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?

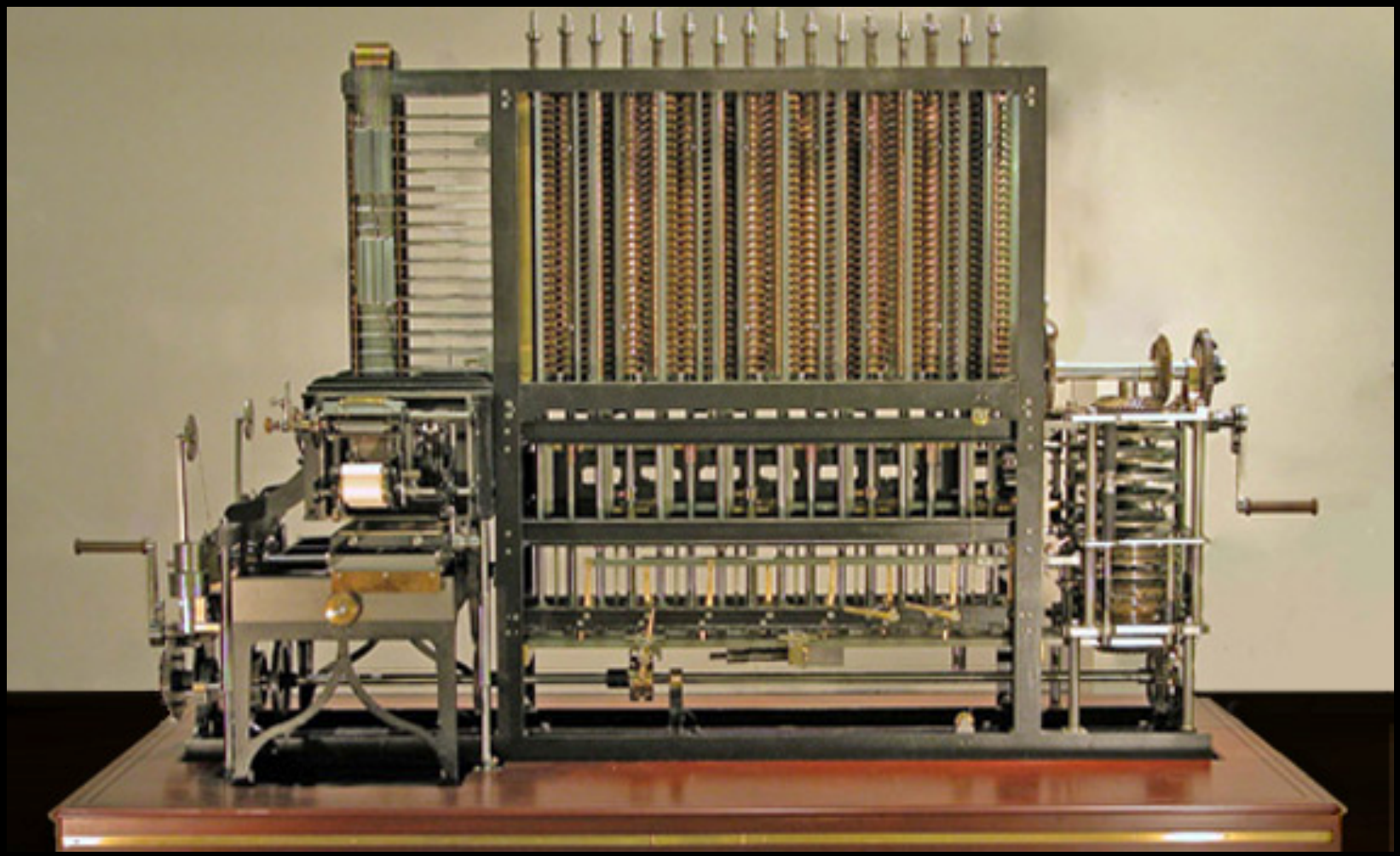
Halley's Comet

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

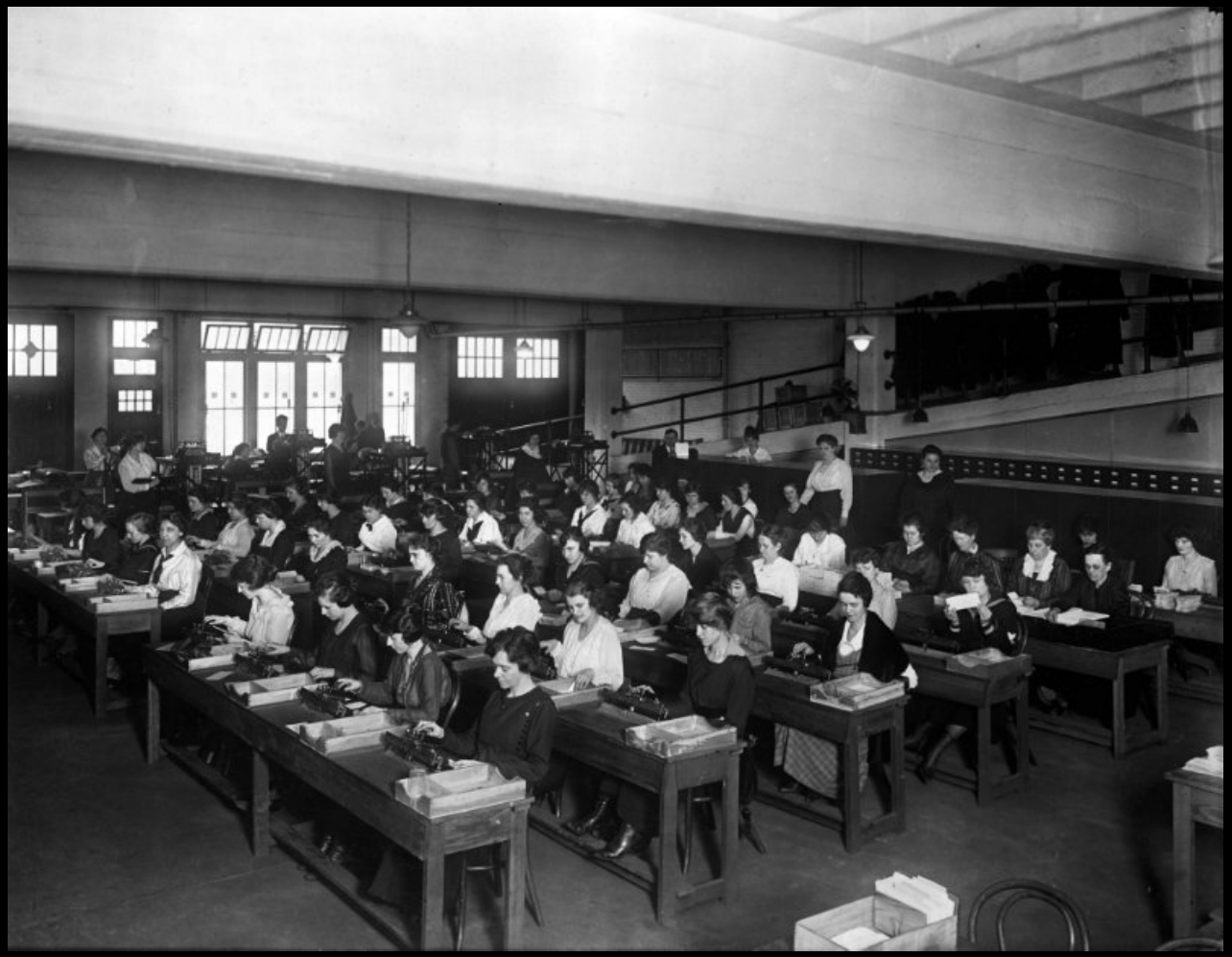
The Age of Steam

The Age of Steam

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

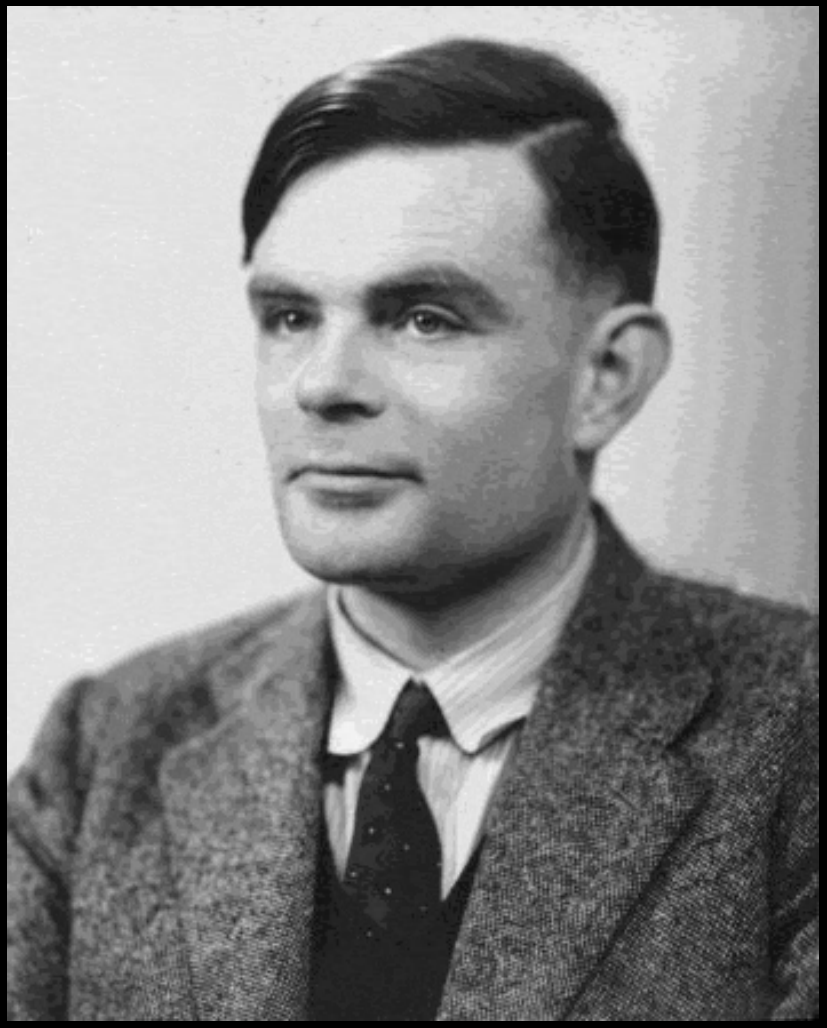


Machines vs. People



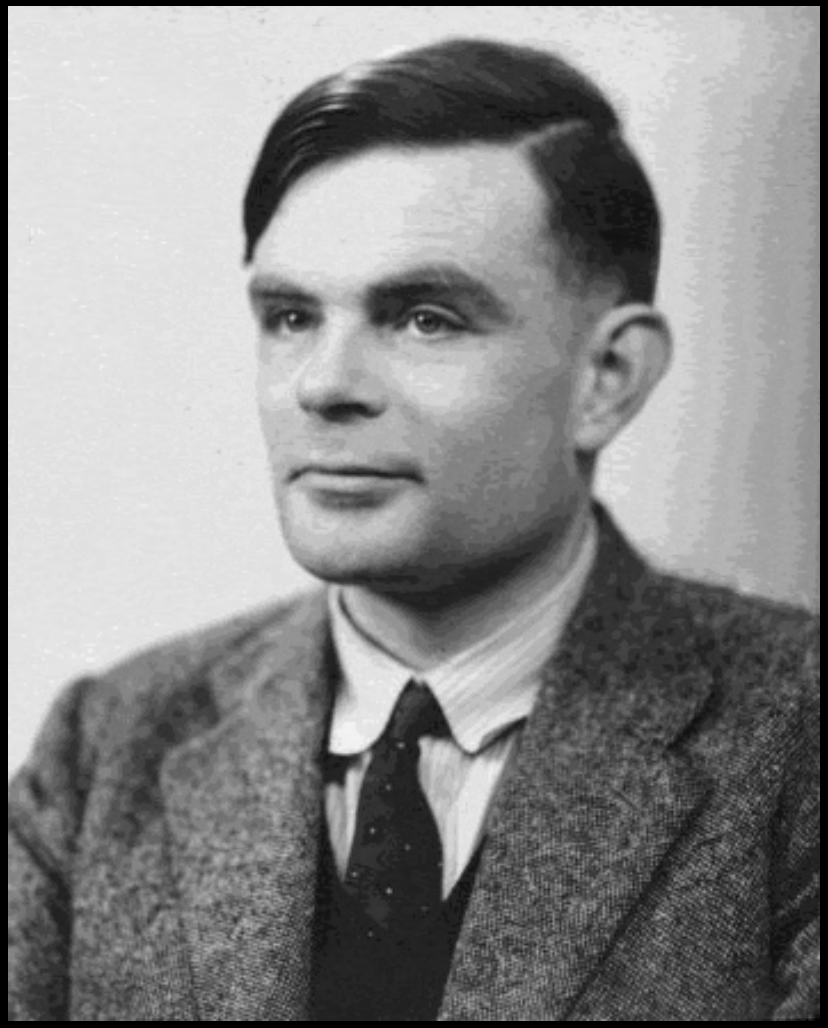
Graphic: computerhistory.org

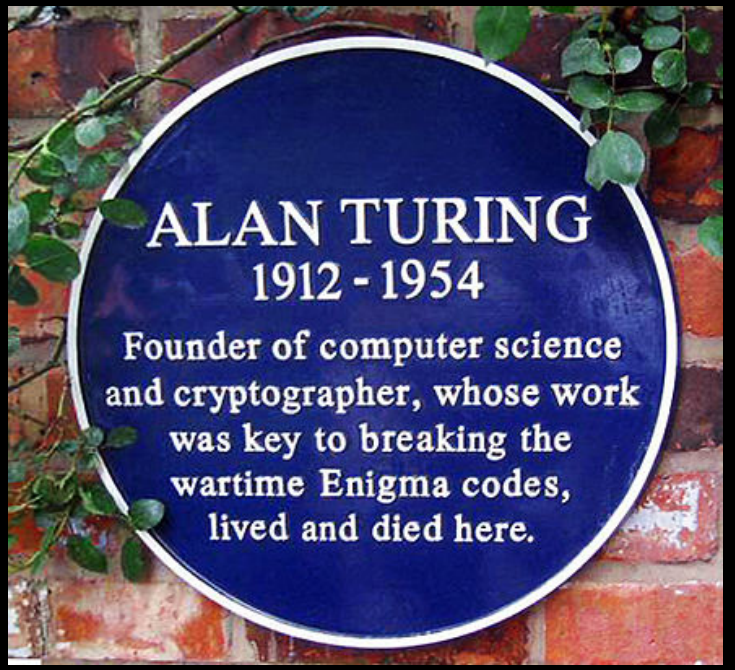
Modern Computation is Born



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?

