Introduction to Operating Systems

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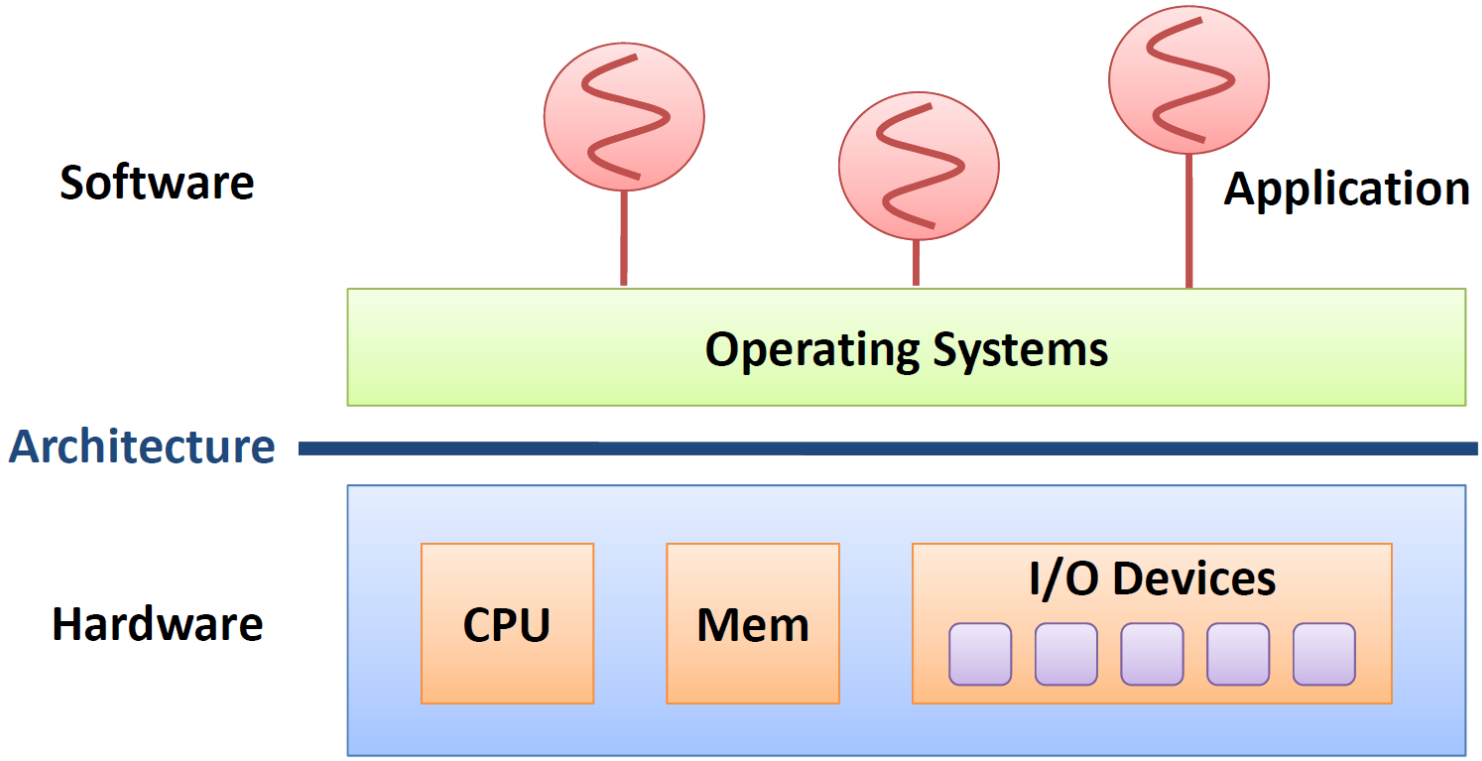
Today's topics

What is OS?

History of OS

Operating system?

Computer systems internals



Why do we learn OS?

To graduate?

To make a better OS or system

- Functionality
- Performance/cost
- Reliability
- Energy efficiency

To make a new hardware up and running

To design OS-aware hardware

To understand computer systems better

Just for fun

What is OS? (1)

Application view

- Provides an execution environment for running programs

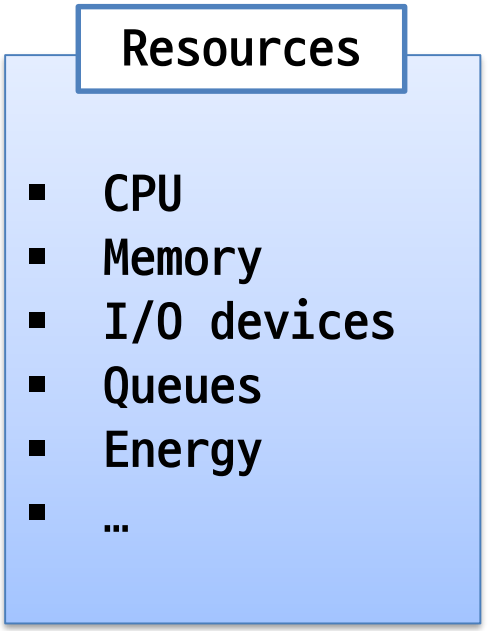
- Provides an abstract view of the underlying computer system
  - Processors → Processes, Threads
  - Memory → Address spaces (virtual memory)
  - Storage → Volumes, Directories, Files
  - I/O Devices → Files (ioctls)
  - Networks → Files (sockets, pipes, ...)
  - …

What is OS? (2)

System view

- Manages various resources of a computer system

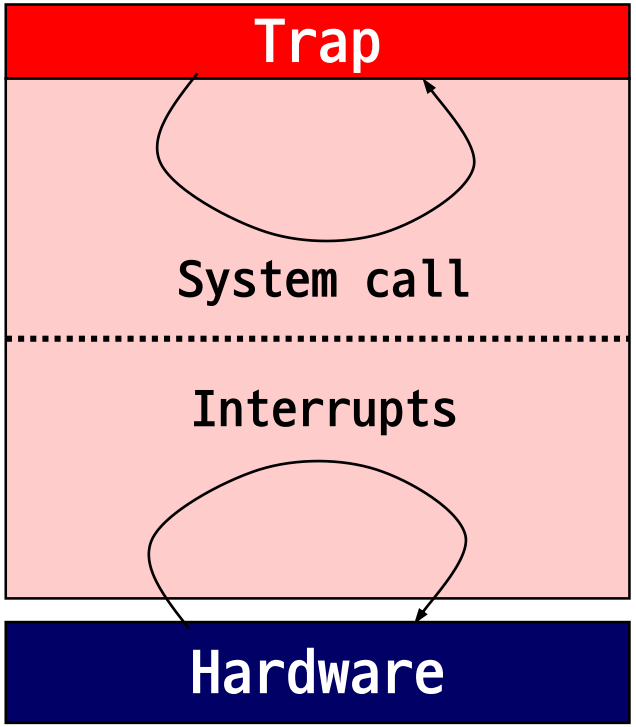
- Sharing
- Protection
- Fairness
- Efficiency
- ...



