DEPARTMENT OF
COMPUTER SCIENCE

THE NEW AGE OF DISCOVERY

M&Ms: Computing Past, Present, and Future

Gregory D. Hager
Professor and Chair

JOHNS HOPKINS
UNIVERSITY
WHITING SCHOOL OF ENGINEERING

The Semester at a Glance

- The Past: How did computing come to be?
- The Present: The way things work
- The Future: What can't computers do now and, if they could, what would change?
- Your investment: Discussion, Quizzes

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How Did Computing Come to Be? The People

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Questions

- What is computing?
- Why do we need it?
- Who invented computing?
- Are the limits to what can be computed?

Why Compute?

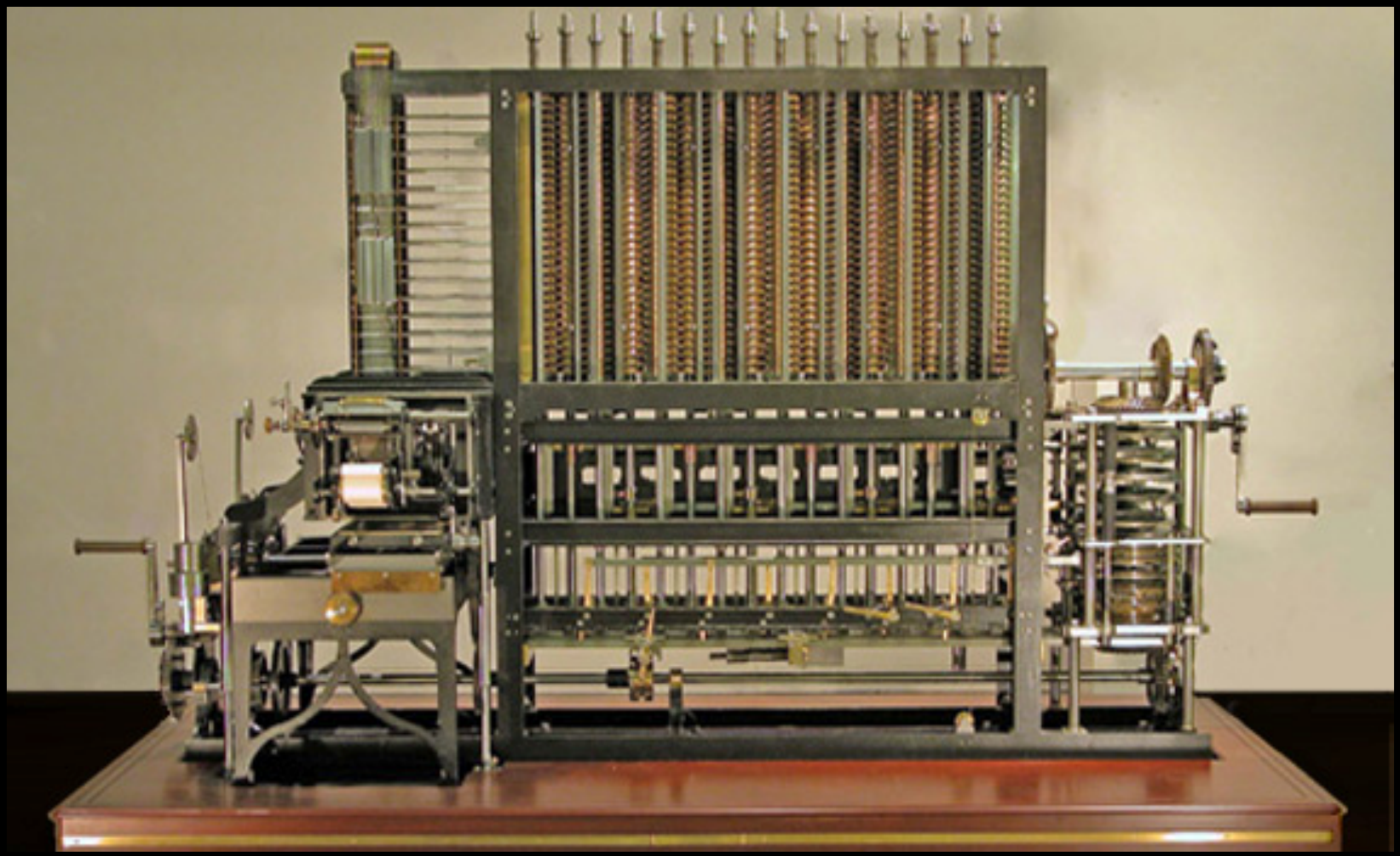
Halley's Comet

Can you predict where a ballistic object will go over time?