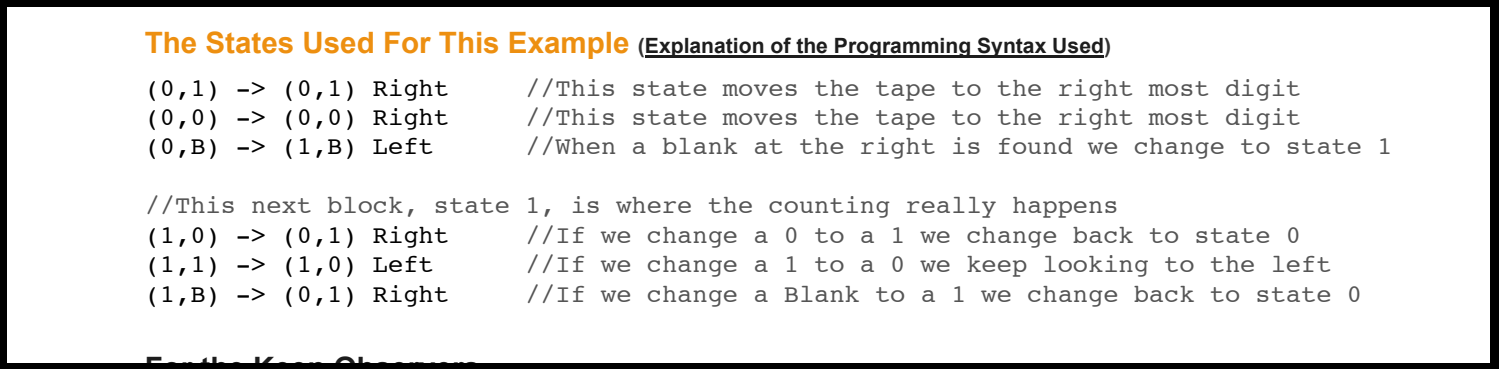
- On Computable Numbers, with an Application to the *Entscheidungsproblem*" (1936)
  - The "Turing Machine"

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
```

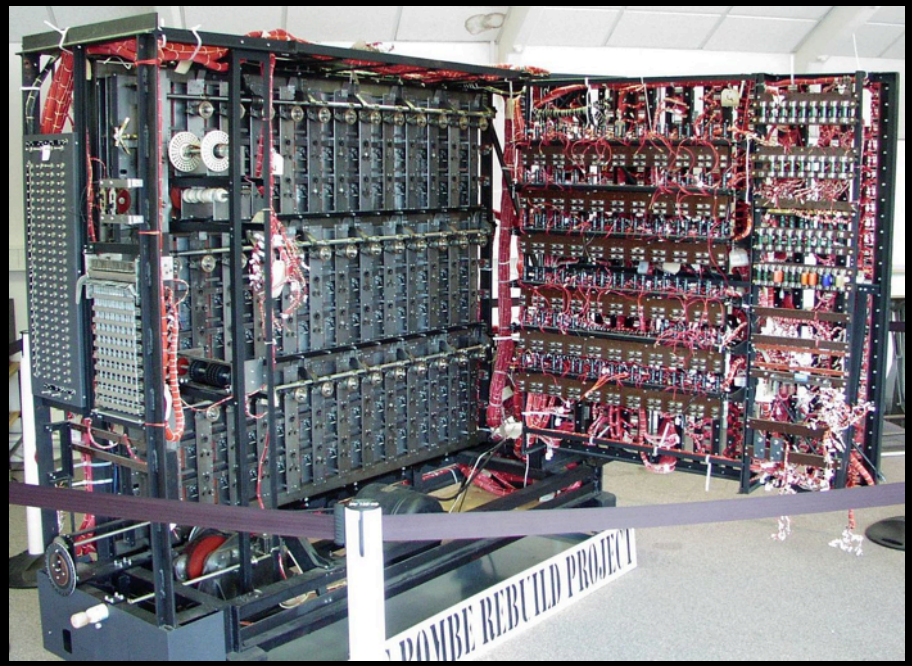
Halting Problem Proof Idea

- 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

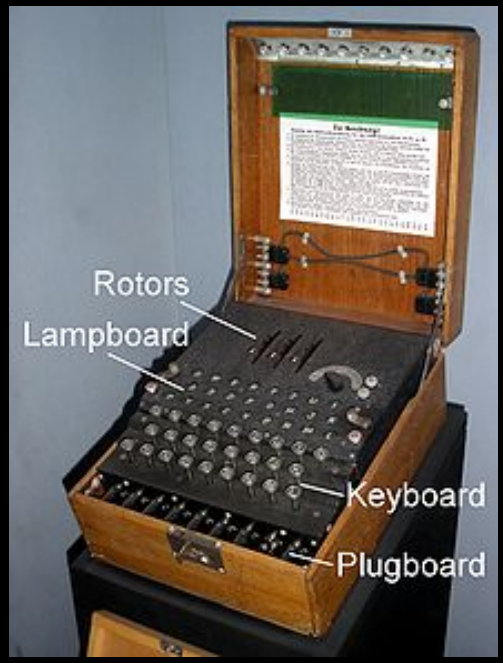
What Did Turing Do

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

The Bombe

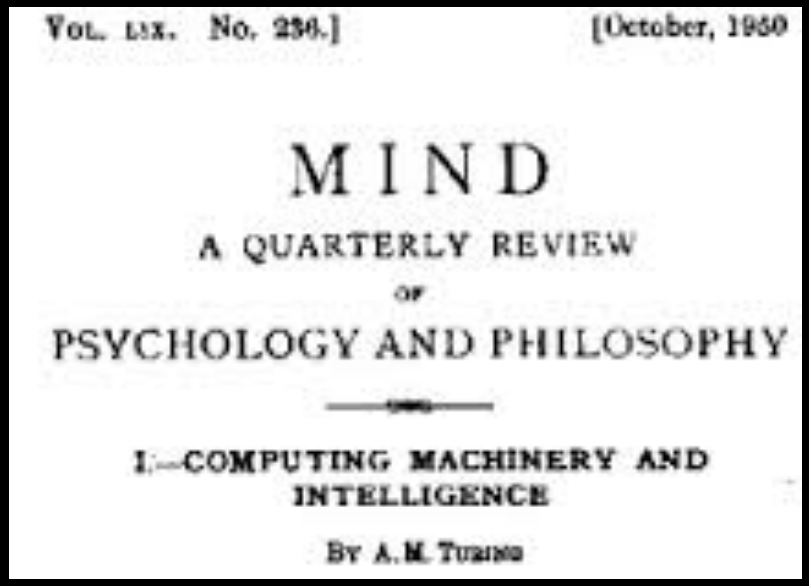


The Enigma



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

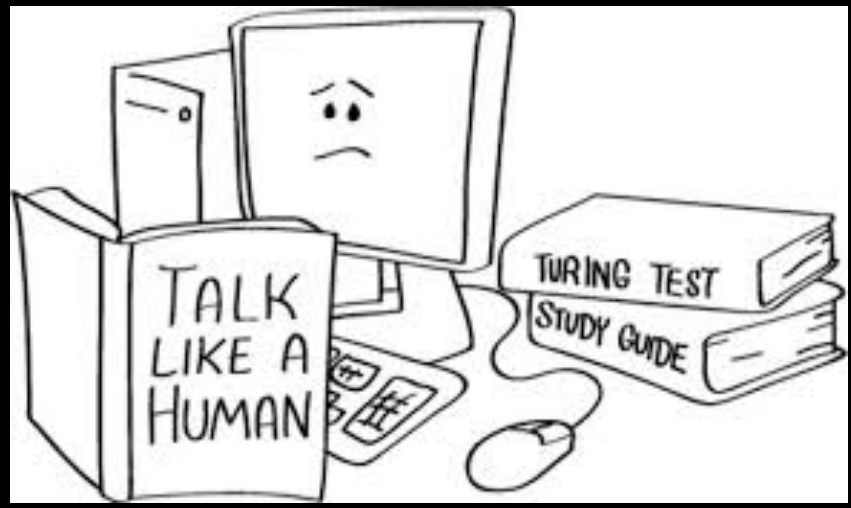
A QUARTERLY REVIEW

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
- http://en.wikipedia.org/wiki/John_von_Neumann

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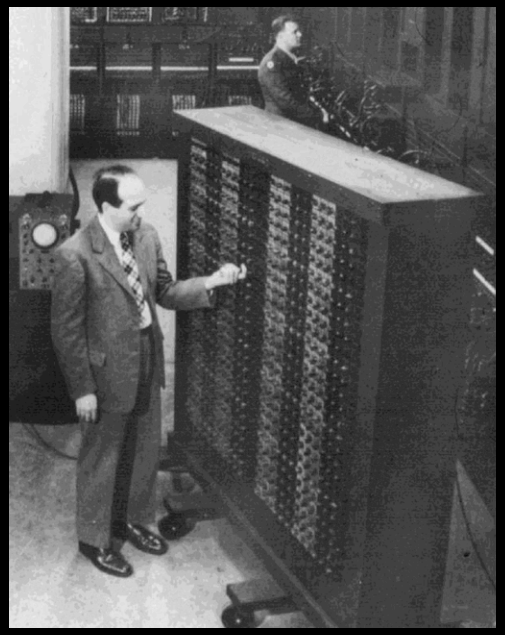
THE NEW AGE OF DISCOVERY

How Did Computing Come to Be?