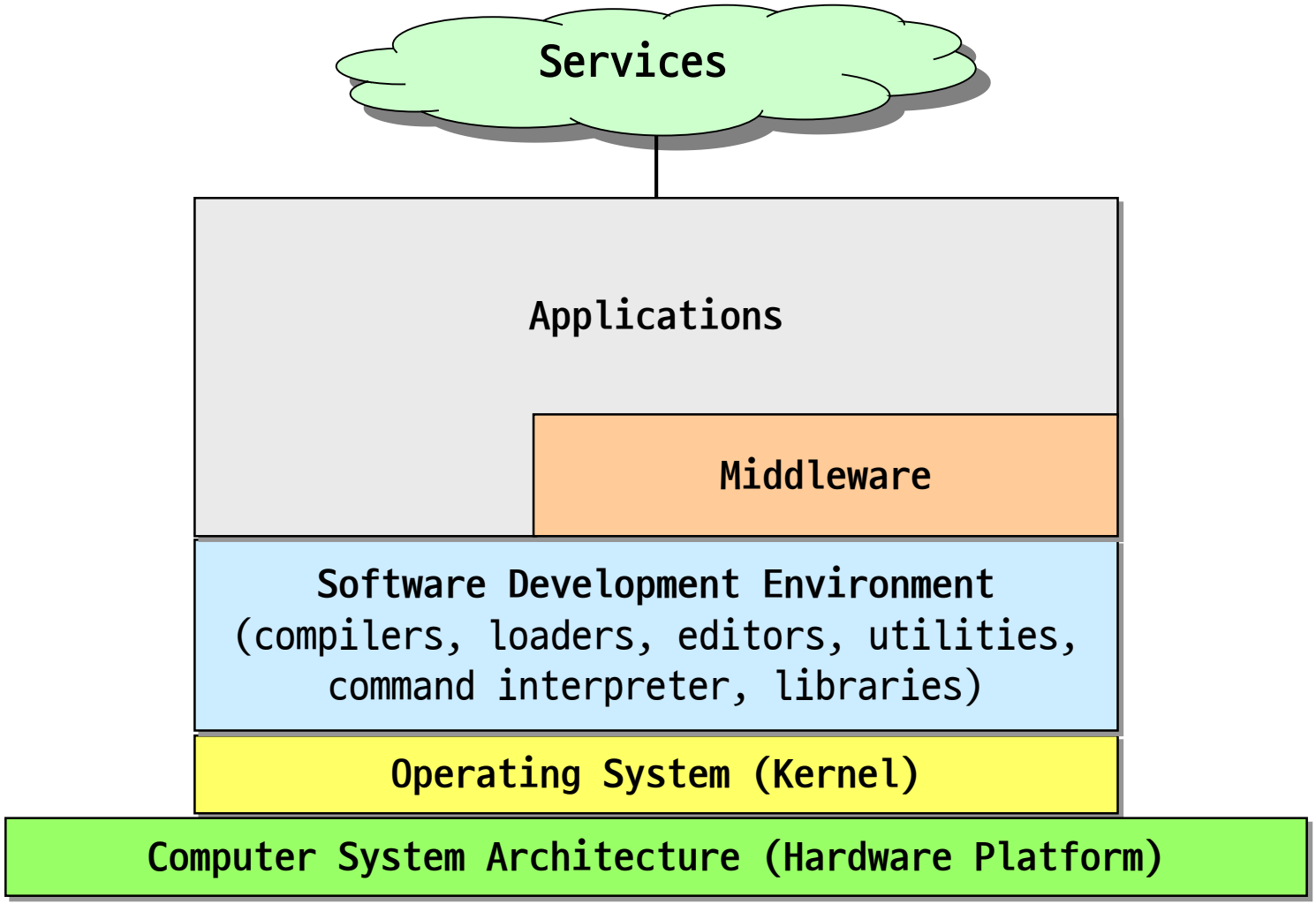
What is OS? (3)

Implementation view

- Highly-concurrent, event-driven software



Computer systems

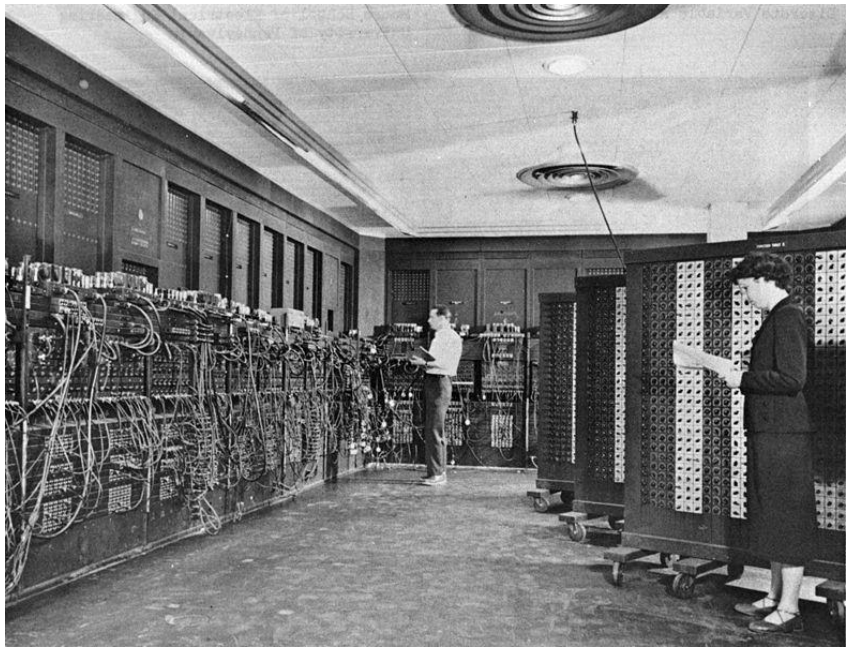


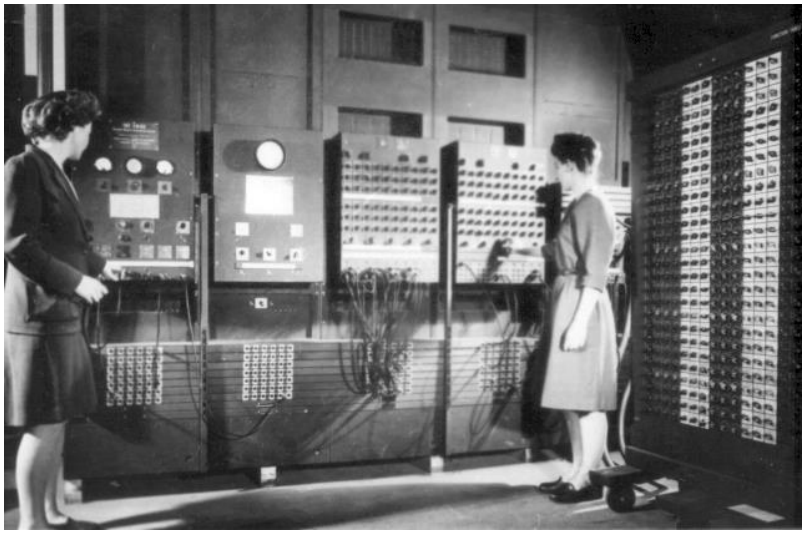
1st Generation (1945-55) - Vacuum tubes and plugboards