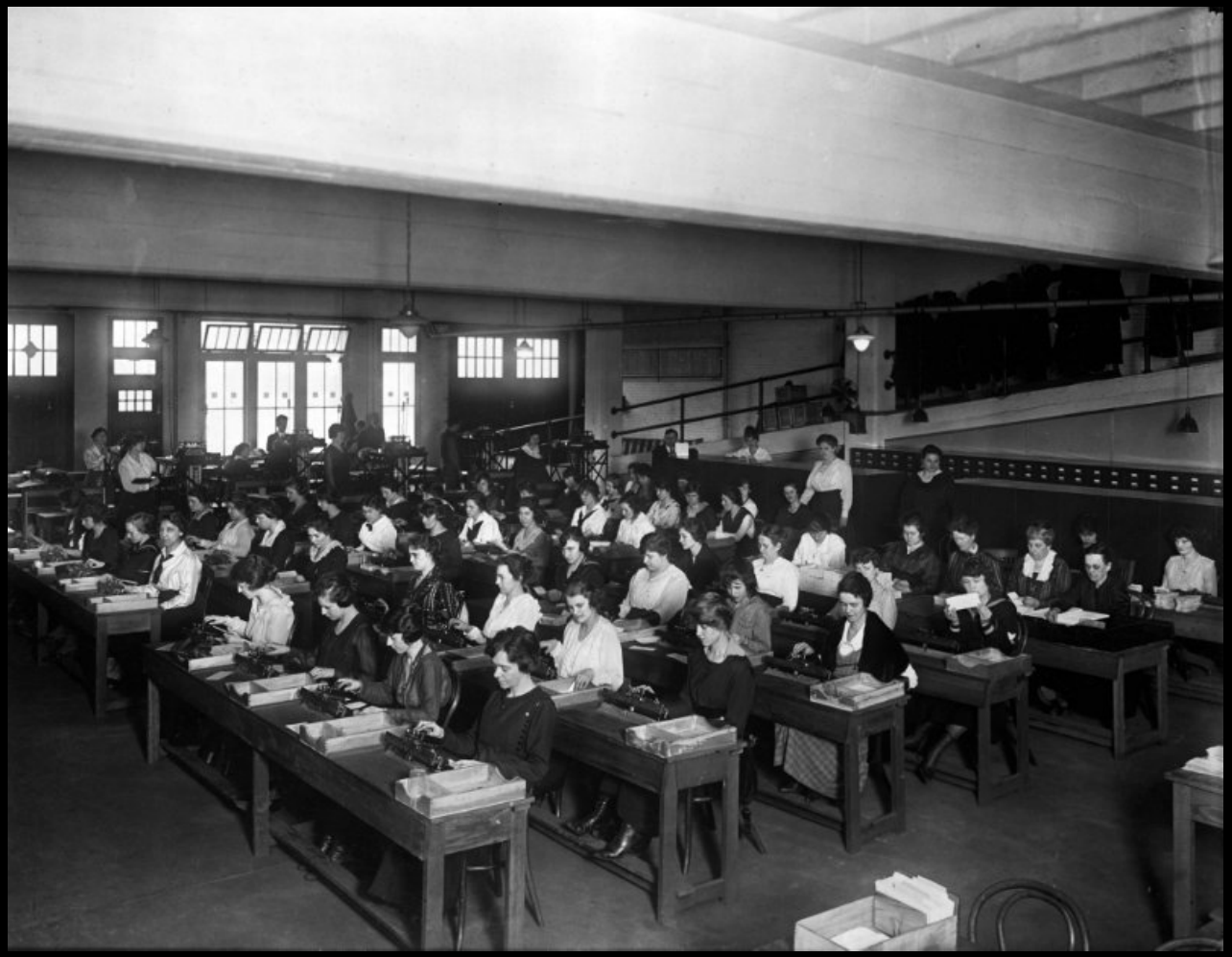
The Age of Steam

The Age of Steam

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

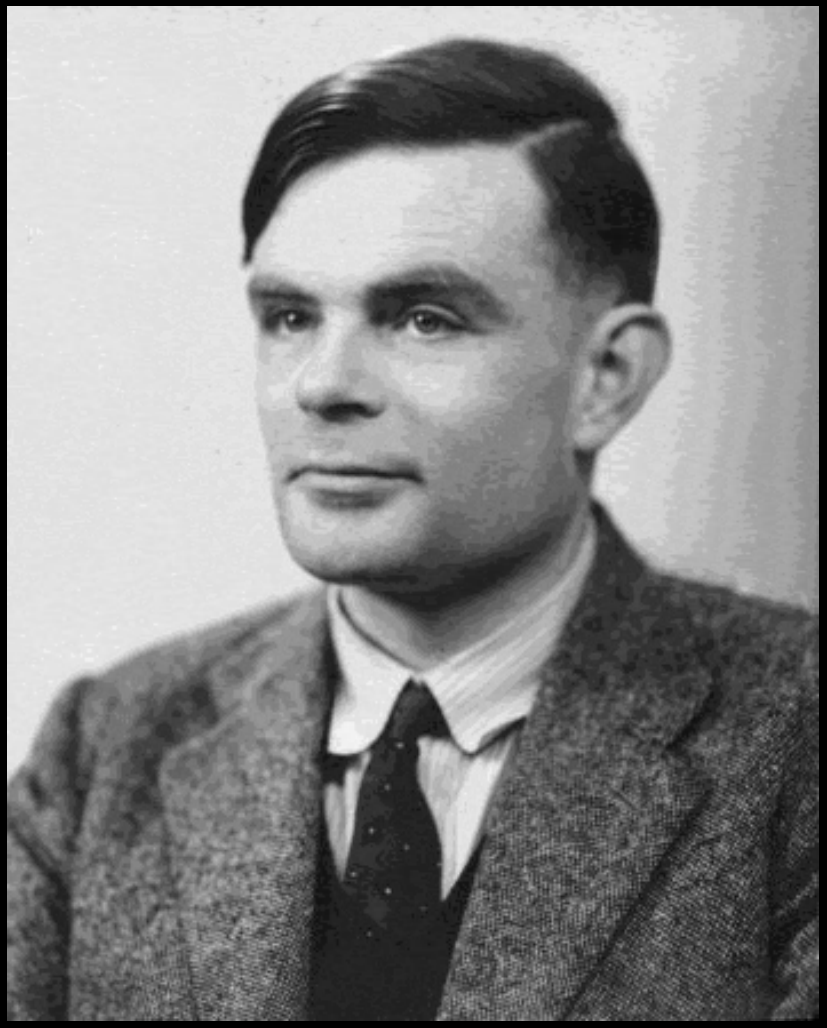


Machines vs. People



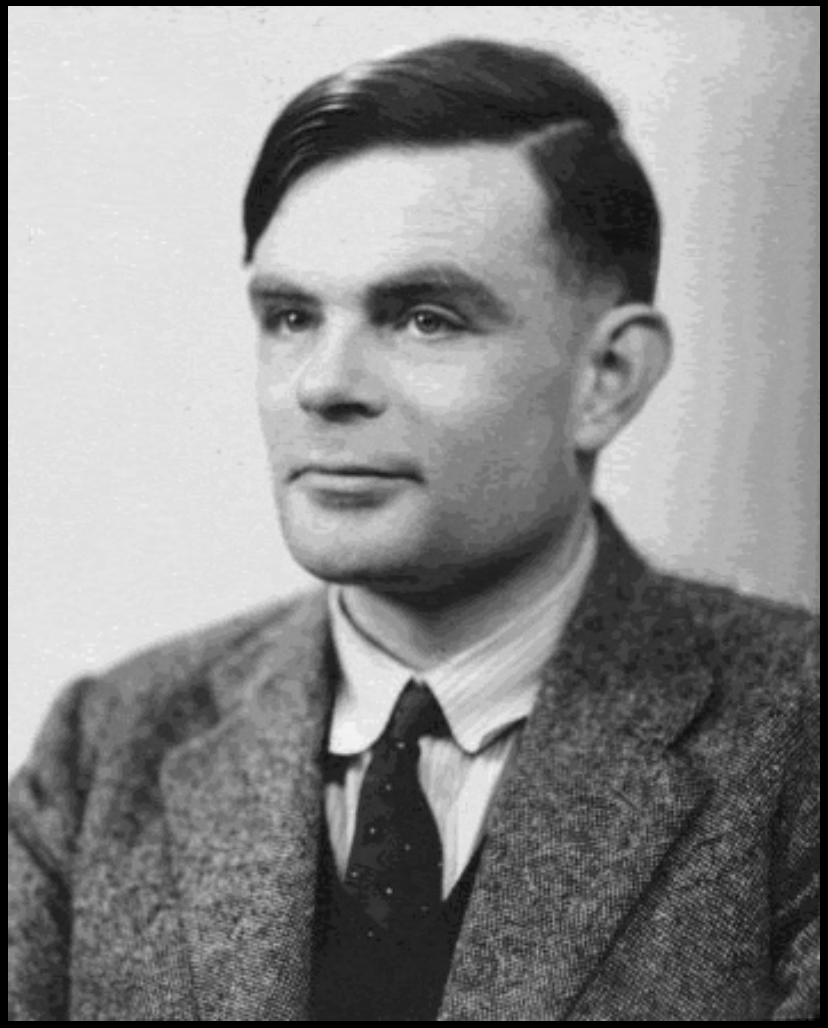
Graphic: computerhistory.org

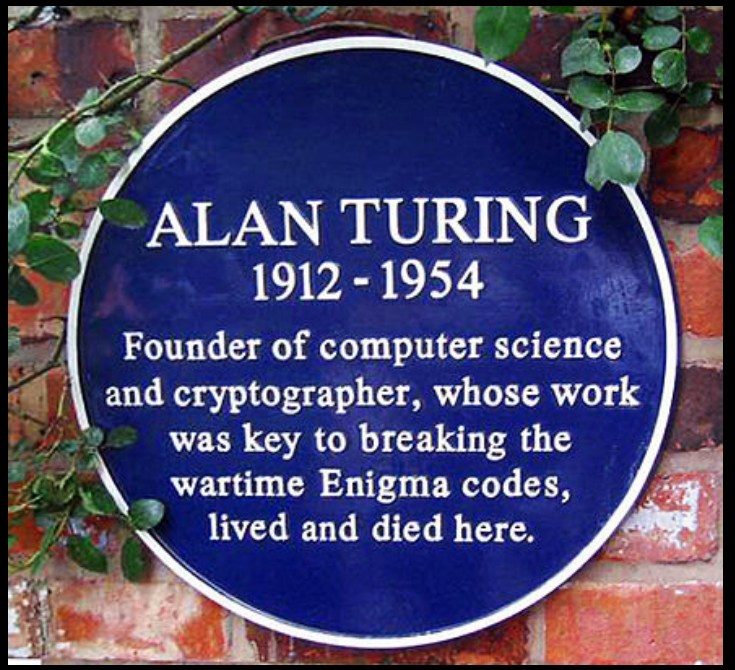
Modern Computation is Born



Graphic: wikipedia.org

Modern Computation is Born





- Widely consider the father of theoretical computer science and artificial intelligence

Graphic: wikipedia.org

What Did Turing Do?

- On Computable Numbers, with an Application to the *Entscheidungsproblem*" (1936)
  - The "Turing Machine"

Image: aturingmachine.com

What Did Turing Do?

- On Computable Numbers, with an Application to the *Entscheidungsproblem*" (1936)
  - The "Turing Machine"

https://www.youtube.com/watch?feature=player_embedded&v=E3keLeMwfHY

The States Used For This Example (**Explanation of the Programming Syntax Used**)

```
(0,1) -> (0,1) Right     //This state moves the tape to the right most digit
(0,0) -> (0,0) Right     //This state moves the tape to the right most digit
(0,B) -> (1,B) Left      //When a blank at the right is found we change to state 1

//This next block, state 1, is where the counting really happens
(1,0) -> (0,1) Right     //If we change a 0 to a 1 we change back to state 0
(1,1) -> (1,0) Left      //If we change a 1 to a 0 we keep looking to the left
(1,B) -> (0,1) Right     //If we change a Blank to a 1 we change back to state 0
```