The Machines



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From Computability to Computing

What was the world's first computer?

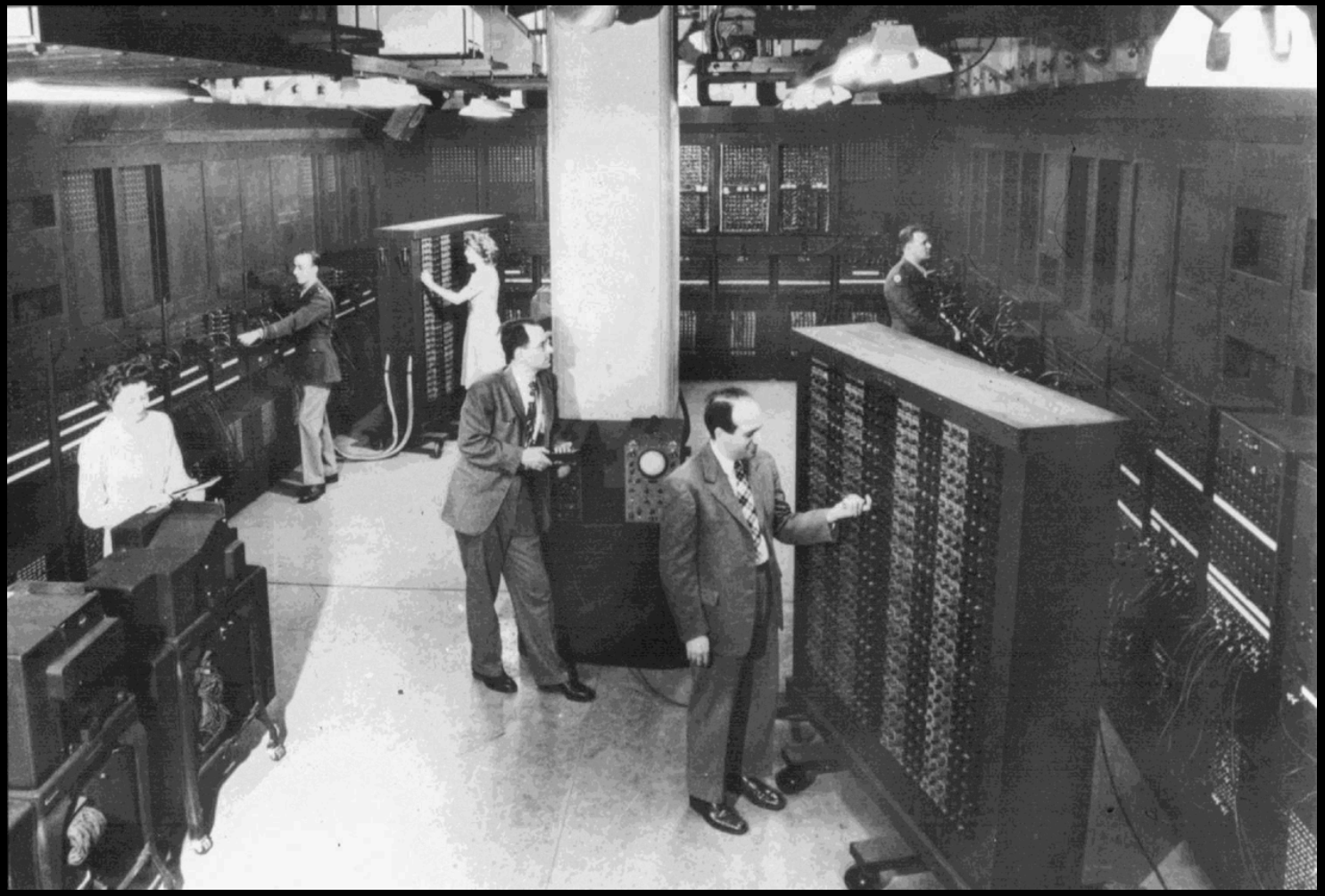
Who invented it?

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

Who is This?

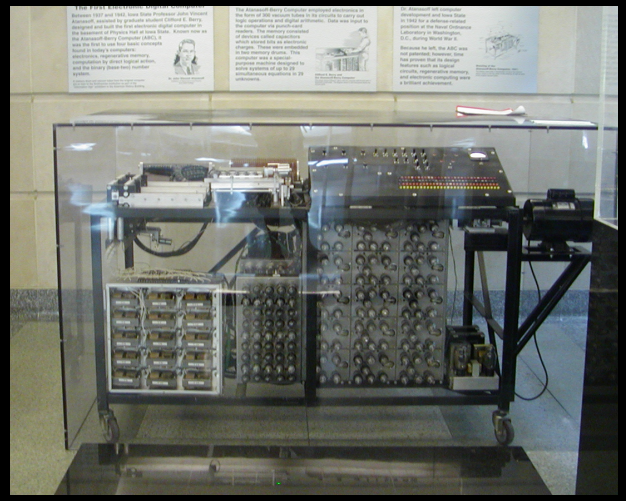
ENIAC



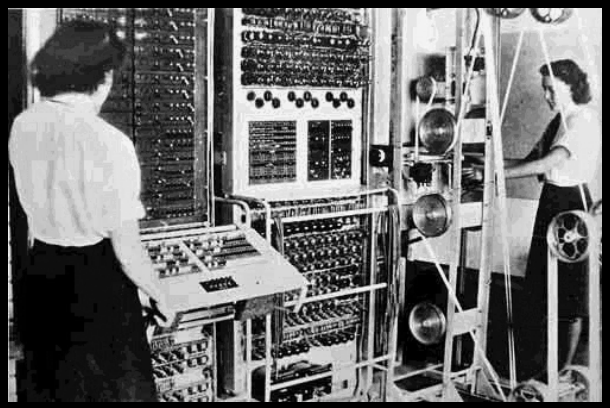
ENIAC, University of Pennsylvania, circa 1946

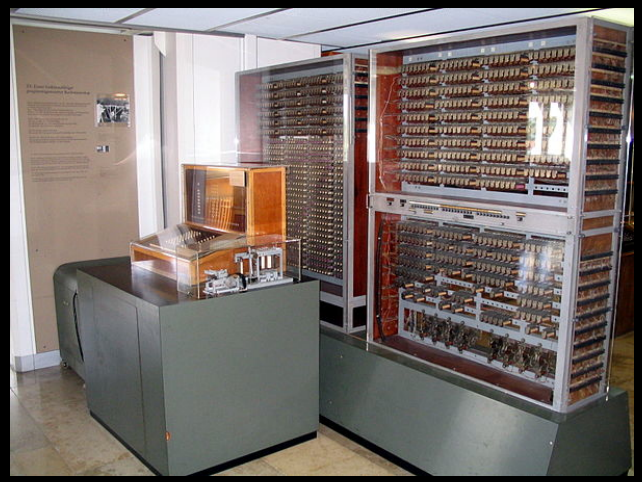
A Personal Connection

Were They First?

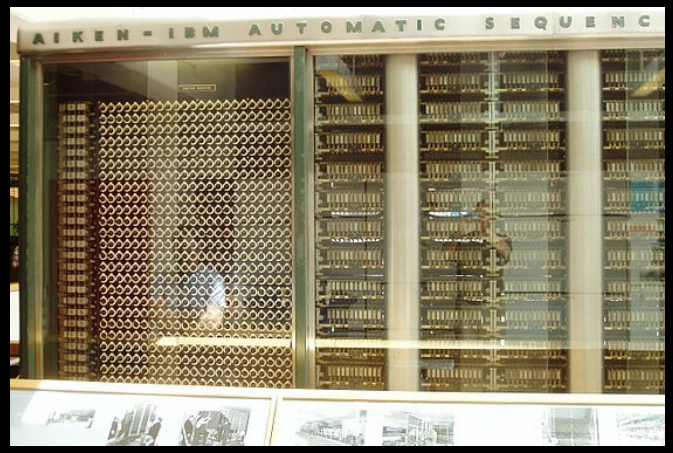


Atanasoff-Berry, 1942
Colossus, 1943



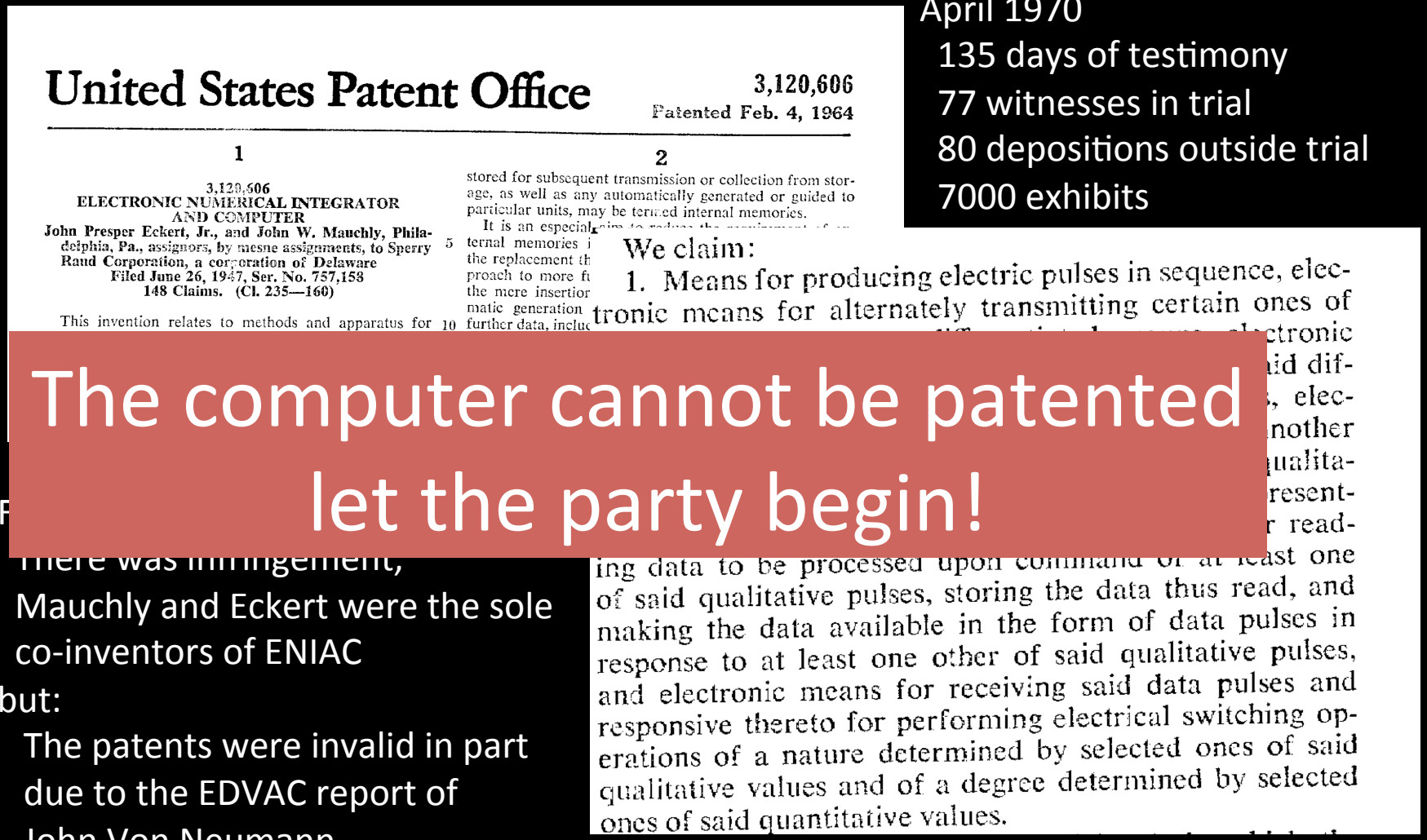


Zuse Z3, 1941
Harvard Mark 1, 1944



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. 757,158
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-[illegible] 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!