No OS

No programming languages

No assembly languages





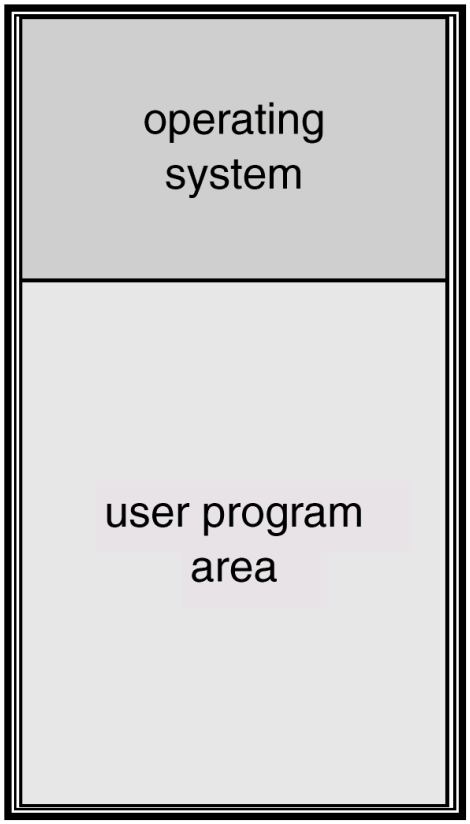
ENIAC (Electronic Numerical Integrator And Computer), 1946

2nd Generation (1955-65) - Transistors and mainframes

Batch systems

- One job at a time
- Card readers, tape drives, line printers

- OS is always resident in memory and merely transfers a control
- CPU is underutilized due to the bottleneck in I/O



3rd Generation (1965-80) - Integrated circuits (ICs)

Architectural advances

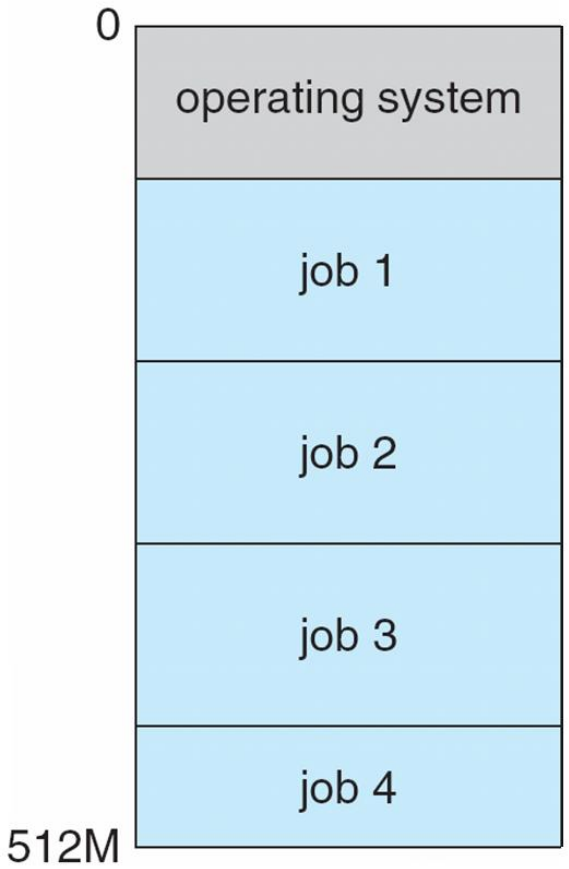
- Using ICs: better performance/price
- Disk drives
- On-line terminals

- The notion of "Computer Architecture":
  - IBM System/360 family

3rd Generation (1965-80) - Integrated circuits (ICs)

Multiprogrammed systems

- Increase CPU utilization
- OS features
  - Job scheduling
  - Memory management
  - CPU scheduling
  - Protection
- Spooling (Simultaneous Peripheral Operation On-Line)



3rd Generation (1965-80) - Integrated circuits (ICs)

Time-sharing systems

- Improve response time
- OS features
  - Swapping
  - Virtual memory
  - File system
  - Sophisticated CPU scheduling
  - Synchronization
  - Interprocess communication
  - Interactive shell
  - More protection, ...

4th Generation (1980–) – LSIs & VLSIs

Architectural advances

- Microprocessors: smaller and faster
- Storage: larger and faster
- Personal computers
- CPU work is offloaded to I/O devices

Modern OS features

- GUI (Graphical User Interface)
- Multimedia
- Internet & Web
- Networked / Distributed, etc.

The computer revolution

Progress in computer technology

- Underpinned by Moore's Law

Makes novel applications feasible

- Computers in automobiles
- Cell phones
- Human genome project
- World Wide Web
- Search Engines
- AI computation