For the Keen Observers

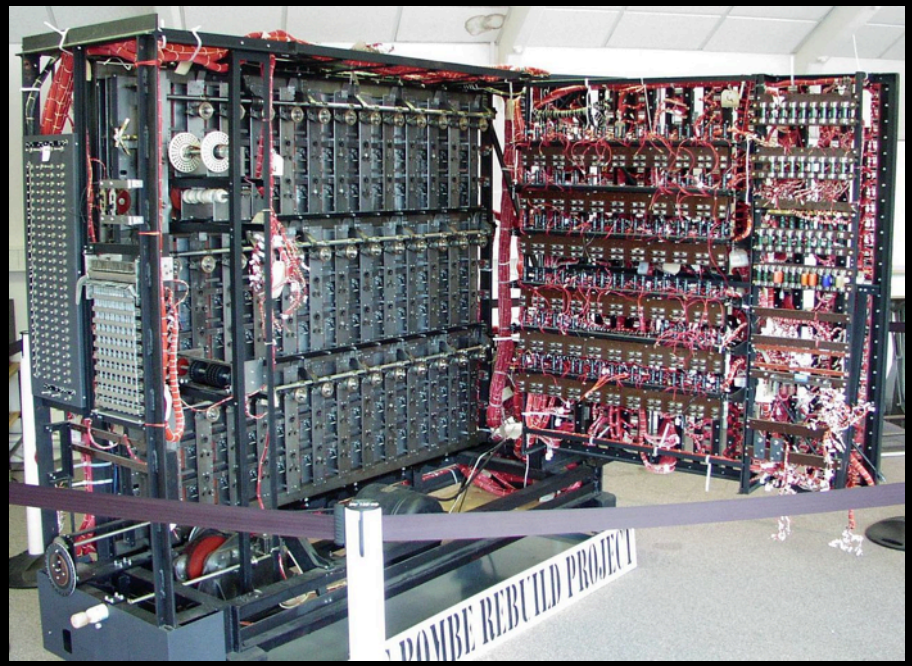
Halting Problem Proof Idea

- Suppose h(i,x)
  - returns 1 if program i halts on x;
  - 0 otherwise
- Consider a program g(i) that
  - Returns 0 if h(i,i) = 0
  - Goes into an infinite loop otherwise
- Suppose g(g) -> 0
  - but then h(g,g) =0, so g doesn't halt and return 0
- g(g) -> undefined (infinite loop),
  - but then h(g,g) =1, so g halts and returns 0

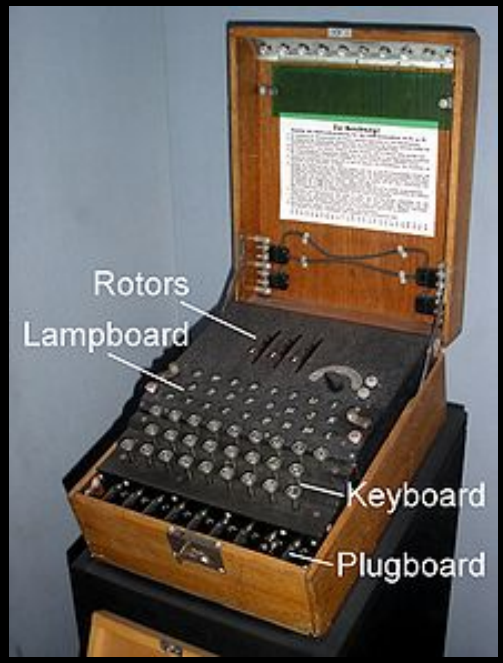
What Did Turing Do

- Turing, Alan (c. 1941). "Report on the applications of probability to cryptography". The National Archives of the UK: HW 25/37.

The Bombe

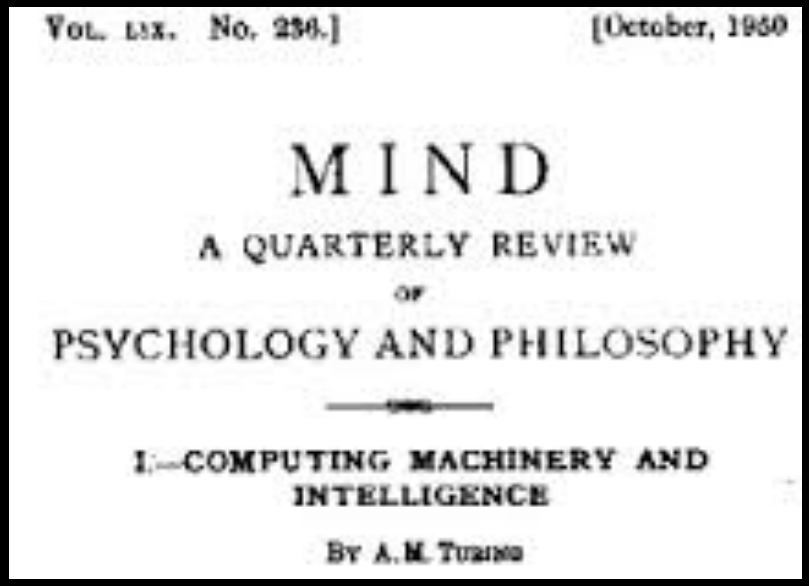


The Enigma



What Did Turing Do?

- Turing, Alan (October 1950), "Computing Machinery and Intelligence", *Mind* **LIX** (236): 433–460, doi:10.1093/mind/LIX.236.433



VOL. LIX. No. 236.] [October, 1950

MIND

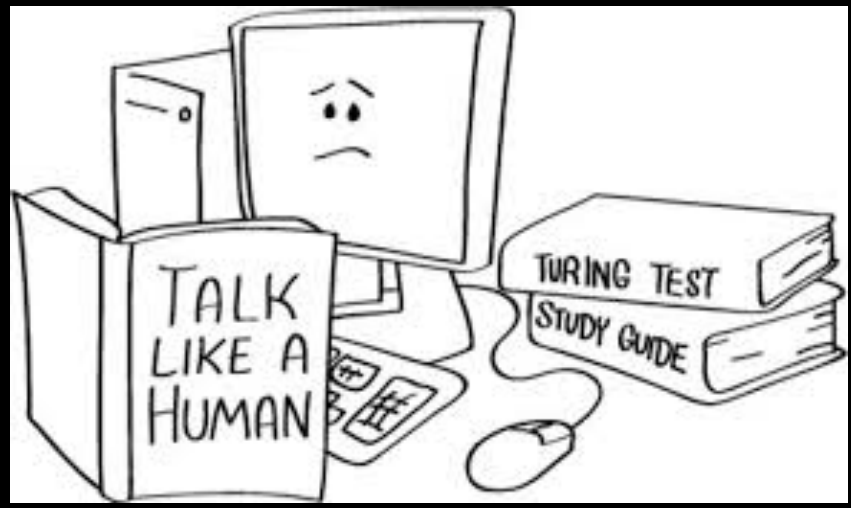
A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND INTELLIGENCE

BY A. M. TURING



Some Ideas

- What is intelligence?
  - The "Turing test" – intelligence is phenomenological
  - *Nevertheless I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted.*
- Are there fundamental reasons machines could not be intelligent?
- Could machines be taught like people?
  - Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain.

Sources

- David Alan Grier, *When Computers Were Human*, Princeton University Press, 2005
- Andrew Hodges, *Alan Turning: The Enigma*, Princeton University Press, 1985 (reissue 2012)
- aturingmachine.com
- computerhistory.org
- http://en.wikipedia.org/wiki/Alan_Turing

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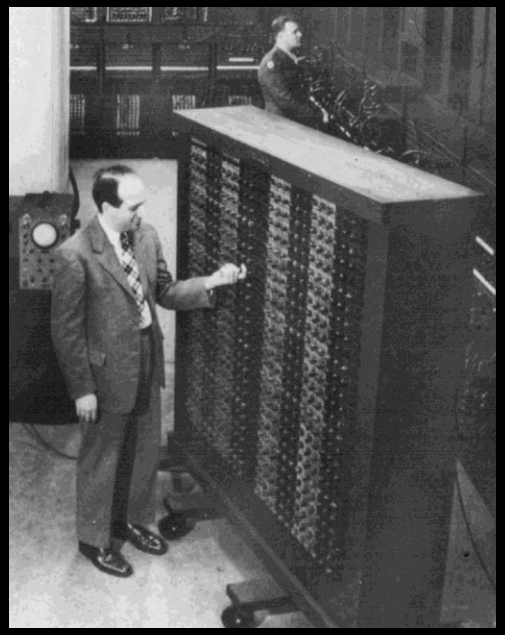
THE NEW AGE OF DISCOVERY

How Did Computing Come to Be?
The Machines



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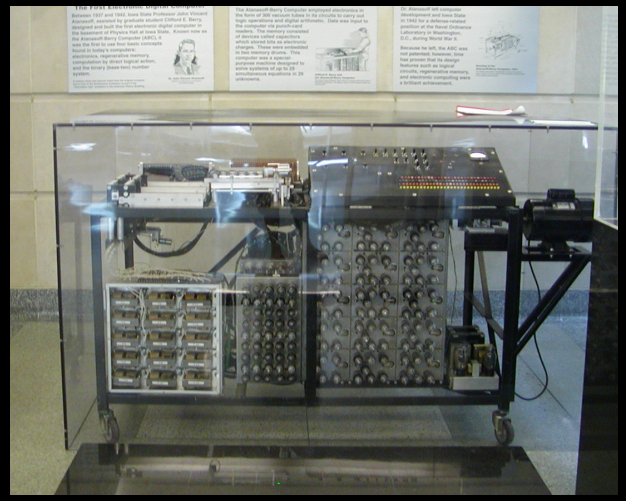
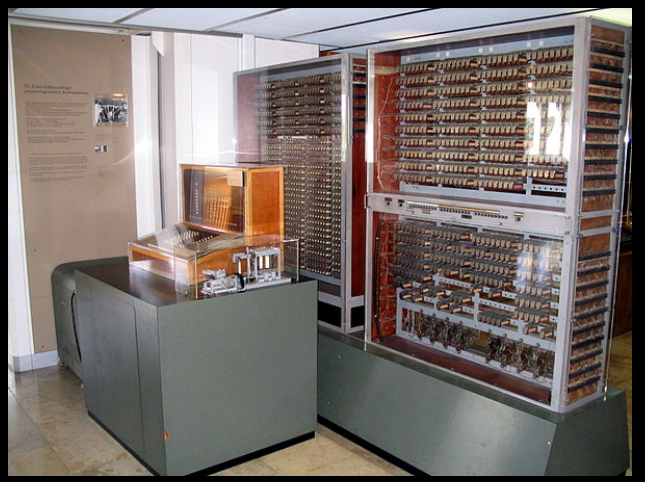
From Computability to Computing

What Was the First Computer?