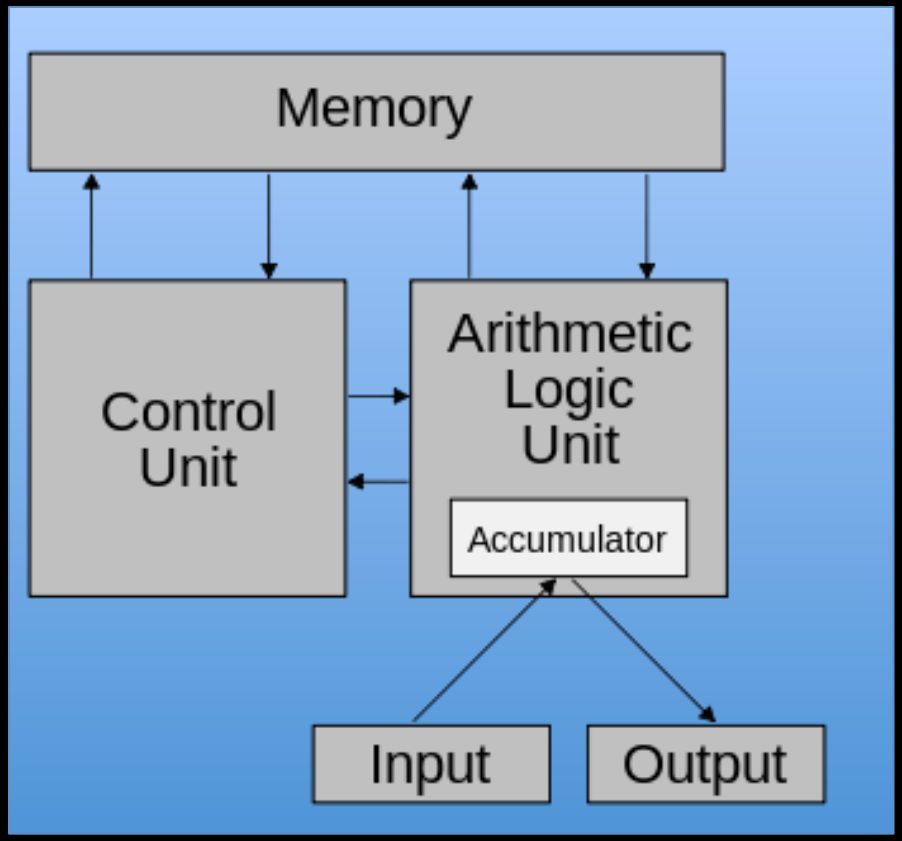
[illegible] was infringement,
Mauchly and Eckert were the sole co-inventors of ENIAC

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)

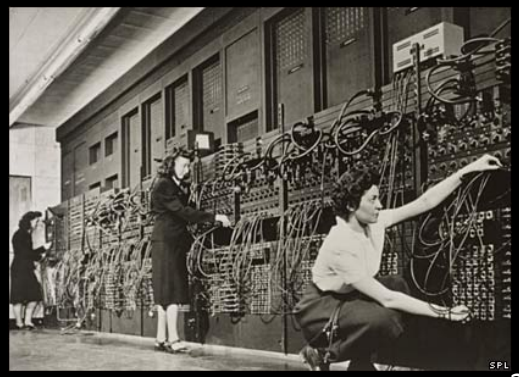


Who Invented Programming?

Ada Lovelace

Grace Hopper

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



Out of the Lab and Into the World

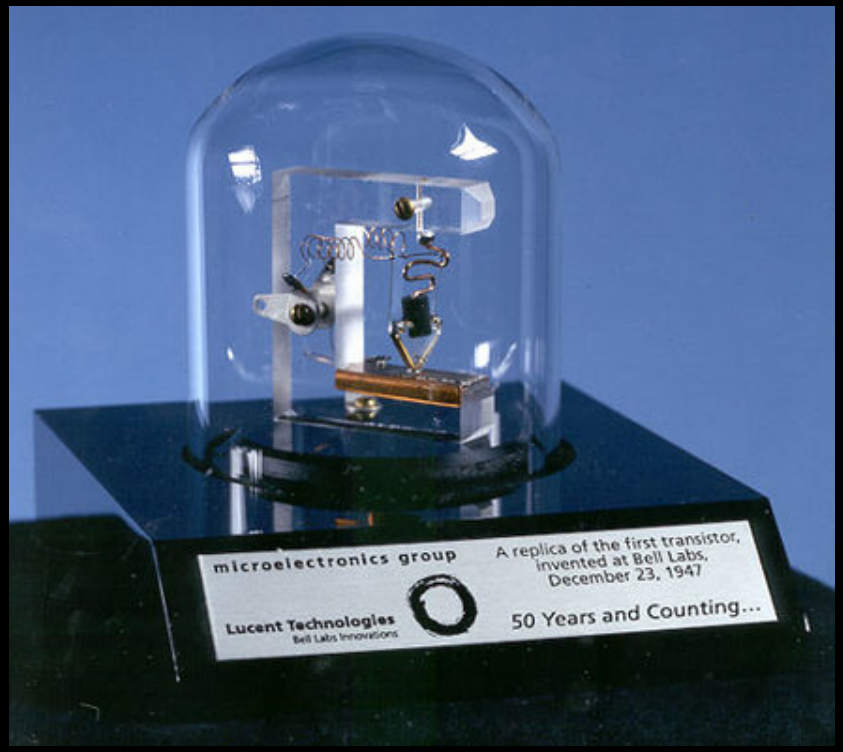
"I think there is a world market for maybe five computers."

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



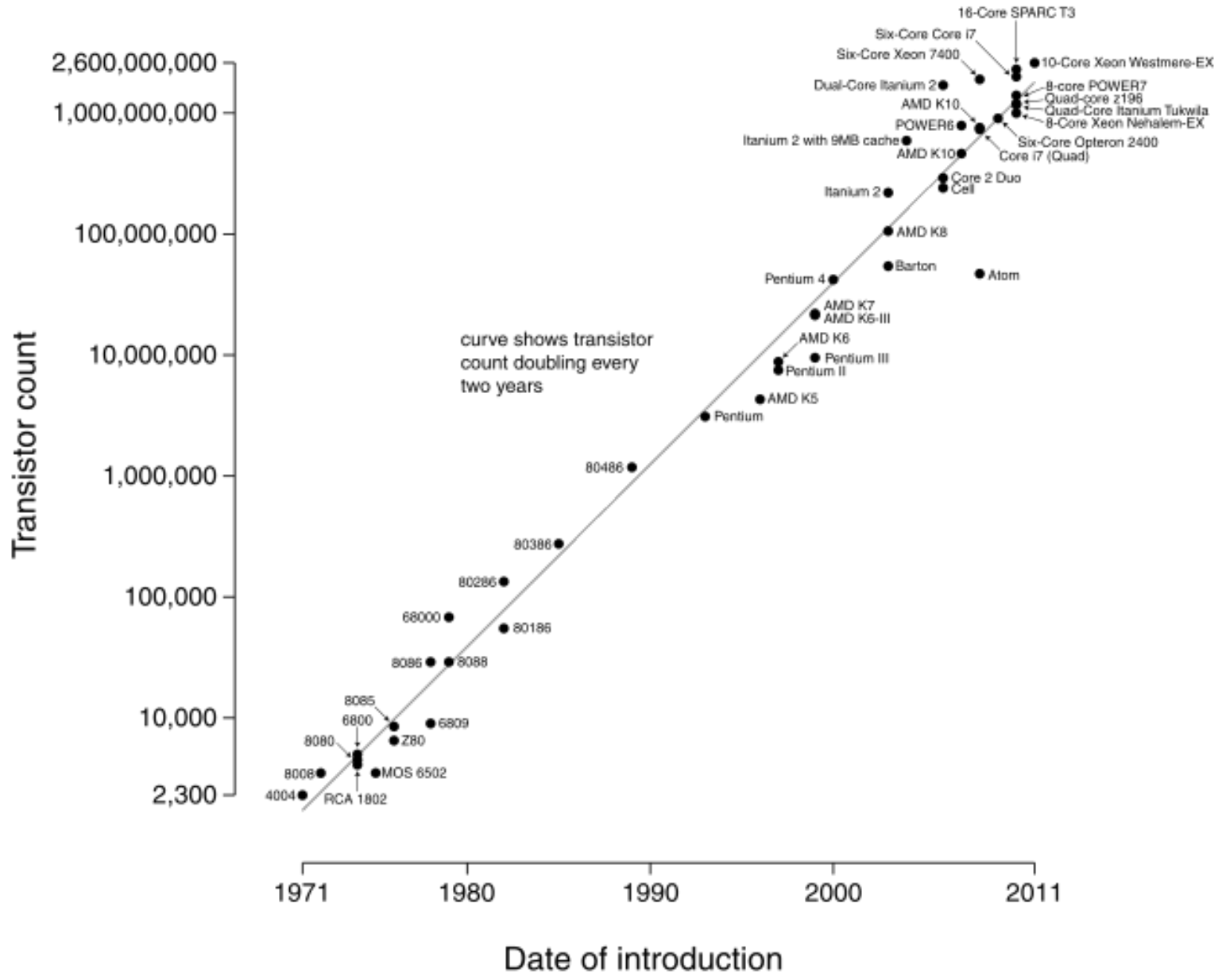
First invented, 1947
1956 Nobel prize in physics

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

The Next Wave

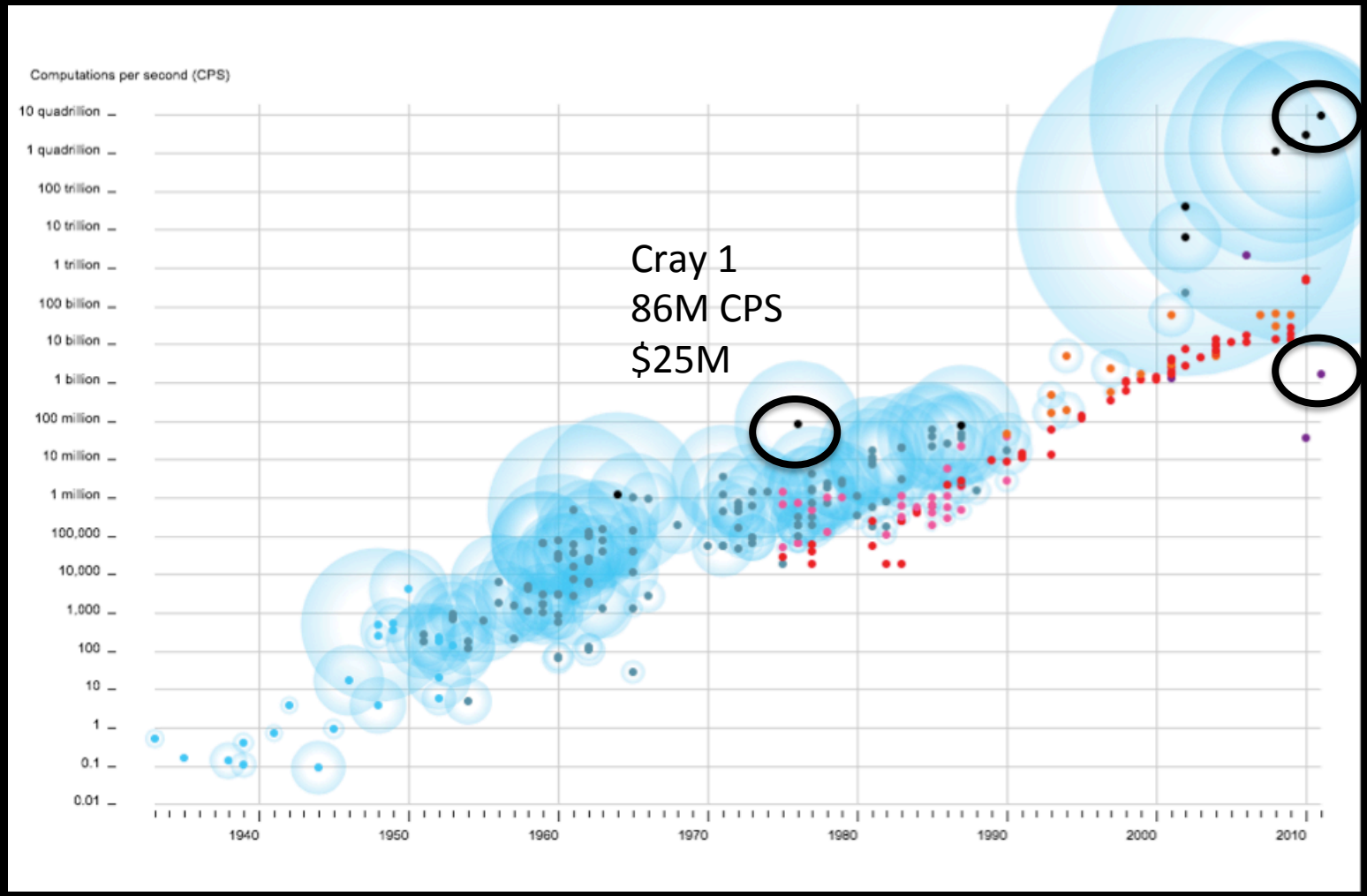
- IBM 360
  - Common instruction set for entire family
  - Registers
  - Microcode
  - Interrupts
  - Floating point

- 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
AMD K10
Quad-Core Itanium Tukwila
8-Core Xeon Nehalem-EX
POWER6
Itanium 2 with 9MB cache
Six-Core Opteron 2400
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
- The 60-70's – the development of the minicomputer (Ics)

DEC PDP8, 1964
-> PDP 11 -> Vax

The Growing Wave

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