Computers are pervasive and mobile

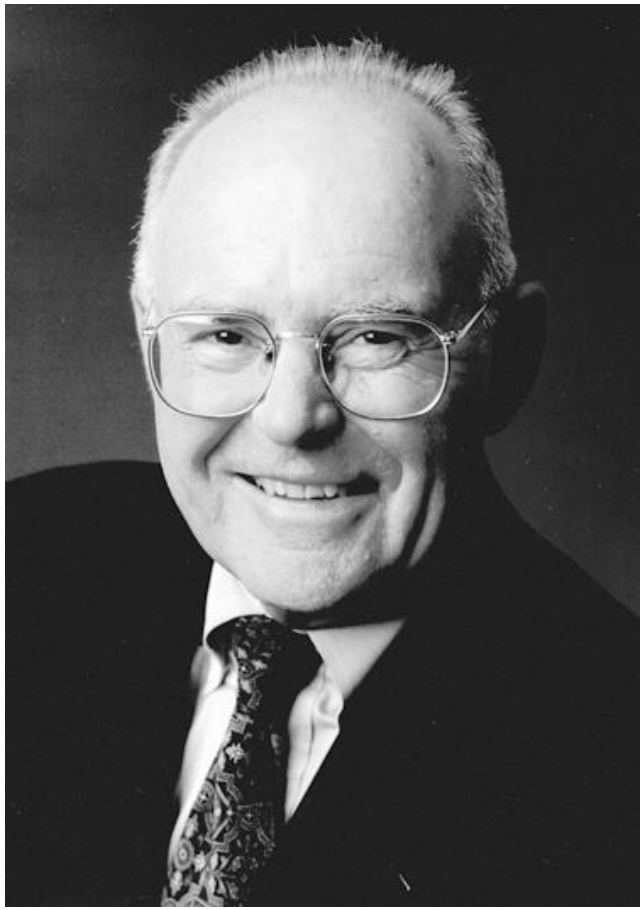
Gordon Moore, 1929 –

Cofounded Intel in 1968 with Robert Noyce

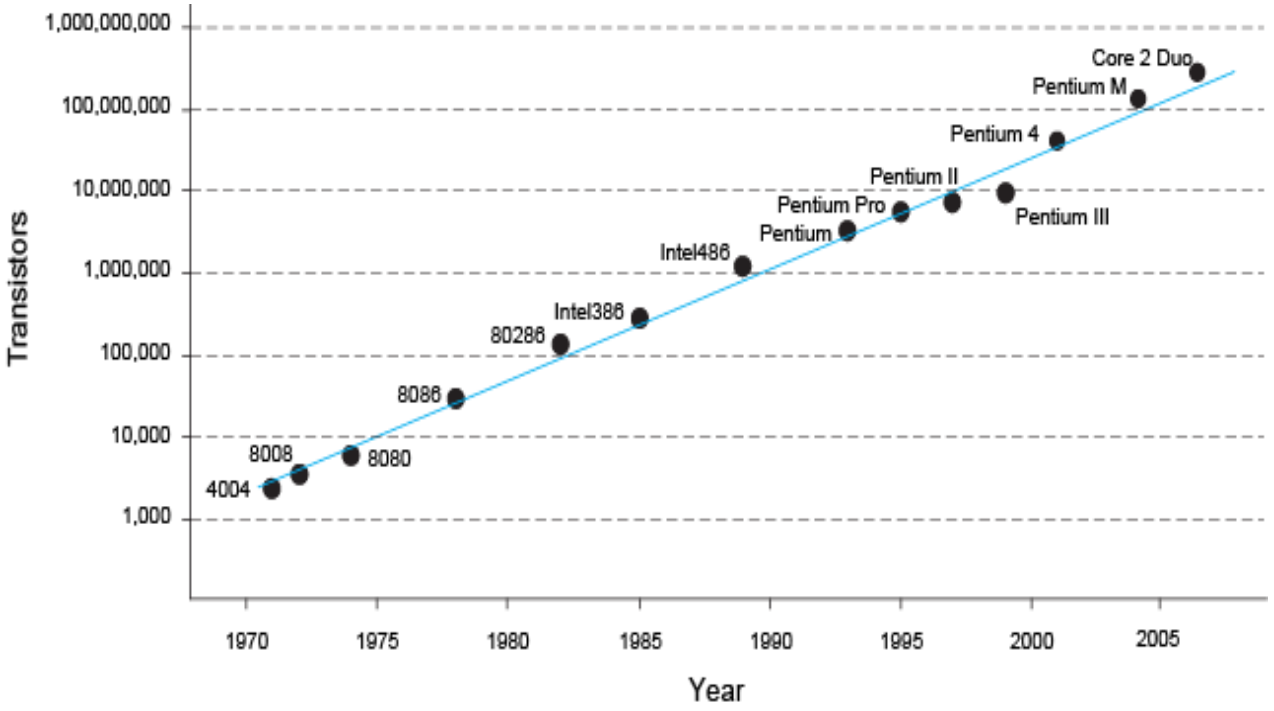
Moore's Law

- The number of transistors on a computer chip doubles every year (observed in 1965)