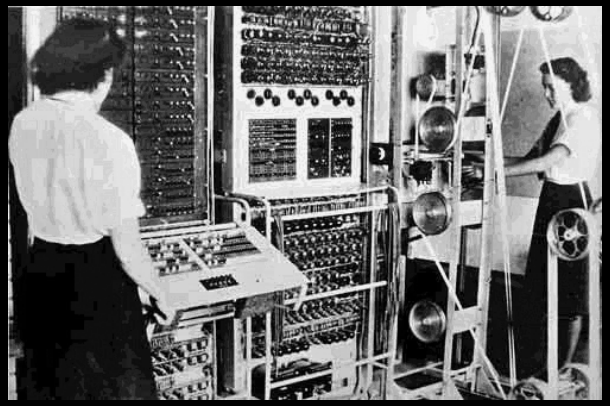


Atanasoff-Berry, 1942



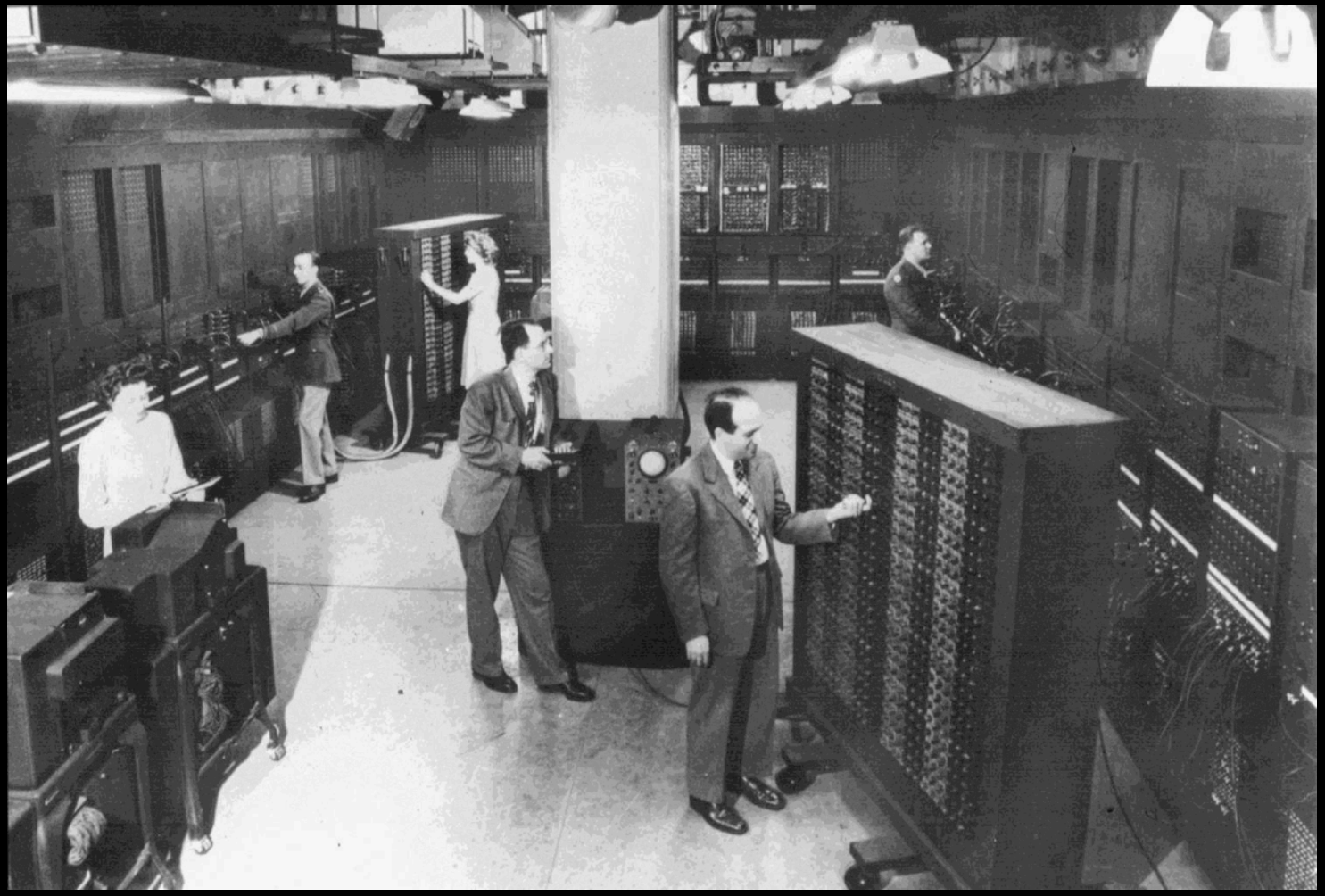
Zuse Z3, 1941

Colossus, 1943



Harvard Mark 1, 1944

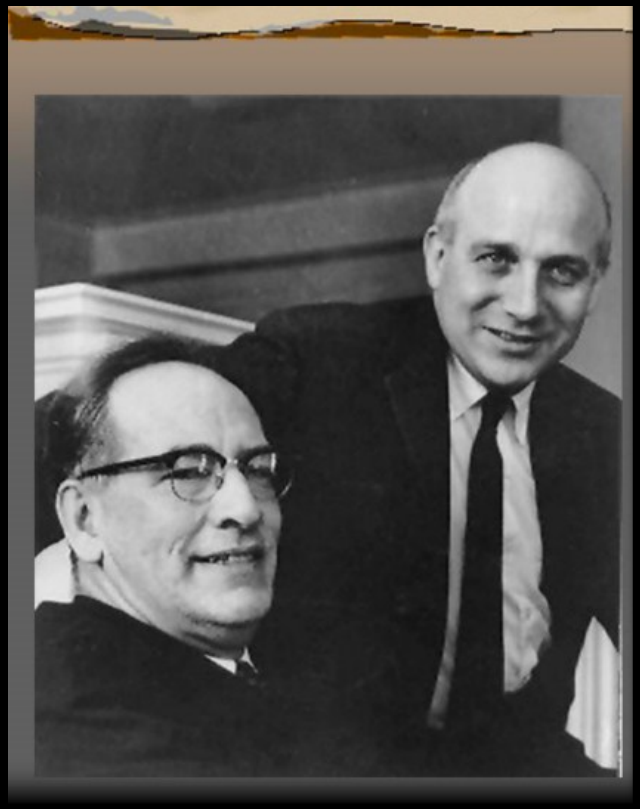
ENIAC



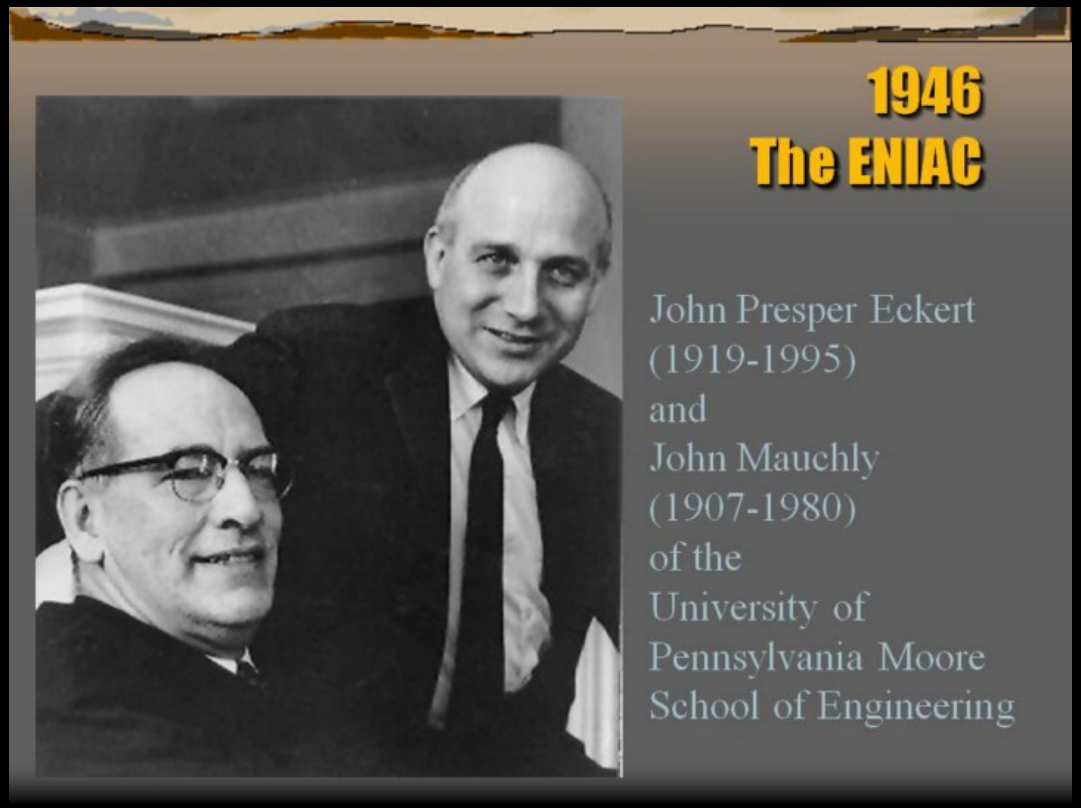
ENIAC, University of Pennsylvania, circa 1946

