Slow to encode and decode
- For more information see

Thanks for listening!