Since 1975, transistor counts have doubled every two years



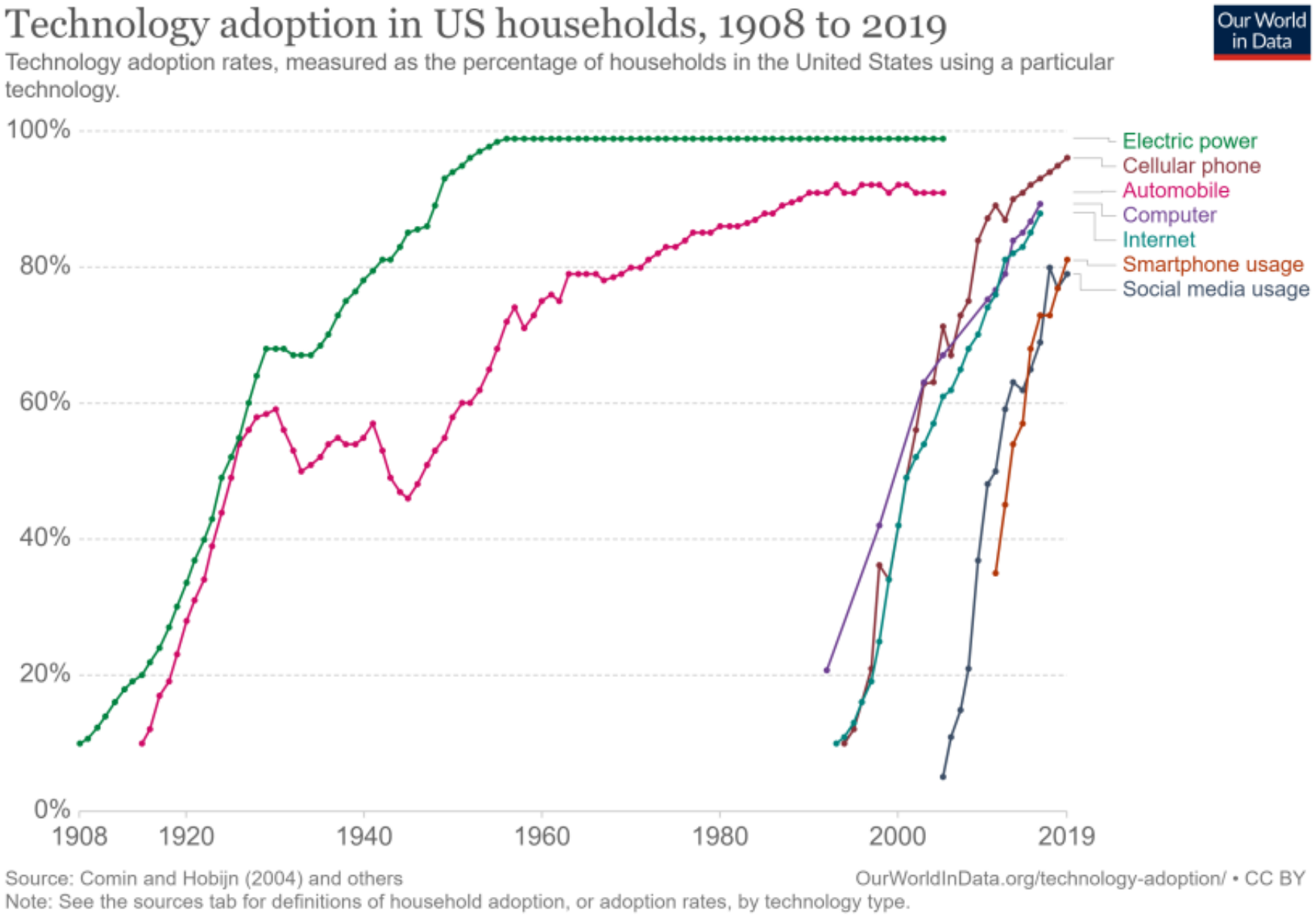
Moore's law



"If the automobile had followed the same development cycle as the computer, a Rolls-Royce would today cost $100, get one million miles to the gallon, and explode once a year . . ."

– Robert Cringley

Adoption of technology



OS history

CTSS (1961, MIT)
(Compatible Time Sharing System)

OS/360 (1964, IBM)

MULTICS (1965, MIT, Bell Labs, GE)
(MULTiplexed Information and Computing Service)

Unix (1969, Bell Labs)

Multics (1)

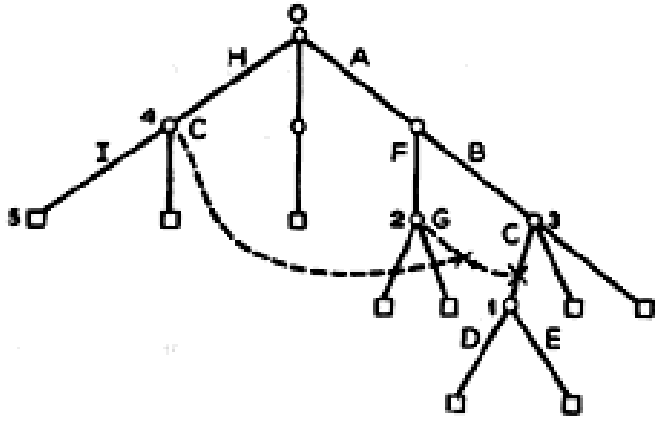
Multics

- Multiplexed Information and Computing Service
- A time-shared, multi-processor mainframe "computing utility"
- Originally started by MIT, GE, and Bell Labs for GE-645, a 36-bit system, in 1965
  - Bell Labs quit in 1969 and built Unix
  - GE's computer business, including Multics, was taken over by Honeywell in 1970
  - Last system shutdown on 10/31/2000
- http://www.multicians.org

Multics (2)

Multics innovations

- Hierarchical file system
  - File / directory / path name / working directory
  - Access Control Lists (ACLs)
  - Long names on entries
  - Multiple names on entries
  - Symbolic links
  - Storage quotas
  - Removable devices
  - The backup procedures



- Lots of developments in management of virtual memory including segmentation and paging

Multics (3)

Multics innovations (cont'd)

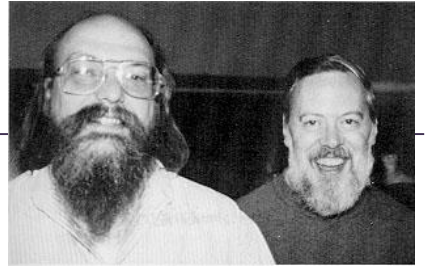
- Separating the command shell from the OS kernel
- Dynamic linking
- Implementation of an OS in a high level language (PL/1)
- Management of shared memory
- Mapping of logical disk volumes onto physical volumes
- Many developments in the area of secure computer systems
  - Multics was rated B2 by the NCSC in 1985
  - A subsequent system (based on the Multics experience) built by Honeywell was the first computer system ever rated A1

Multics (4)

Multics innovations (cont'd)

- Multics Relational Data Store (MRDS) in 1976
  - The first commercial relational DBMS
  - The MRDS query language was similar to early SQL
  - Concurrent access to a database by multiple processes was supported
  - The database could be backed up in its entirety
- Spreadsheets were developed on the Multics platform
- Multics supports BCPL, BASIC, APL, FORTRAN, LISP, C, COBOL, ALGOL 68, and Pascal
- Many optimizations for the LISP language through work on the Multics MACLISP compiler

Unix (1)



Ken Thomson & Dennis Ritchie

"… When BTL (Bell Telephone Laboratories) withdrew from the Multics project, they needed to rewrite an operating system in order to play space war on another smaller machine (a DEC PDP-7 with 4K memory for user programs). The result was a system which a punning colleague called UNICS (UNiplexed Information and Computing Services) – an 'emasculated Multics'; no one recalls whose idea the change to UNIX was."

-- Peter H. Salus, A Quarter Century of Unix, Addision-Wesley, 1994.

"… It was the summer of '69. In fact, my wife went on vacation to my family's place in California.... I allocated a week each to the operating system, the shell, the editor, and the assembler, to reproduce itself, and during the month she was gone, it was totally rewritten in a form that looked like an operating system, with tools that were sort of known, you know, assembler, editor, and shell .... Yeh, essentially one person for a month."