A Personal Connection

And the Inventors Were …



And the Inventors Were …



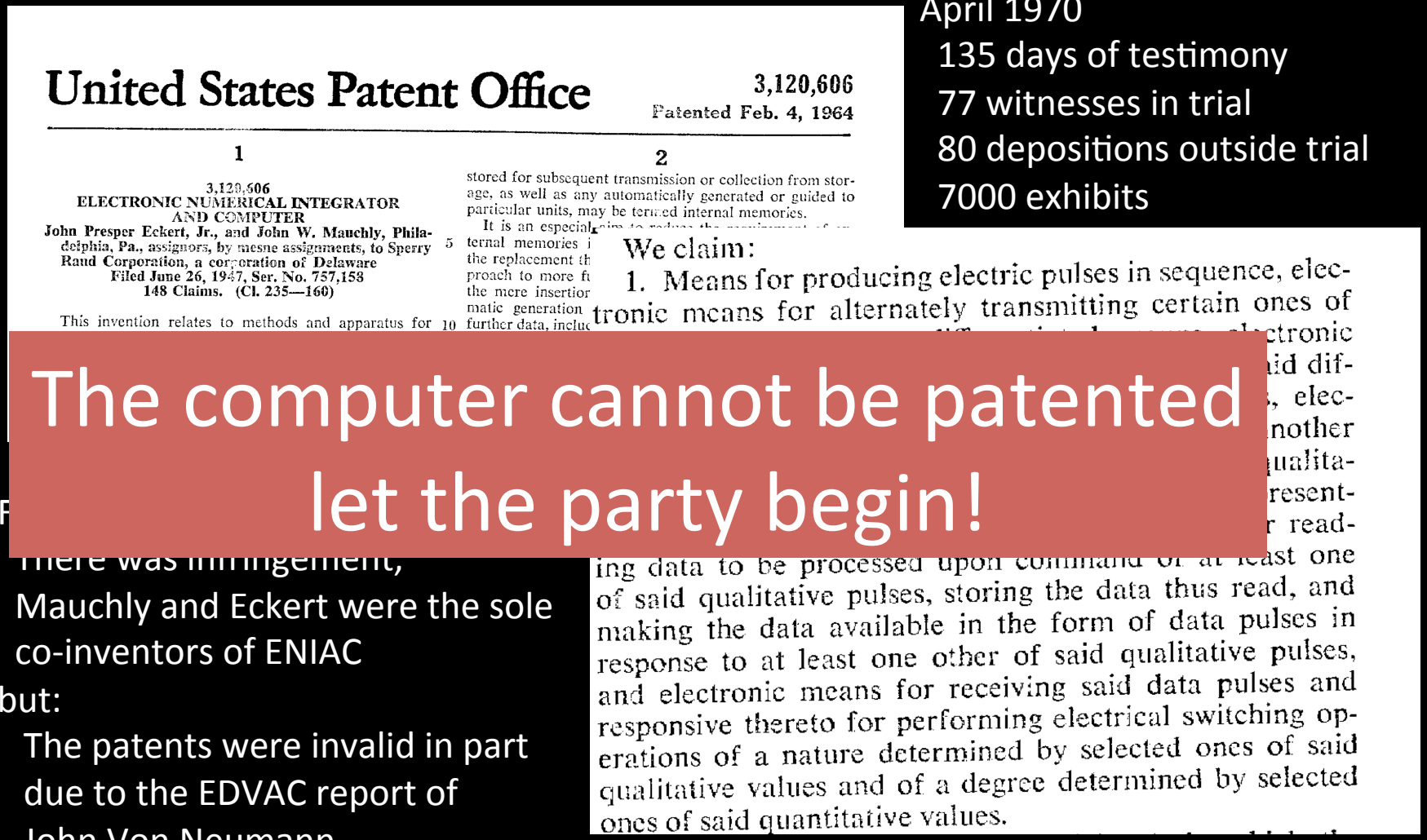
EDVAC 1949

Who is This?

- John (Janos) Von Neumann (12/03-2/57)
- Hungarian-American mathematician
- Contributions to many fields, including the idea of a "stored program" computer

IBM/Sperry Rand vs. Honeywell

April 1970
- 135 days of testimony
- 77 witnesses in trial
- 80 depositions outside trial
- 7000 exhibits



United States Patent Office 3,120,606 Patented Feb. 4, 1964

1

3,120,506
ELECTRONIC NUMERICAL INTEGRATOR AND COMPUTER
John Presper Eckert, Jr., and John W. Mauchly, Philadelphia, Pa., assignors, by mesne assignments, to Sperry Rand Corporation, a corporation of Delaware
Filed June 26, 1947, Ser. No. 757,153
148 Claims. (Cl. 235—160)

This invention relates to methods and apparatus for

2

stored for subsequent transmission or collection from storage, as well as any automatically generated or guided to particular units, may be termed internal memories.

It is an especial[illegible] ternal memories i[illegible] the replacement th[illegible] proach to more fl[illegible] the mere insertion[illegible] matic generation[illegible] further data, includ[illegible]

We claim:

1. Means for producing electric pulses in sequence, electronic means for alternately transmitting certain ones of [illegible]ctronic [illegible]id dif-[illegible], elec-[illegible]nother [illegible]ualita-[illegible]resent-[illegible]r read-ing data to be processed upon command of at least one of said qualitative pulses, storing the data thus read, and making the data available in the form of data pulses in response to at least one other of said qualitative pulses, and electronic means for receiving said data pulses and responsive thereto for performing electrical switching operations of a nature determined by selected ones of said qualitative values and of a degree determined by selected ones of said quantitative values.

The computer cannot be patented let the party begin!

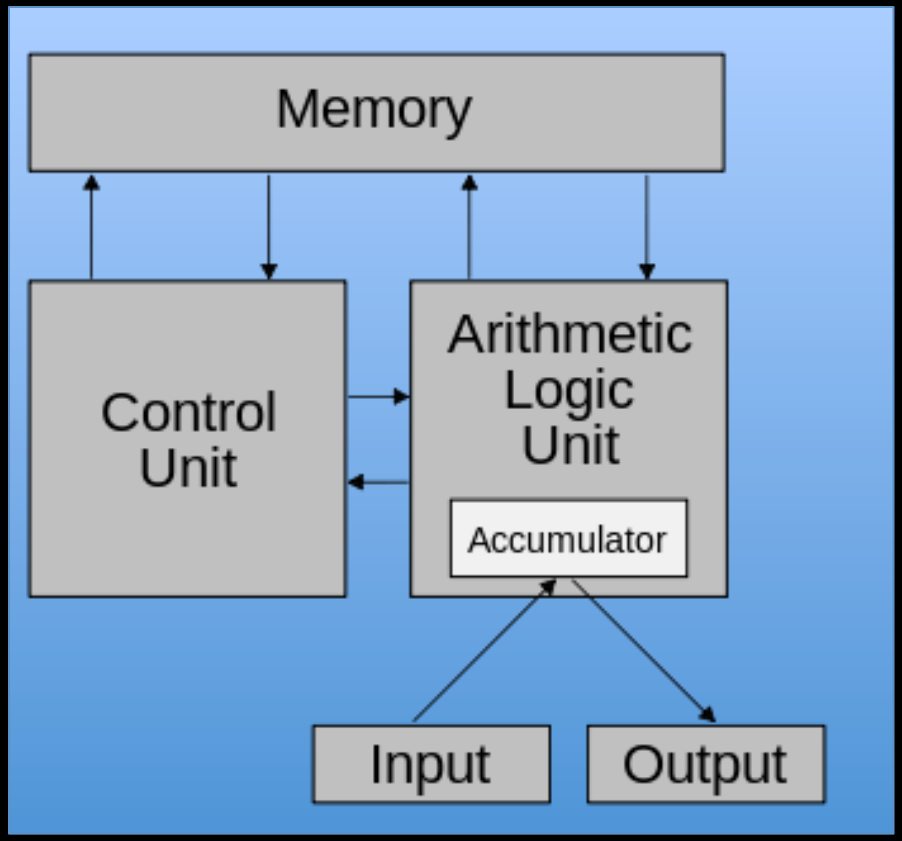
There was infringement,
Mauchly and Eckert were the sole co-inventors of ENIAC

but:

The patents were invalid in part due to the EDVAC report of John Von Neumann

Going Forward: Three Key Ideas

- All electronic
- Discrete binary logic
- Stored programs
  (programs as data)

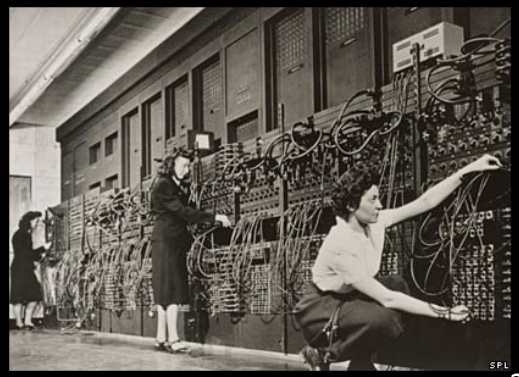


Who Invented Programming?