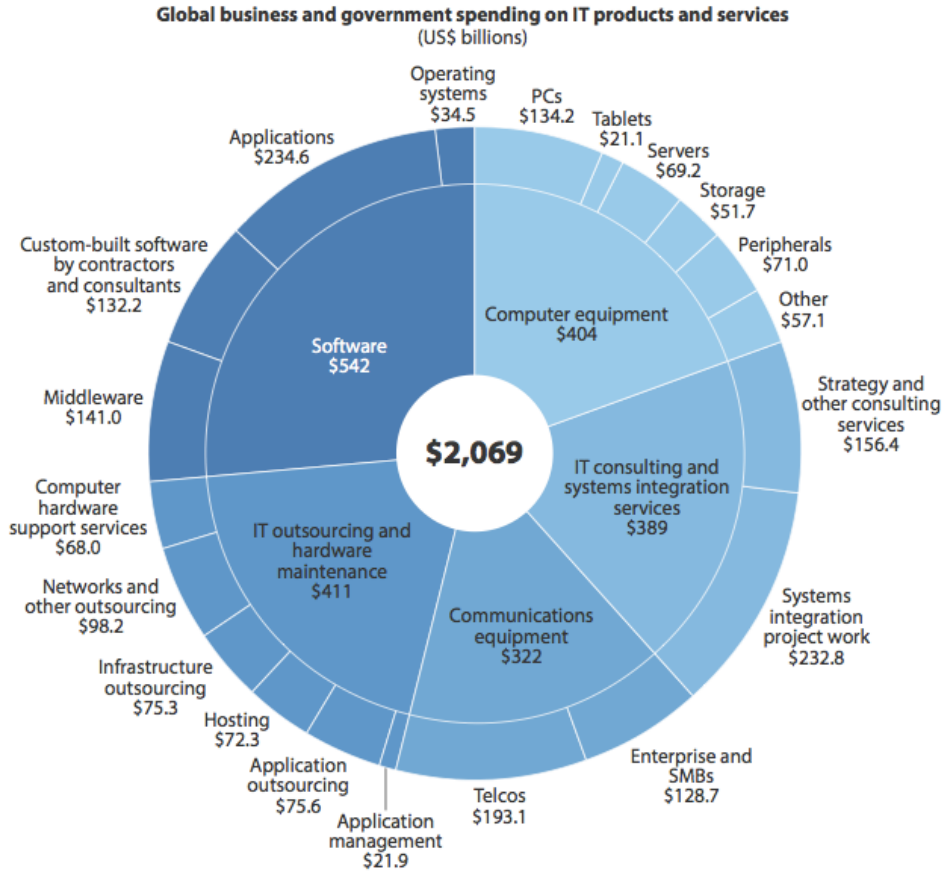
Sun microsystems, late-80's

The PC Revolution

The PC Revolution

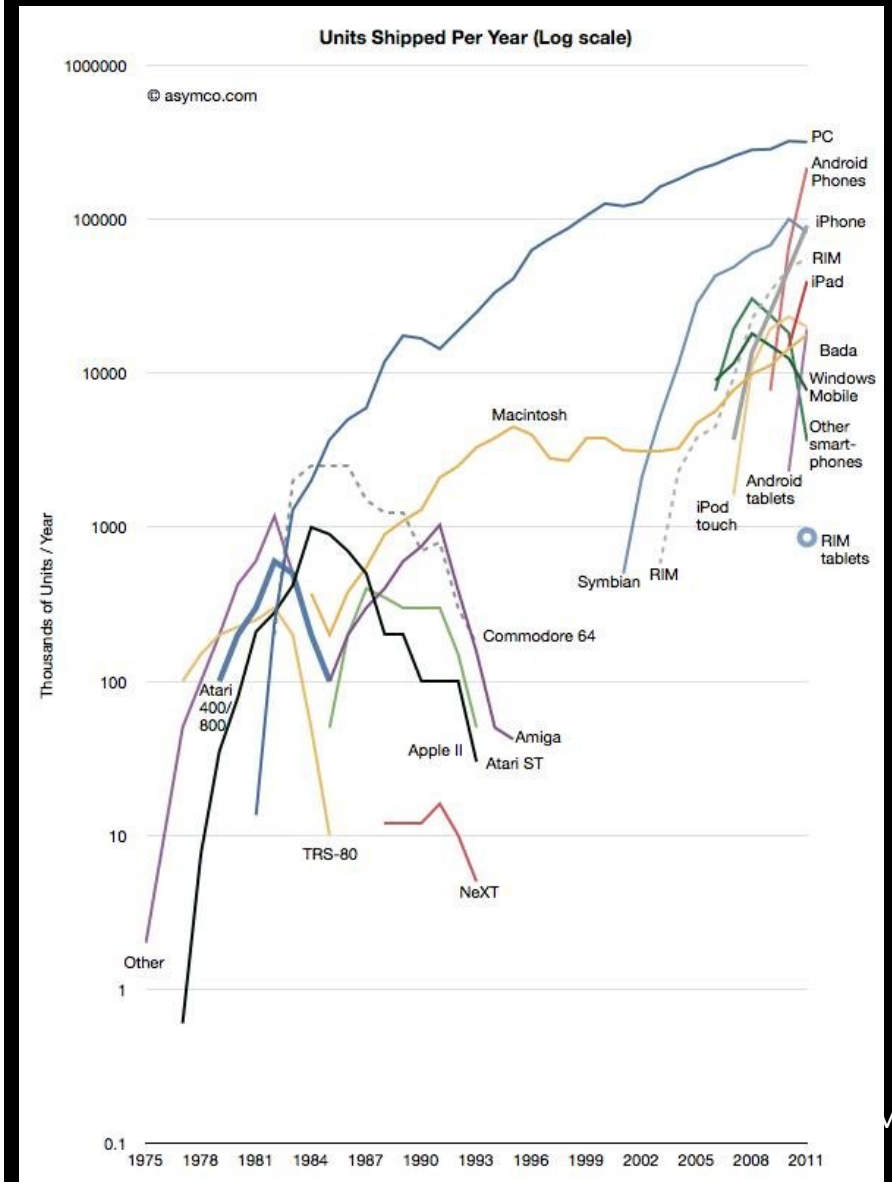
Figure 3 The Global Tech Industry Wheel: Purchases Of IT Products And Services In 2013

The spreadsheet associated with this figure contains additional data.



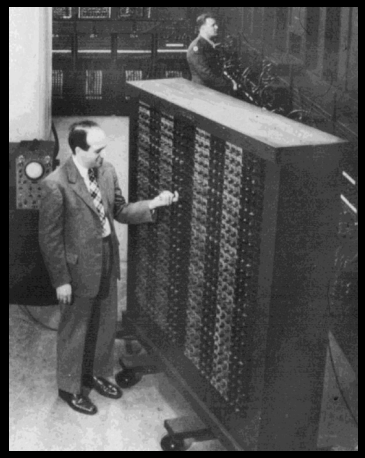
Business Ins

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

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://money.cnn.com/interactive/technology/computing-power-timeline/
- http://en.wikipedia.org/wiki/History_of_computing_hardware_(1960s–present)
- http://en.wikipedia.org/wiki/Sun_Microsystems
- http://www.businessinsider.com/the-complete-history-of-computer-and-gadget-sales-in-one-elegant-chart-2012-1
- http://en.wikipedia.org/wiki/Honeywell_v._Sperry_Rand

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How Did Computing Come to Be?
Computing For the Masses

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For Today

- What are your first thoughts when you think of computing?
- What are some of the threads that have opened up computing to broader society?
- What are the social impacts/questions that face computing today?

Some Other Questions

- Where does software fit in the world?