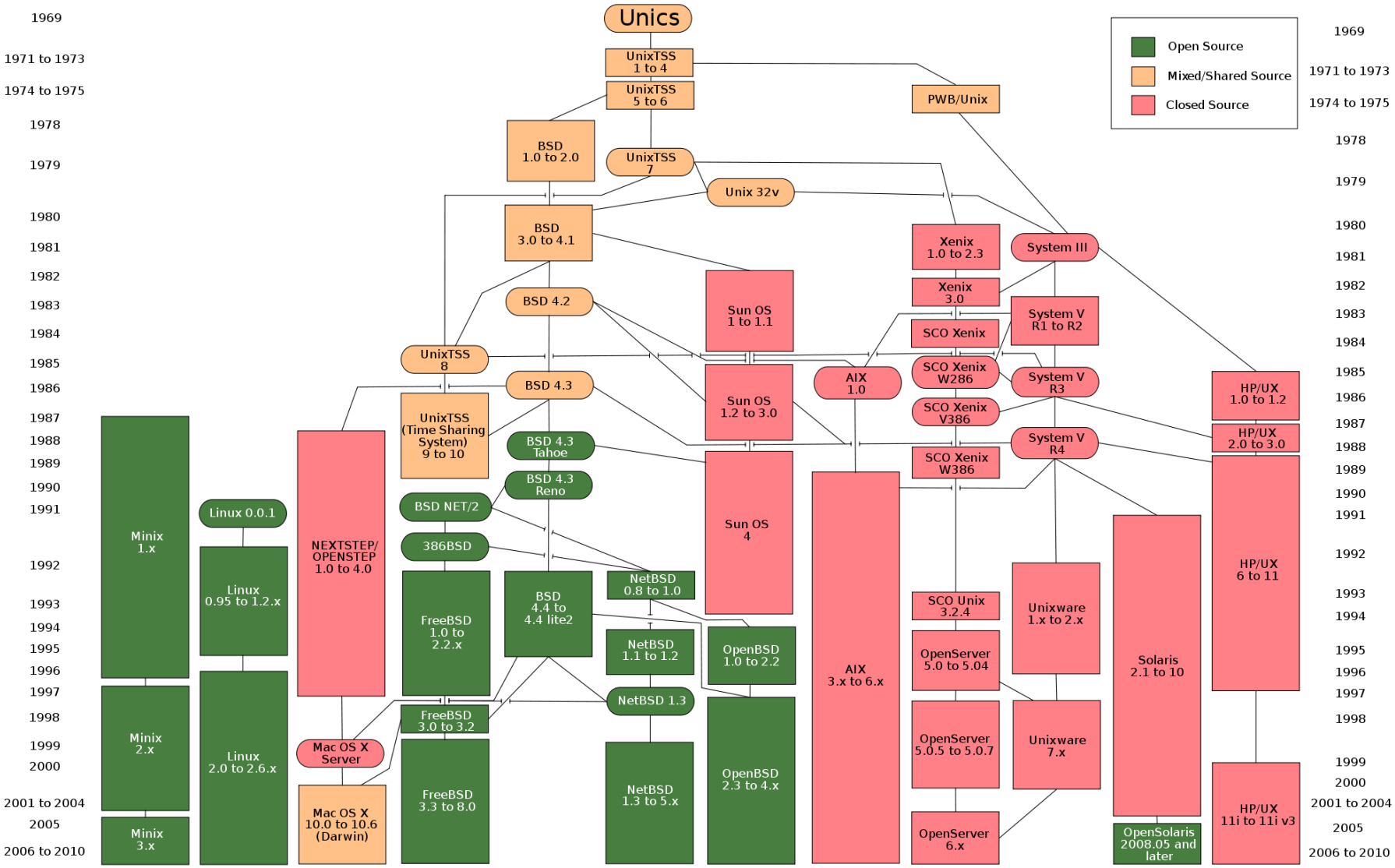
-- Ken Thompson

Unix (2)

Unix Features

- Hierarchical file systems
  - Special files: uniform I/O, naming, and protection
  - Removable file systems via mount/umount
  - i-node
- Process control
  - fork(), exec(), wait(), exit()
  - Pipes for inter-process communication
- Shells
  - Standard I/O and I/O redirection
  - Filters
  - Command separators
  - Shell scripts
- Signals

Unix (3)


Unics
UnixTSS 1 to 4
UnixTSS 5 to 6
UnixTSS 7
BSD 1.0 to 2.0
BSD 3.0 to 4.1
BSD 4.2
BSD 4.3
BSD 4.3 Tahoe
BSD 4.3 Reno
UnixTSS 8
UnixTSS (Time Sharing System) 9 to 10
BSD NET/2
386BSD
FreeBSD 1.0 to 2.2.x
FreeBSD 3.0 to 3.2
FreeBSD 3.3 to 8.0
BSD 4.4 to 4.4 lite2
NetBSD 0.8 to 1.0
NetBSD 1.1 to 1.2
NetBSD 1.3
NetBSD 1.3 to 5.x
OpenBSD 1.0 to 2.2
OpenBSD 2.3 to 4.x
Unix 32v
PWB/Unix
Sun OS 1 to 1.1
Sun OS 1.2 to 3.0
Sun OS 4
AIX 1.0
AIX 3.x to 6.x
Xenix 1.0 to 2.3
Xenix 3.0
SCO Xenix
SCO Xenix W286
SCO Xenix V386
SCO Xenix W386
SCO Unix 3.2.4
OpenServer 5.0 to 5.04
OpenServer 5.0.5 to 5.0.7
OpenServer 6.x
System III
System V R1 to R2
System V R3
System V R4
Unixware 1.x to 2.x
Unixware 7.x
Solaris 2.1 to 10
OpenSolaris 2008.05 and later
HP/UX 1.0 to 1.2
HP/UX 2.0 to 3.0
HP/UX 6 to 11
HP/UX 11i to 11i v3
Minix 1.x
Minix 2.x
Minix 3.x
Linux 0.0.1
Linux 0.95 to 1.2.x
Linux 2.0 to 2.6.x
NEXTSTEP/ OPENSTEP 1.0 to 4.0
Mac OS X Server
Mac OS X 10.0 to 10.6 (Darwin)
Open Source
Mixed/Shared Source
Closed Source
1969
1971 to 1973
1974 to 1975
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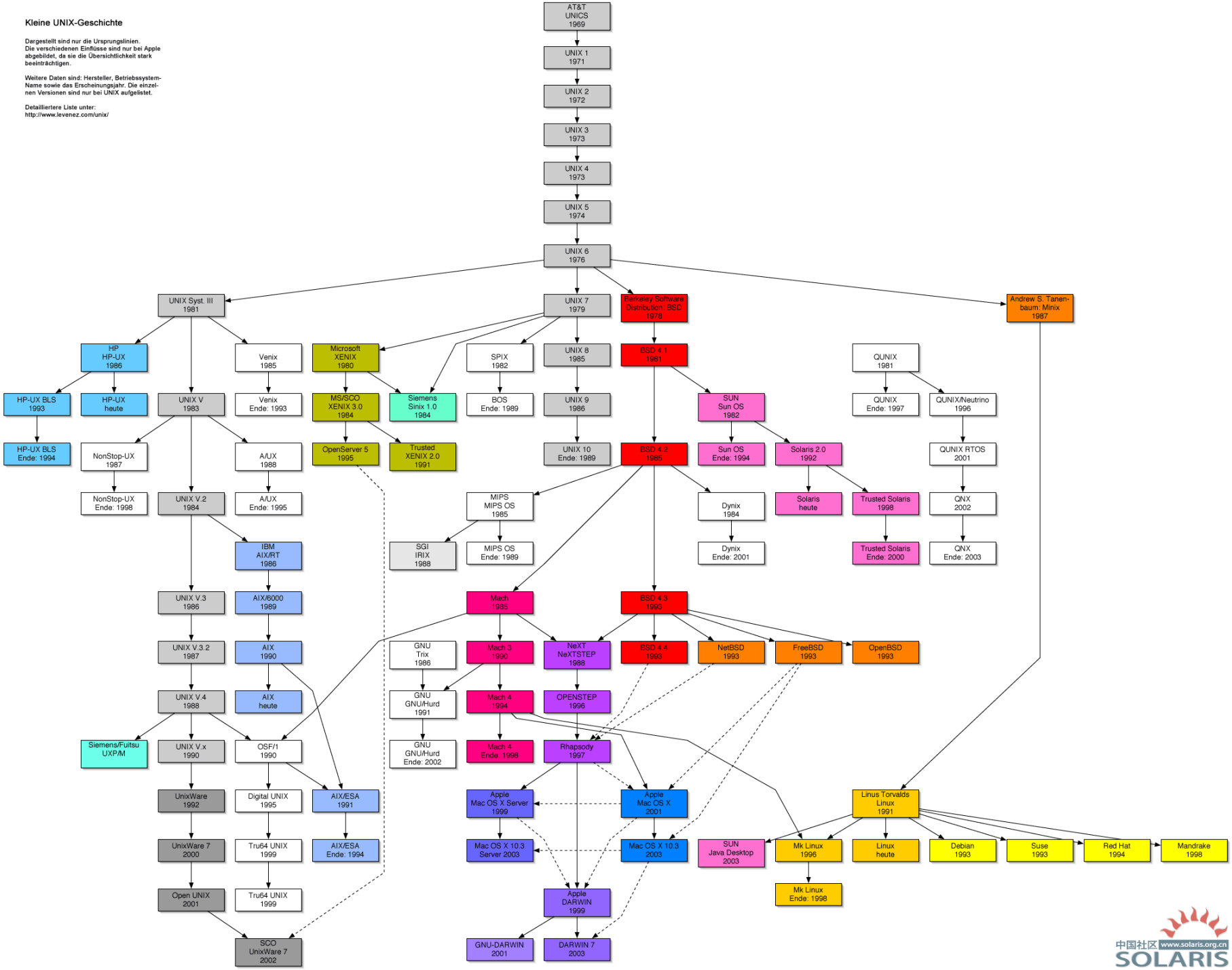
2001 to 2004
2005
2006 to 2010