Ada Lovelace

Grace Hopper

Kathy Kleiman,
Jean Bartik,
Marlyn Meltzer,
Kay Mauchly Antonelli
Betty Holberton



Who Invented Programming?

- Rear Admiral in the Navy
- Invented first compiler (machine independence)
- Invented COBOL
- Coined the term "debugging"

Grace Hopper

http://gracehopper.org

Out of the Lab and Into the World

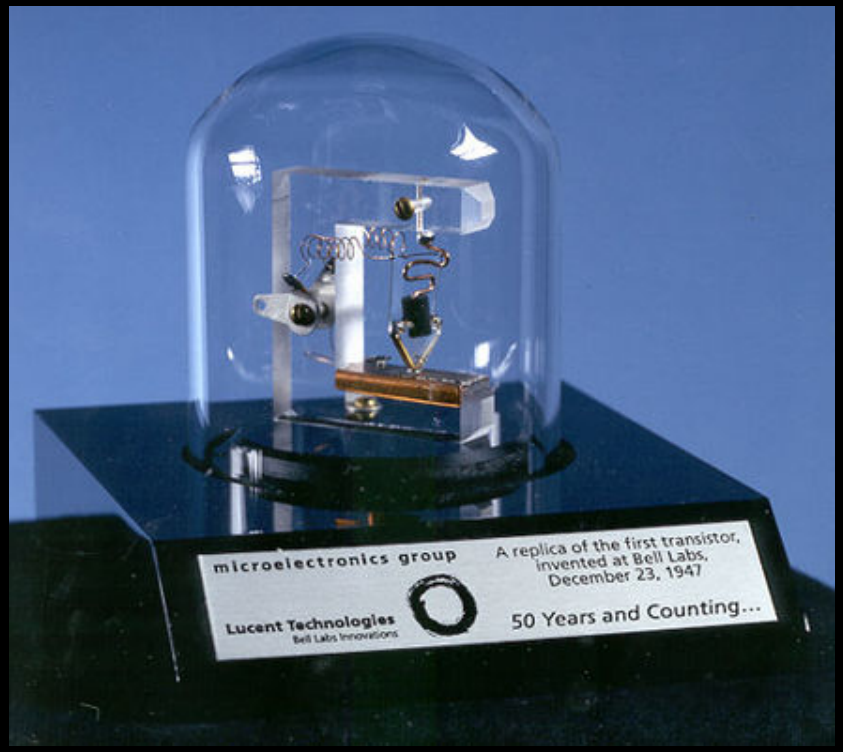
"I think there is a world market for maybe five computers."

Thomas Watson, president of IBM, 1943

If You Make It, They Will Come

- Can you build something that can be delivered and installed?
- UNIVAC I (early 50's)
  - 5200 vacuum tubes
  - 29000 lbs
  - 124kW of power
  - 1000 words of memory
- IBM
  - IBM 704
  - IBM 650

The Next Wave



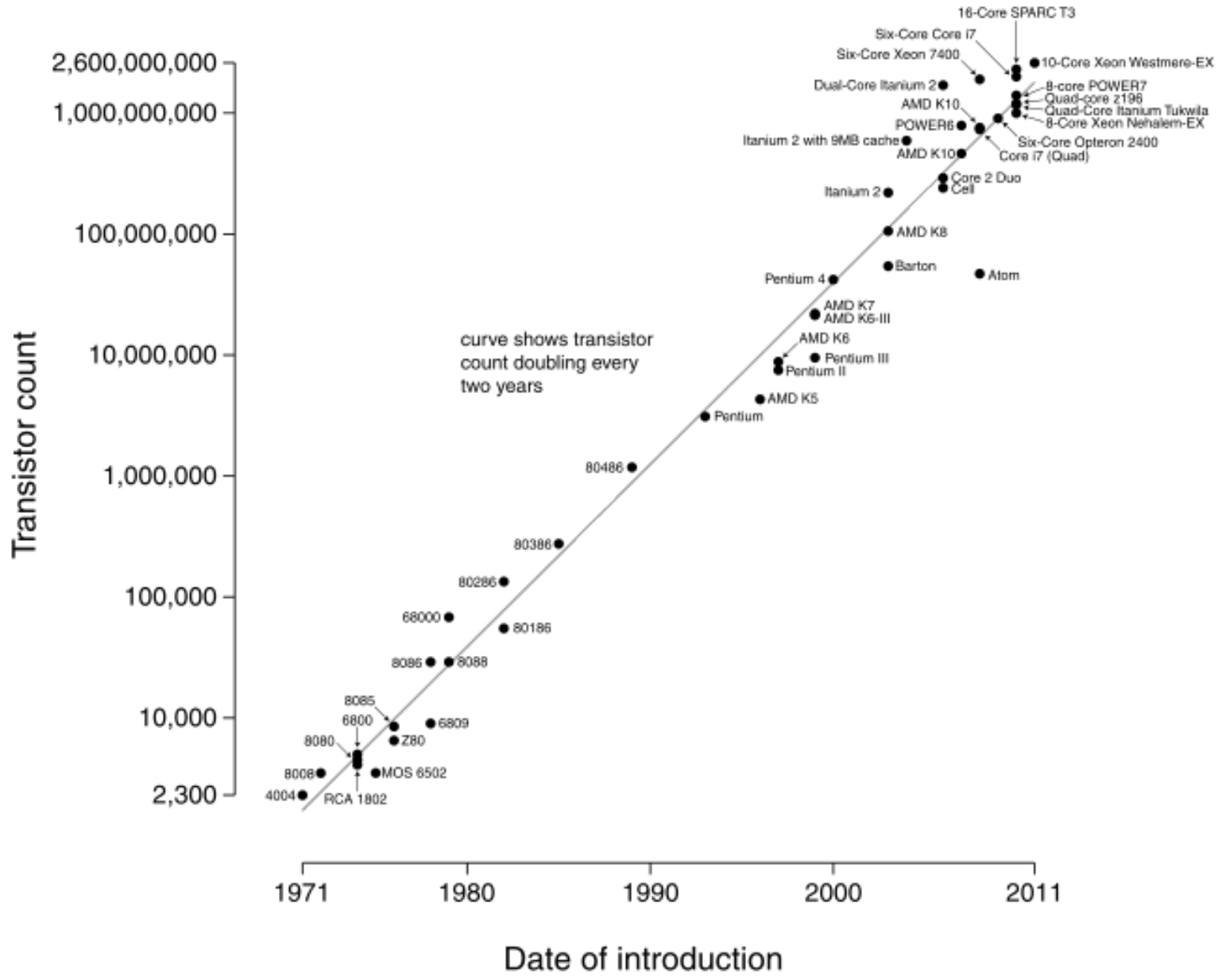
First invented, 1947
1956 Nobel prize in physics

John Bardeen, William Shockley and Walter Brattain at Bell Labs, 1948 (from Wikipedia)