  - More like a book?
  - More like a device?
- How does the business of software differ than the business of building "stuff"?

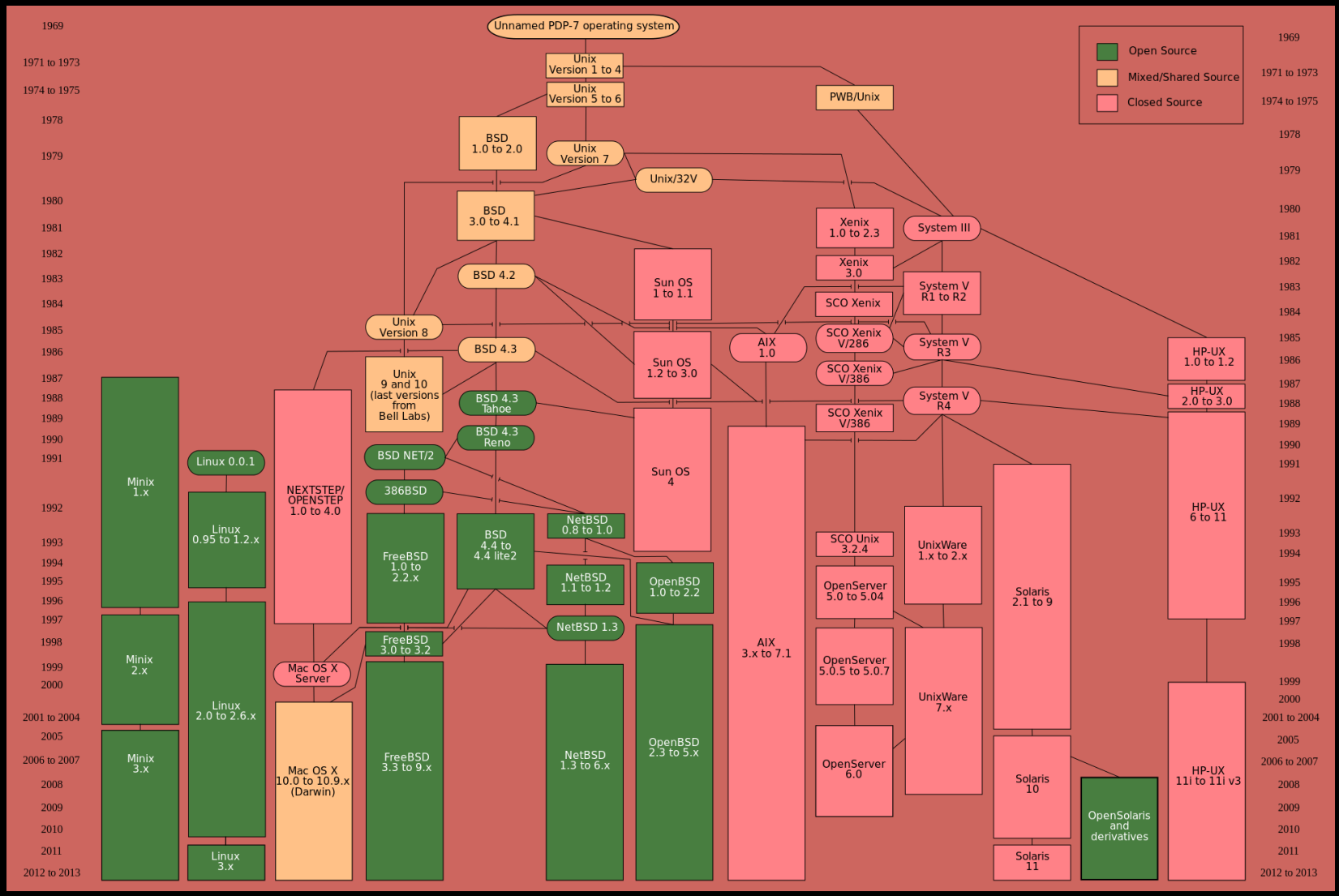
From Machines to Software to Shareware

- What is an OS?
- How is a Modern OS different than early OS?
- When and where did Unix begin?
  - 1972, AT&T Bell Labs
  - Rewrite of Multics in C (Richie)
  - Developed by Ken Thompson
  - One of the first portable OS's
  - Developed as a "programmers workbench"

What are BSD and Linux?

- BSD (1977) = Berkeley Software Distribution
  - An open source form of Unix
- Linux (1991) = Unix-like operating system
  - known for its efficient and powerful kernel
  - Also known for its distribution policy

Unix Lineage



What Is Open Source?

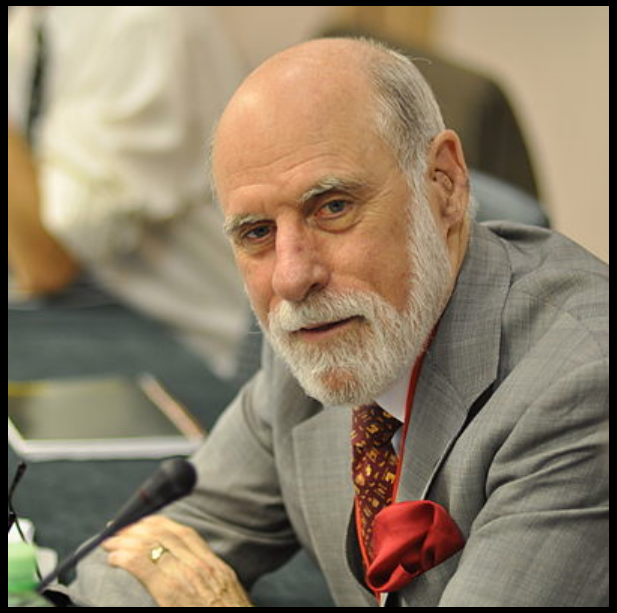
- Open source licenses grant licensees the right to copy, modify and redistribute source code (or content).
  - Apache
  - BSD
  - GNU
- Now O(180k) projects, 1400 licensing models!

Open Source Development

- OSF started in the late 80's – new standard for UNIX
- Modern open-source model developed in the late 90's (with the rise of the internet)
- Collection of development tools (CVS, SVN, GIT ….)
- Some projects (e.g. Linux) with a very advanced structure of accepting changes

Another Quiz

- After the computer itself, what invention probably had the largest impact in computing?

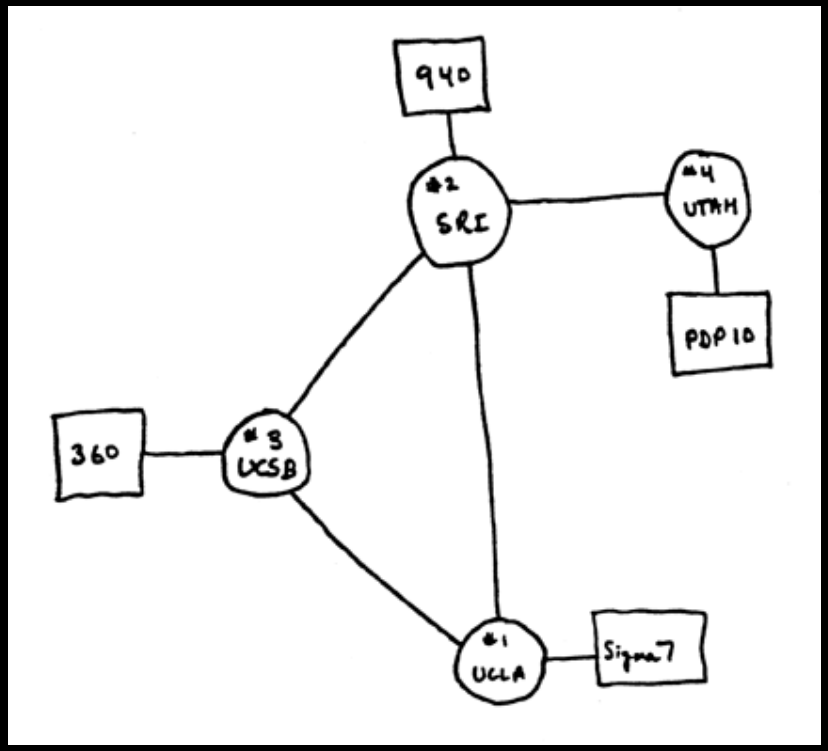


Vinton Cerf

Robert Kahn

Another Quiz

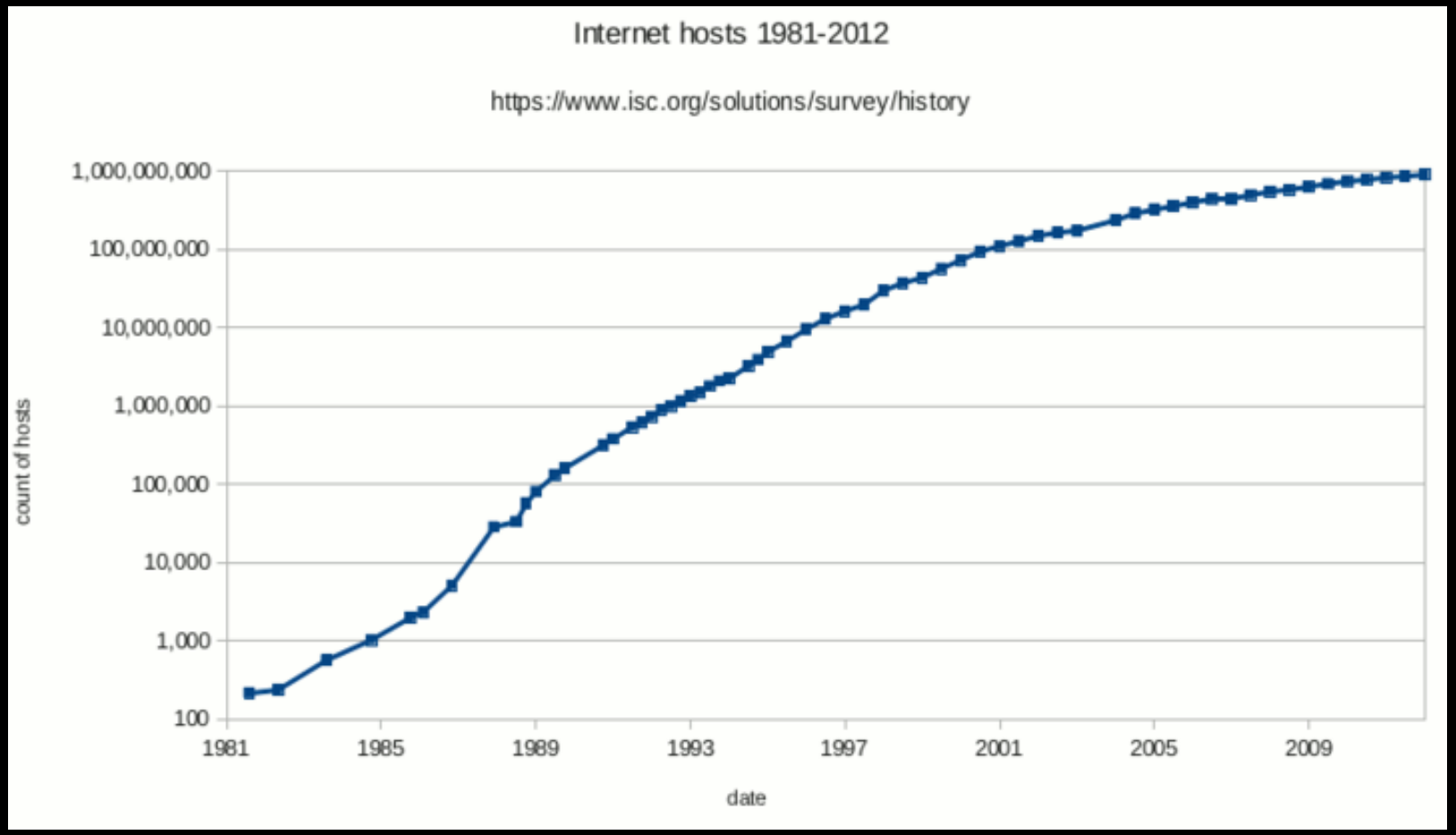
- What were the major differences between land-line phones and arpanet?