Kleine UNIX-Geschichte

Dargestellt sind nur die Ursprungslinien.
Die verschiedenen Einflüsse sind nur bei Apple abgebildet, da sie die Übersichtlichkeit stark beeinträchtigen.

Weitere Daten sind: Hersteller, Betriebssystem-Name sowie das Erscheinungsjahr. Die einzelnen Versionen sind nur bei UNIX aufgelistet.

Detailliertere Liste unter:
http://www.levenez.com/unix/



Unix (4)

Sun Solaris

HP HP-UX

IBM AIX

Compaq (Digital) Tru64

SGI Irix

SCO Unixware

Linux

FreeBSD, NetBSD, OpenBSD

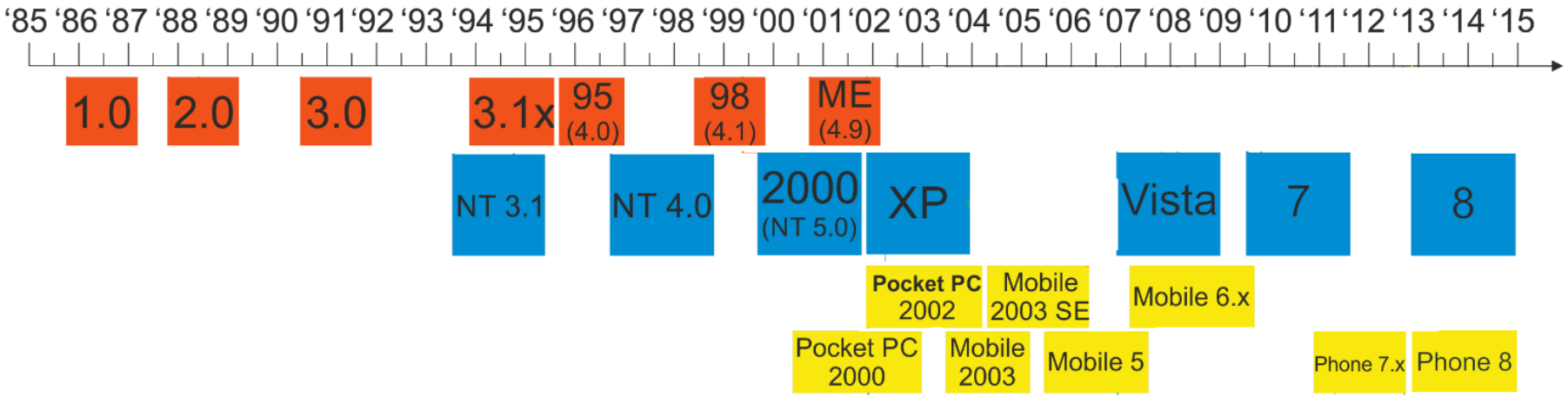
Apple Mac OS X, etc.