The Next Wave

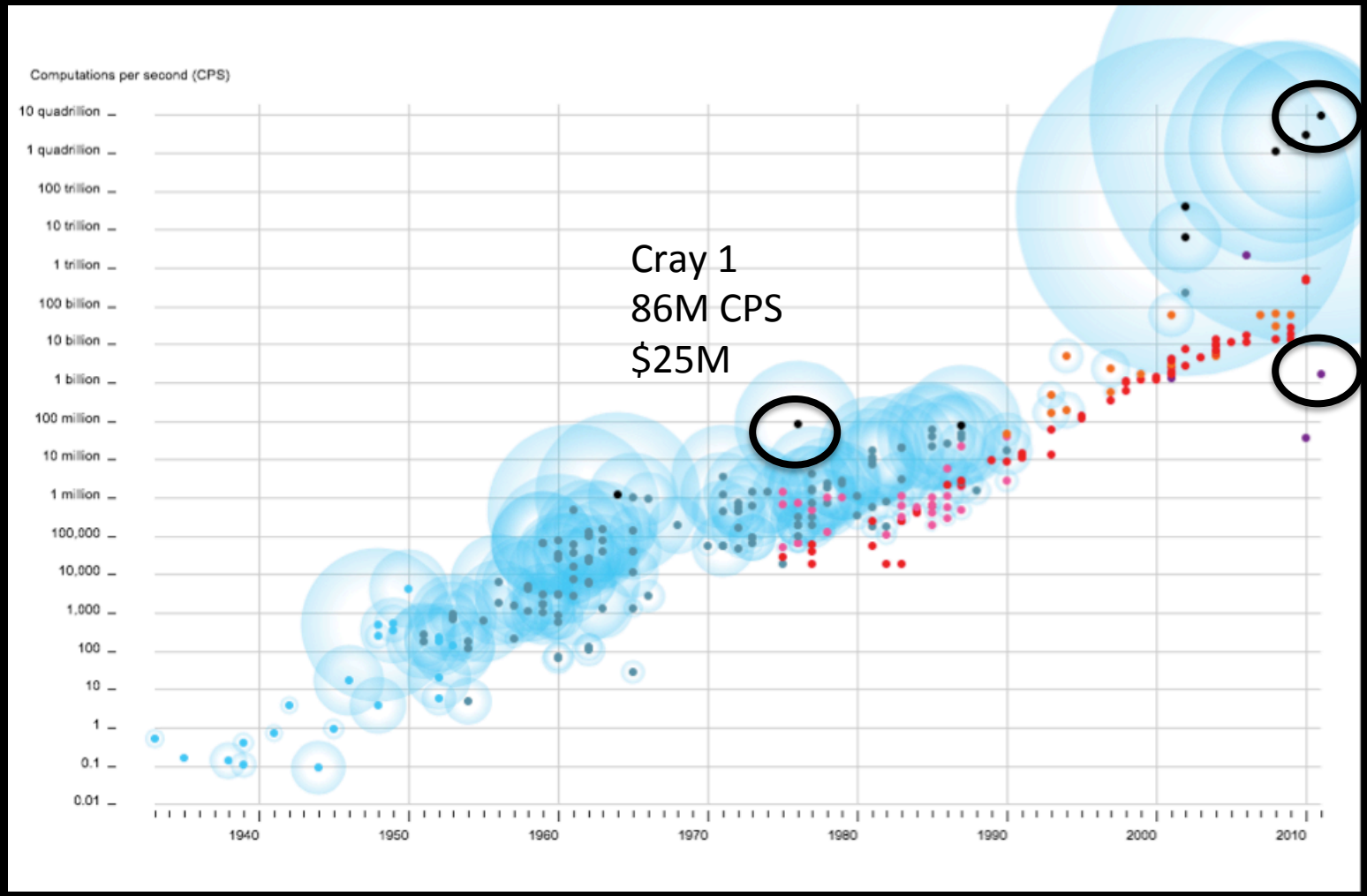
- IBM 360
  - Common instruction set for entire family
  - Registers
  - Microcode
  - Interrupts
  - Floating point

- Even the most recent IBM systems are *still* **software compatible** with the original 360


Transistor count
2,600,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
curve shows transistor count doubling every two years
16-Core SPARC T3
Six-Core Core i7
Six-Core Xeon 7400
10-Core Xeon Westmere-EX
Dual-Core Itanium 2
8-core POWER7
Quad-core z196
Quad-Core Itanium Tukwila
AMD K10
8-Core Xeon Nehalem-EX
POWER6
Six-Core Opteron 2400
Itanium 2 with 9MB cache
Core i7 (Quad)
AMD K10
Core 2 Duo
Cell
Itanium 2
AMD K8
Barton
Atom
Pentium 4
AMD K7
AMD K6-III
AMD K6
Pentium III
Pentium II
AMD K5
Pentium
80486
80386
80286
68000
80186
8086
8088
8085
6800
6809
8080
Z80
8008
MOS 6502
4004
RCA 1802
1971
1980
1990
2000
2011
Date of introduction

oore

A Bit of comparison



http://www.popsci.com/content/computing?dom=PSC&loc=recent&lnk=1&con=IMG

The Growing Wave

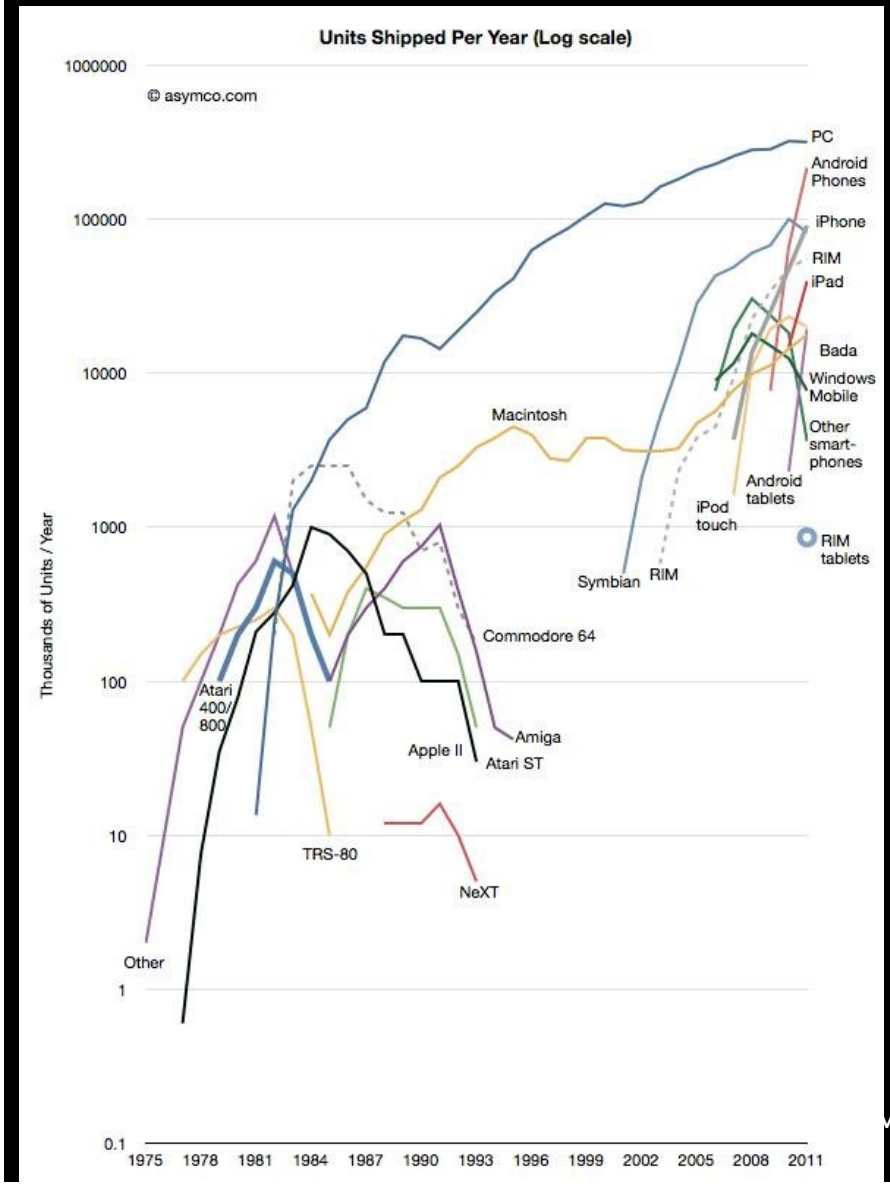
- The 50-60's – mostly mainframes, businesses

Sun microsystems, late-80's

- The 60-70's – the development of the minicomputer based on ICs
- The 80's – personal workstations and PCs based on the microprocessor
  - Also the development of network files systems to support high performance personal workstations.