  - Digital
  - Packet switched



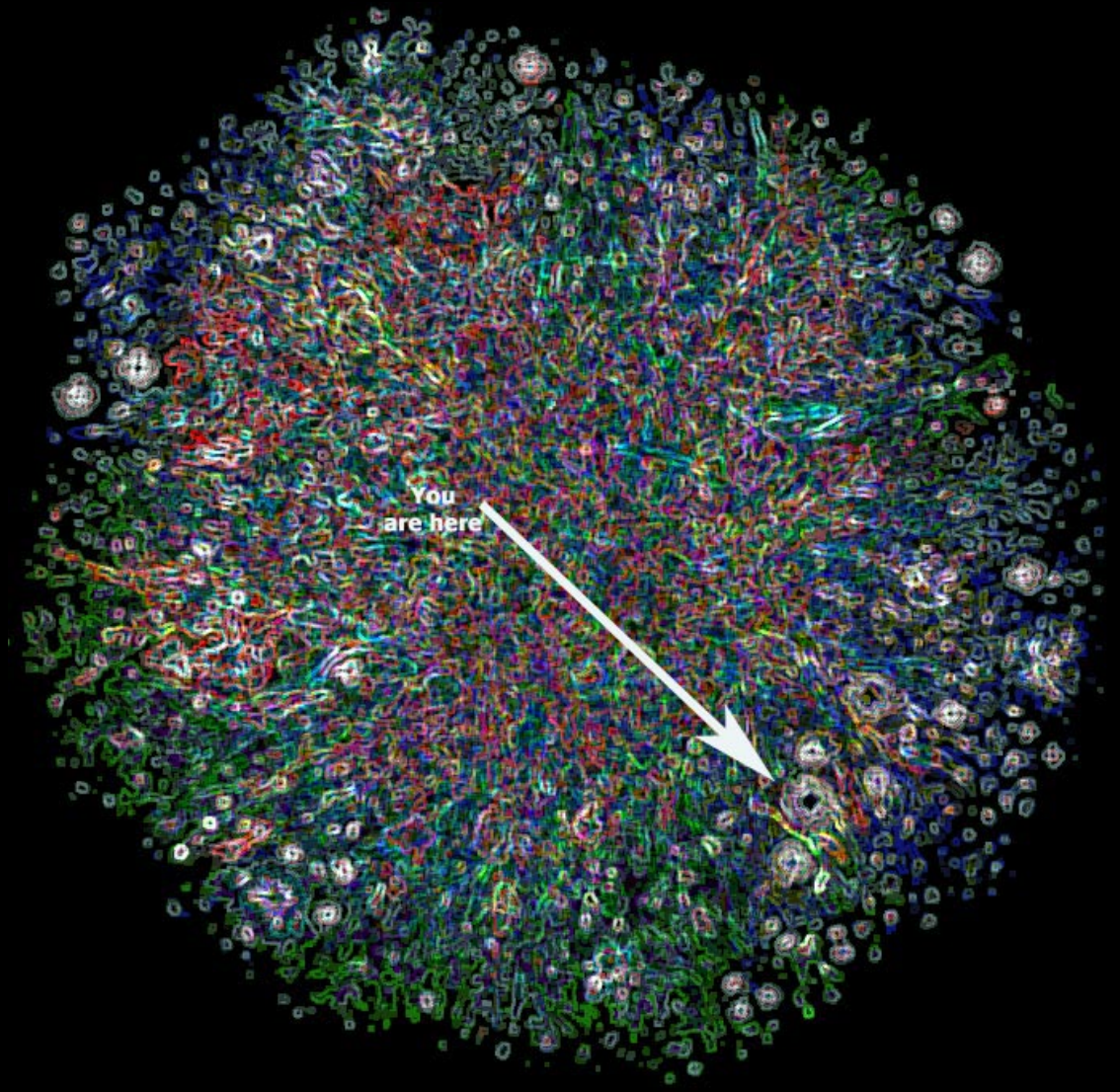
More Quiz

- When did the internet start?
  - First was the ARPAnet (1969)
  - Ethernet (1980) for local networks on shared backbone
  - NSFNET 1986 connecting universities
  - 1995 – first commercial internet
  - 1999 – first wireless standard
  - 2014 – net neutrality at issue!

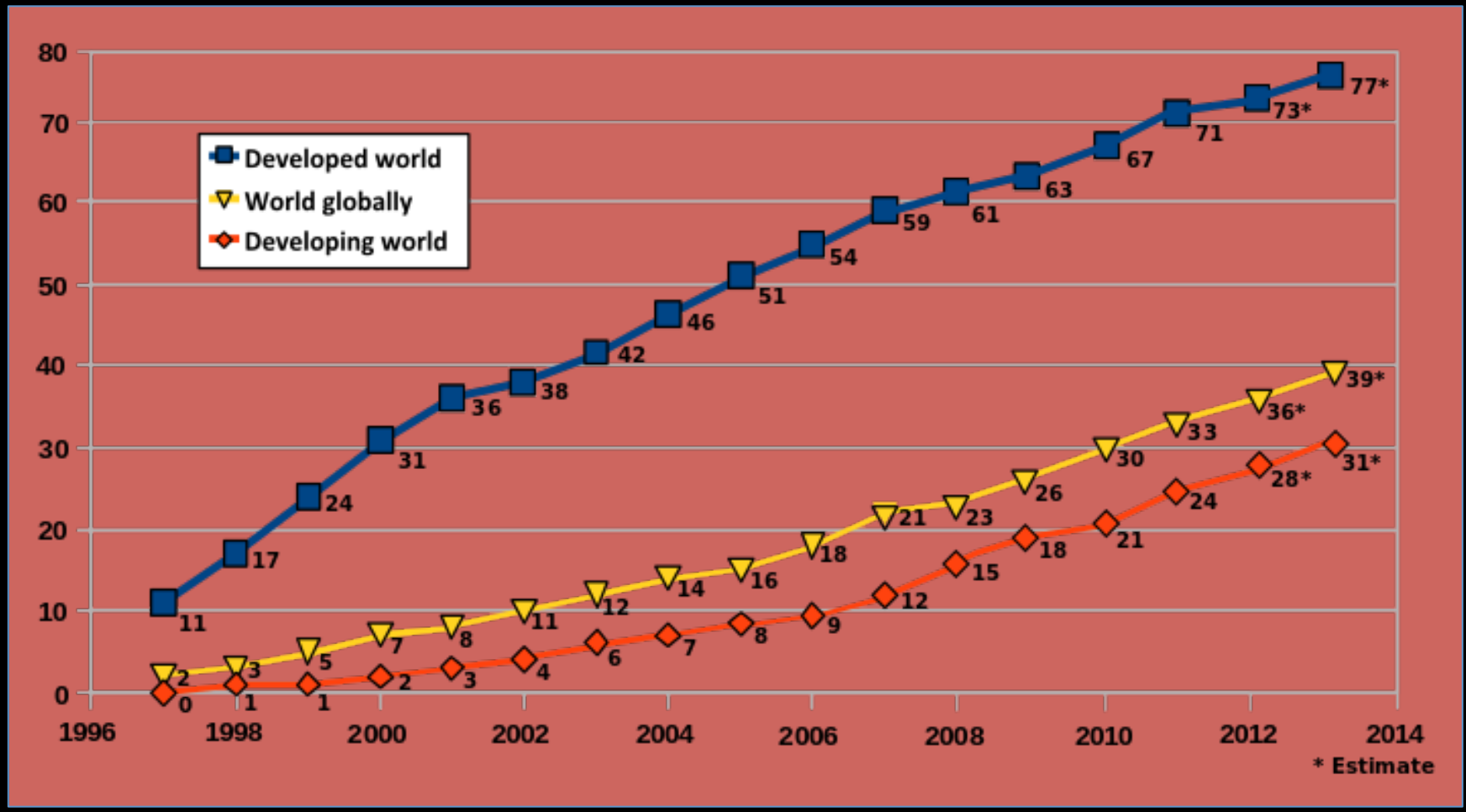
How Many Hosts on the Internet?



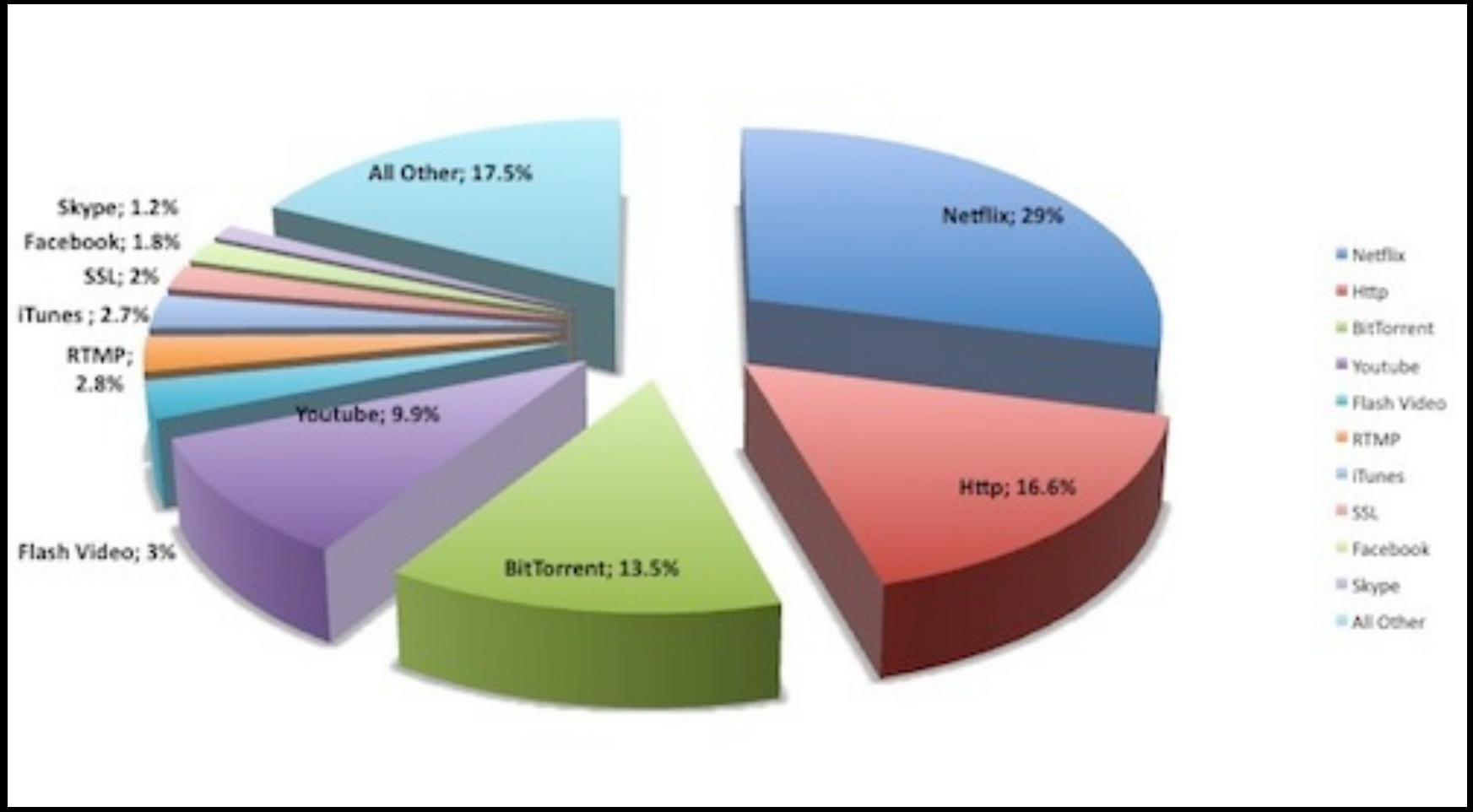
The Internet Today



How Pervasive is the Internet?