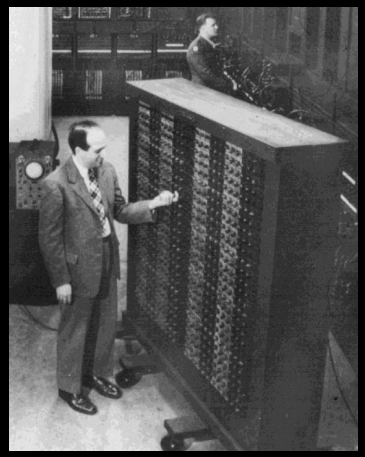
The PC Revolution

The PC Revolution



Graphics: Business Insider,
Annex Bulletin

70 Years of Innovation: A Technology Throwdown!



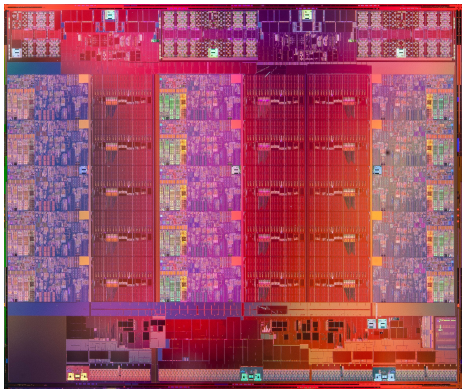
VS

The Technology ThrowDown

- Memory
  - Eniac: 100 words
  - ARM 8-64 Gbytes
- Power consumed
  - Eniac: 200-ish Kw
  - ARM: watts
- Weight
  - Eniac: 30 tons
  - iPhone: ¼ lb
- Computing Power
  - Eniac: 18 cps
  - Arm: 1.6B cps
- Top Speed:
  - Mercedes: 161
  - Tesla: 150 (limited)
- MPG:
  - 14 MPG
  - 85 MPG (typical 30)
- Power:
  - Mercedes: 240/7.1 sec
  - Tesla: 302 hp/3.7 sec

The 1970s to today

1970 Ford Mustang

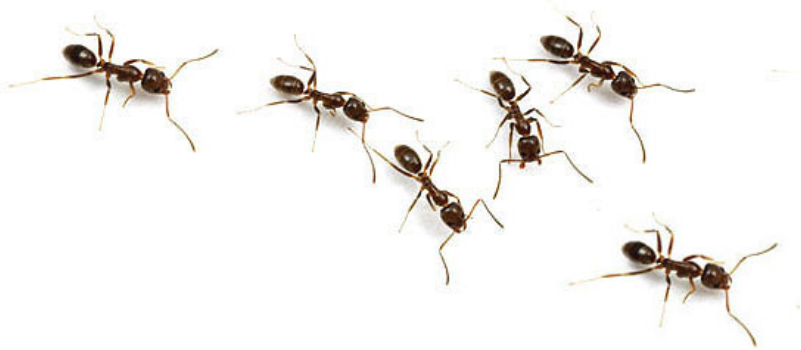


2014 Intel Xeon

What if cars had improved as rapidly as microprocessors?

Courtesy Ed Lazowska

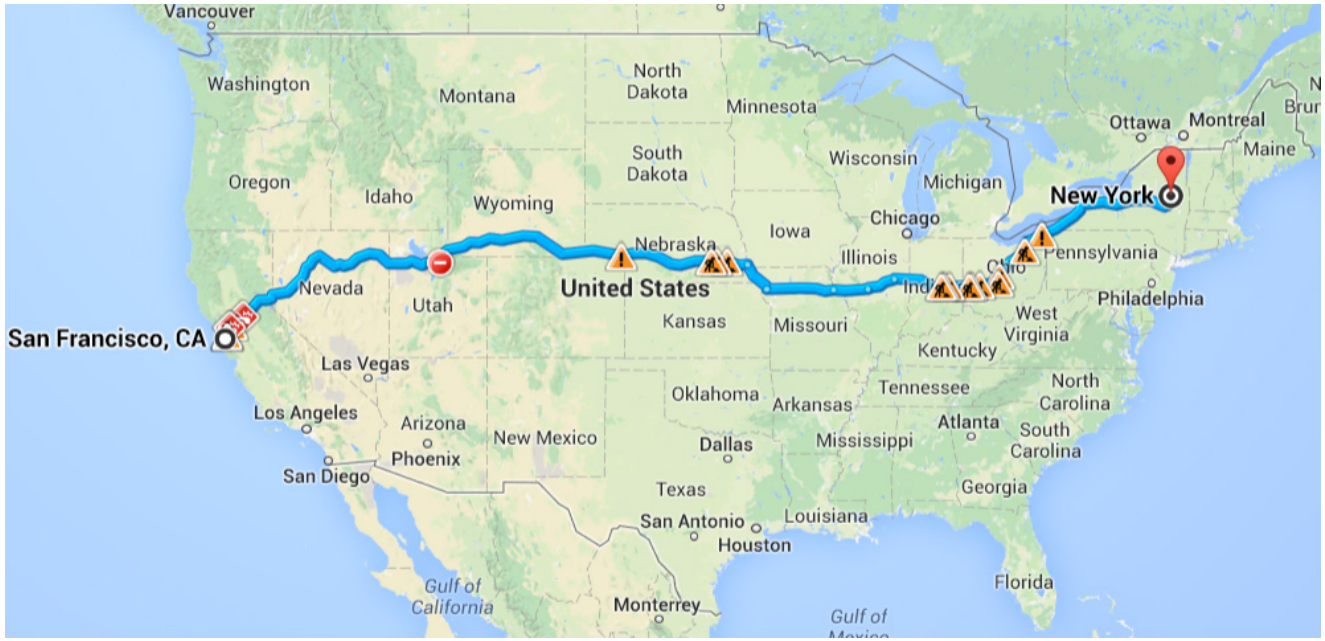
The 1970s to today



Size: A car would be smaller than an ant!
(About 1/5th of an inch long!)

Courtesy Ed Lazowska

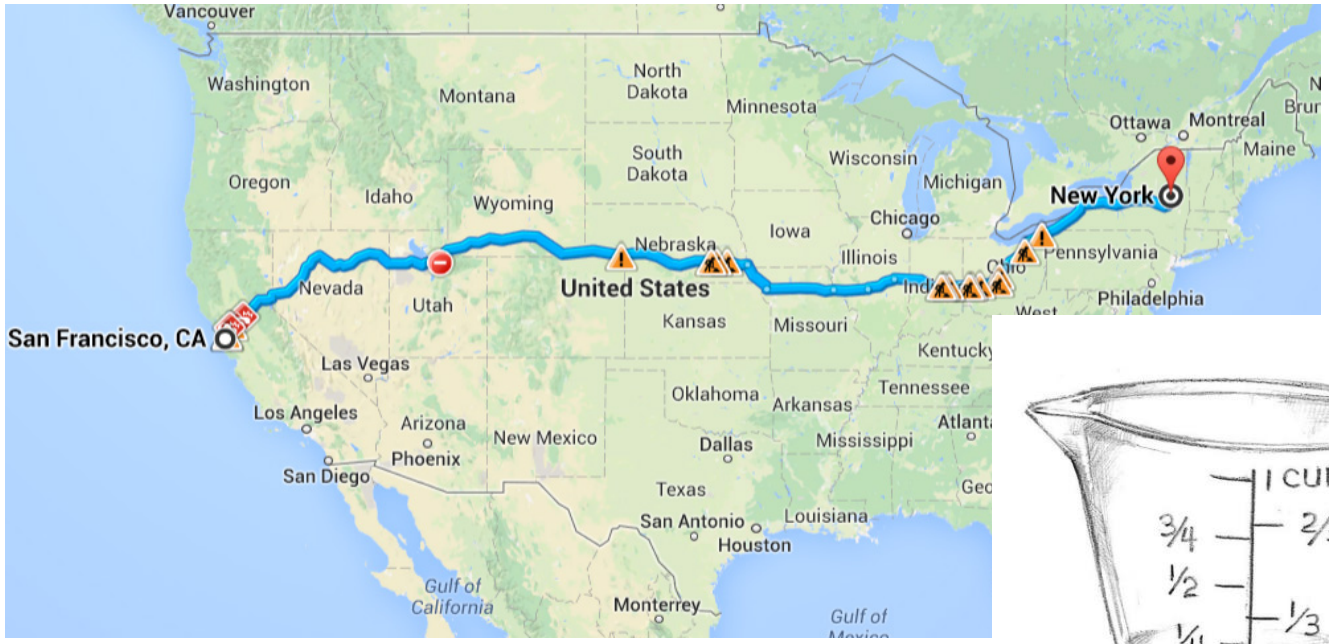
The 1970s to today

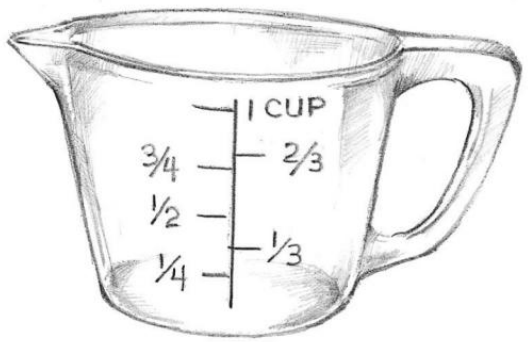


Speed: A car would go 6,000,000 miles per hour!
(San Francisco to New York in 1.7 seconds!)

Courtesy Ed Lazowska

The 1970s to today





Efficiency: A car would get 100,000 miles per gallon!
(San Francisco to New York on 1/2 cup of fuel!)

Courtesy Ed Lazowska

The 1970s to today

Cost: A car would cost less than $10!

Courtesy Ed Lazowska

Sources

- http://en.wikipedia.org/wiki/John_von_Neumann
- http://en.wikipedia.org/wiki/Atanasoff–Berry_computer
- http://en.wikipedia.org/wiki/Z3_(computer)http://en.wikipedia.org/wiki/John_von_Neumann
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- http://en.wikipedia.org/wiki/Honeywell_v._Sperry_Rand