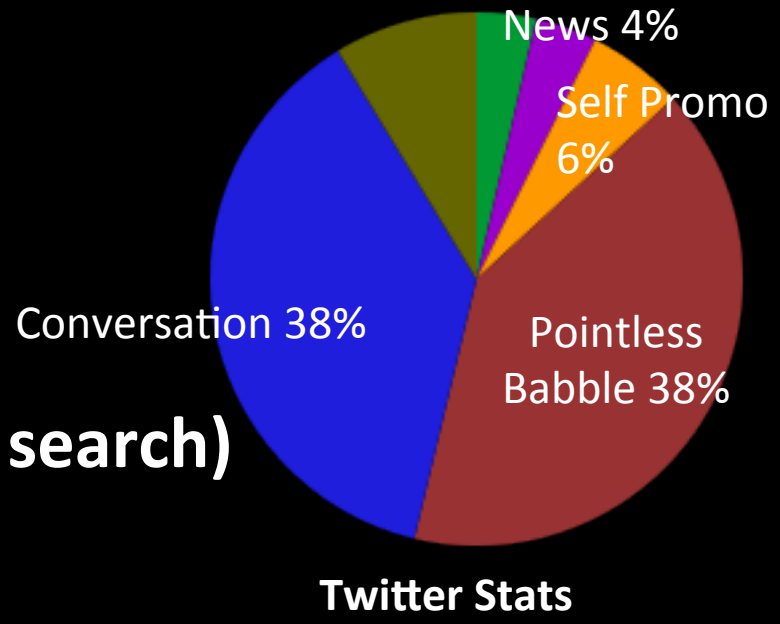


What Do We Do With Bandwidth?



Some Statistics

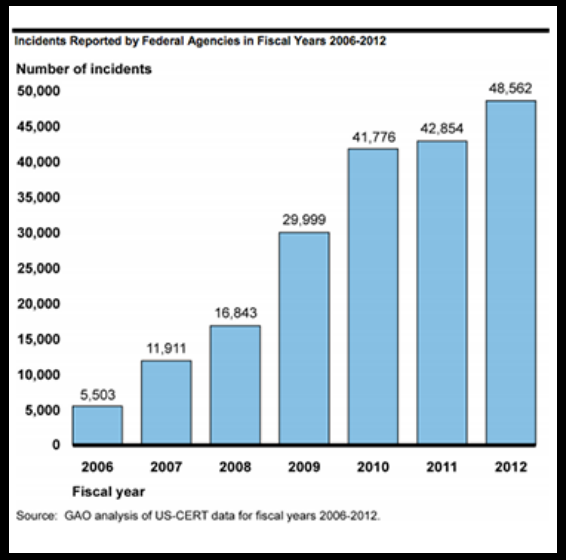
- **Computing Stats**
  - **Email (100 trillion/yr)**
  - **SMS (7 trillion/yr)**
  - **Twitter (60 B tweets/0.5T search)**
  - **Youtube 1B views/day**



http://www.internetlivestats.com/one-second/#google-band

A New Battle Ground?

- Target and Home Depot have had millions of credit cards stolen
- US/Israel culpability in Iranian uranium refinement
- Various denial of service attacks on companies
- IP theft



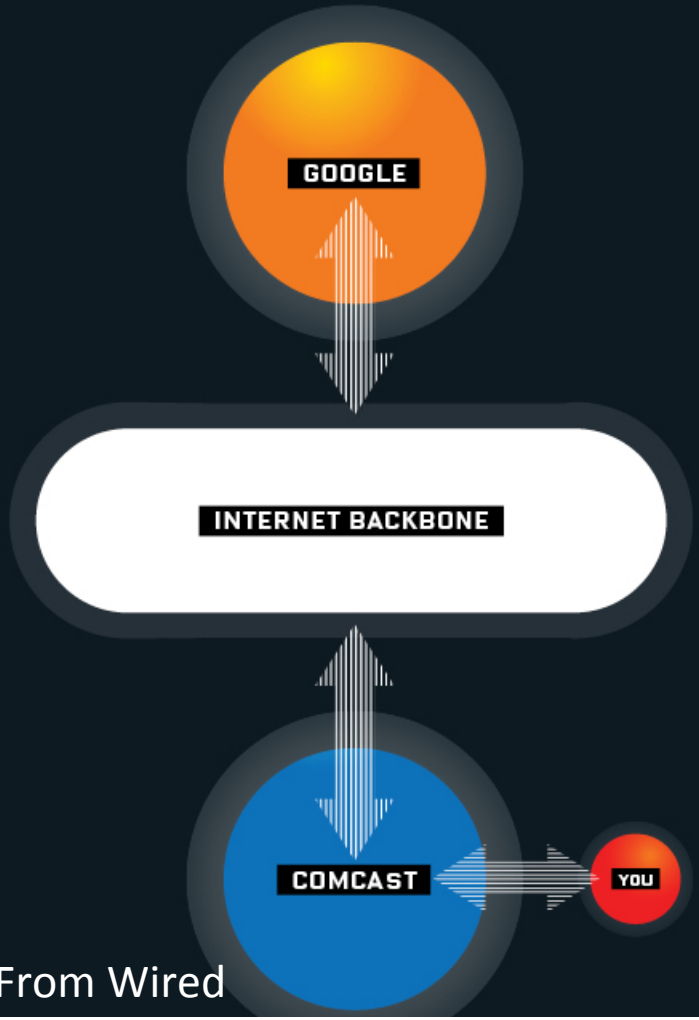
What Is Net Neutrality?

- …the principle that Internet service providers and governments should treat all data on the Internet equally, not discriminating or charging differentially by user, content, site, platform, application, type of attached equipment, and modes of communication.

  – From Wikipedia

What you think the Internet looks like

If you think at all about how Google and other web services arrive at your home, you probably think that Google sends stuff into a massive "internet backbone" of cables and data centers, before it streams into your living room through Comcast or Verizon or some other home internet service provider. But it's more complicated than that.

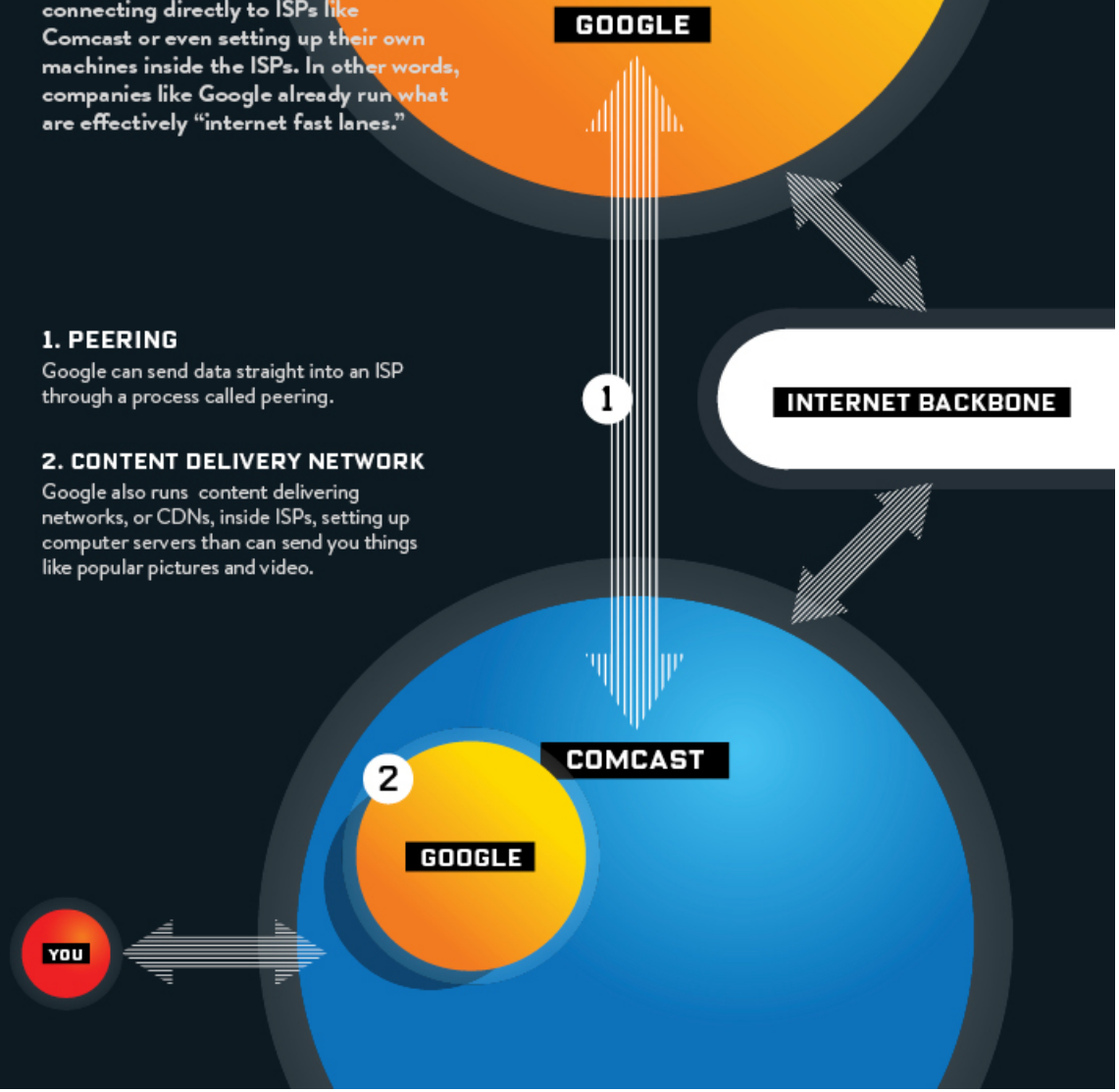


What the Internet really looks like

Today, so that they can get you stuff quicker, massive web services like Google will bypass the internet backbone, connecting directly to ISPs like Comcast or even setting up their own machines inside the ISPs. In other words, companies like Google already run what are effectively "internet fast lanes."

1. PEERING
Google can send data straight into an ISP through a process called peering.

2. CONTENT DELIVERY NETWORK
Google also runs content delivering networks, or CDNs, inside ISPs, setting up computer servers than can send you things like popular pictures and video.



From Wired

Questions To Debate

- Is the net today really neutral?
- Do you think net neutrality is good/bad/ irrelevant -- why?
- What (alternative) rules would you impose?