Multics vs. Unix

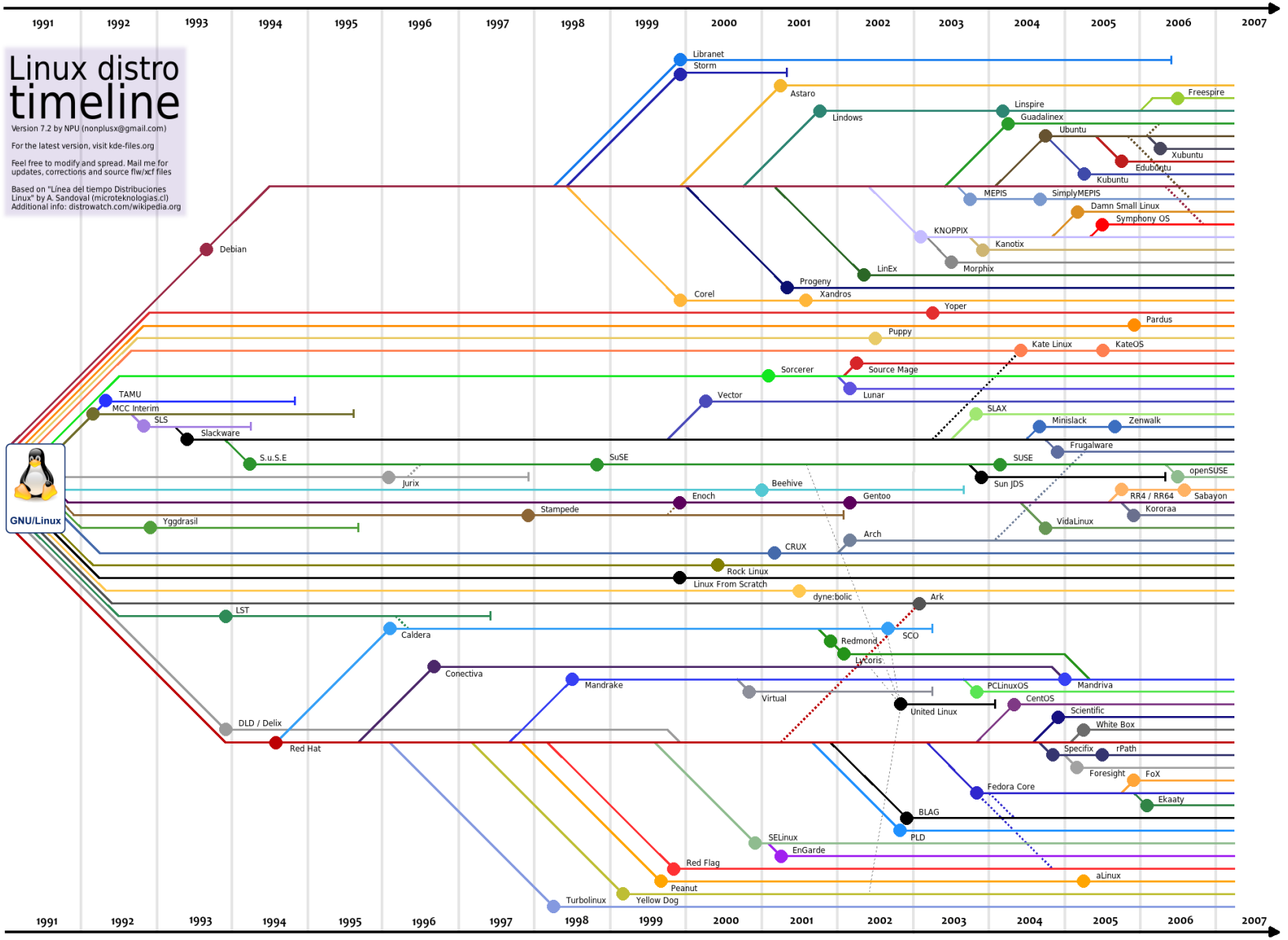
Comparison

- Multics:
  - Top-down approach
  - 150 Man-Years for design and system programming
  - Another 50 Man-Years for improvements
  - Too complicated, too costly hardware
  - Many novel ideas had a great impact
- Unix:
  - Bottom-up approach
  - Simplicity and ease of use
  - Low cost hardware, university adoption
  - 2 Man-Years
  - The root of the modern operating systems

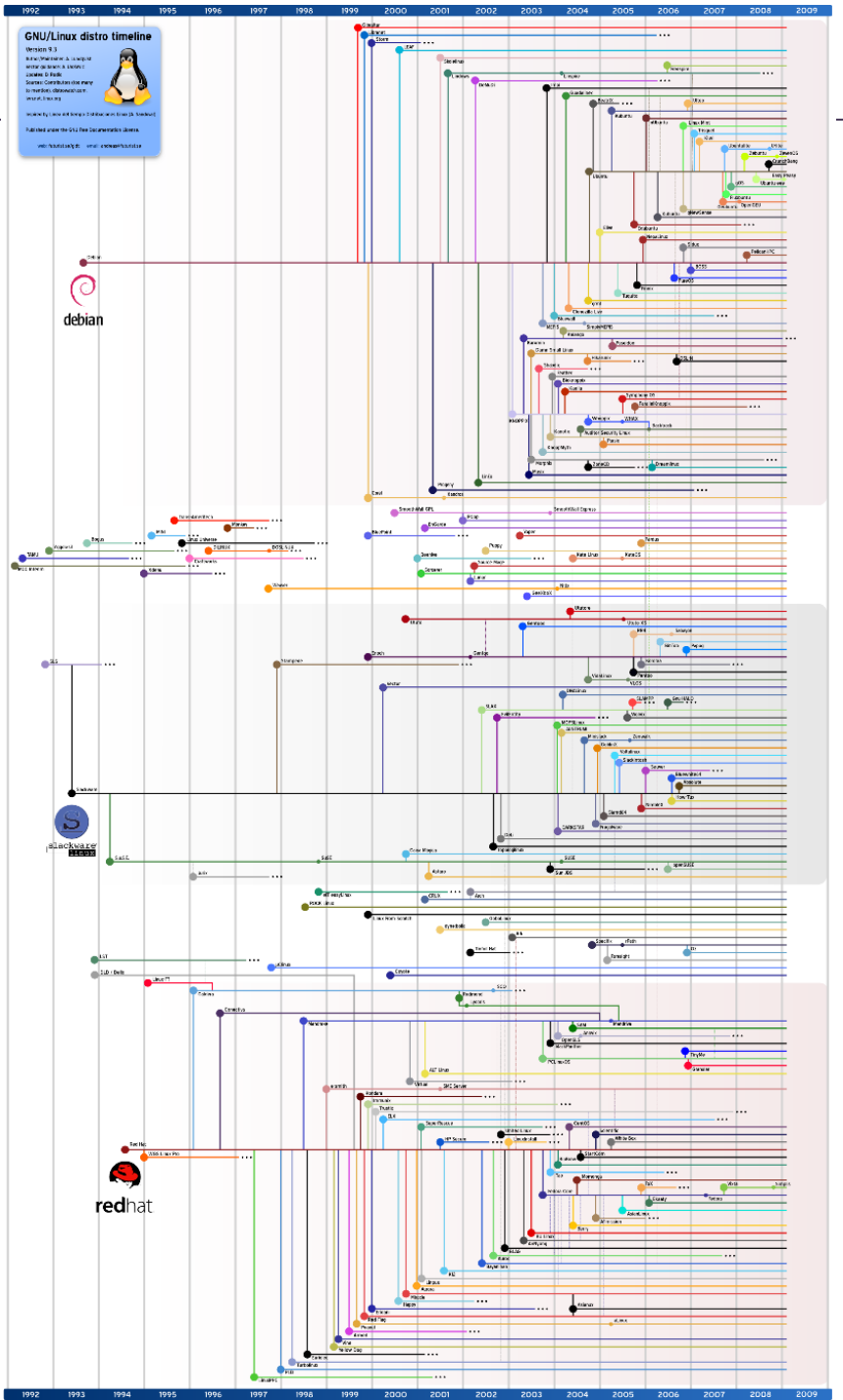
Windows history



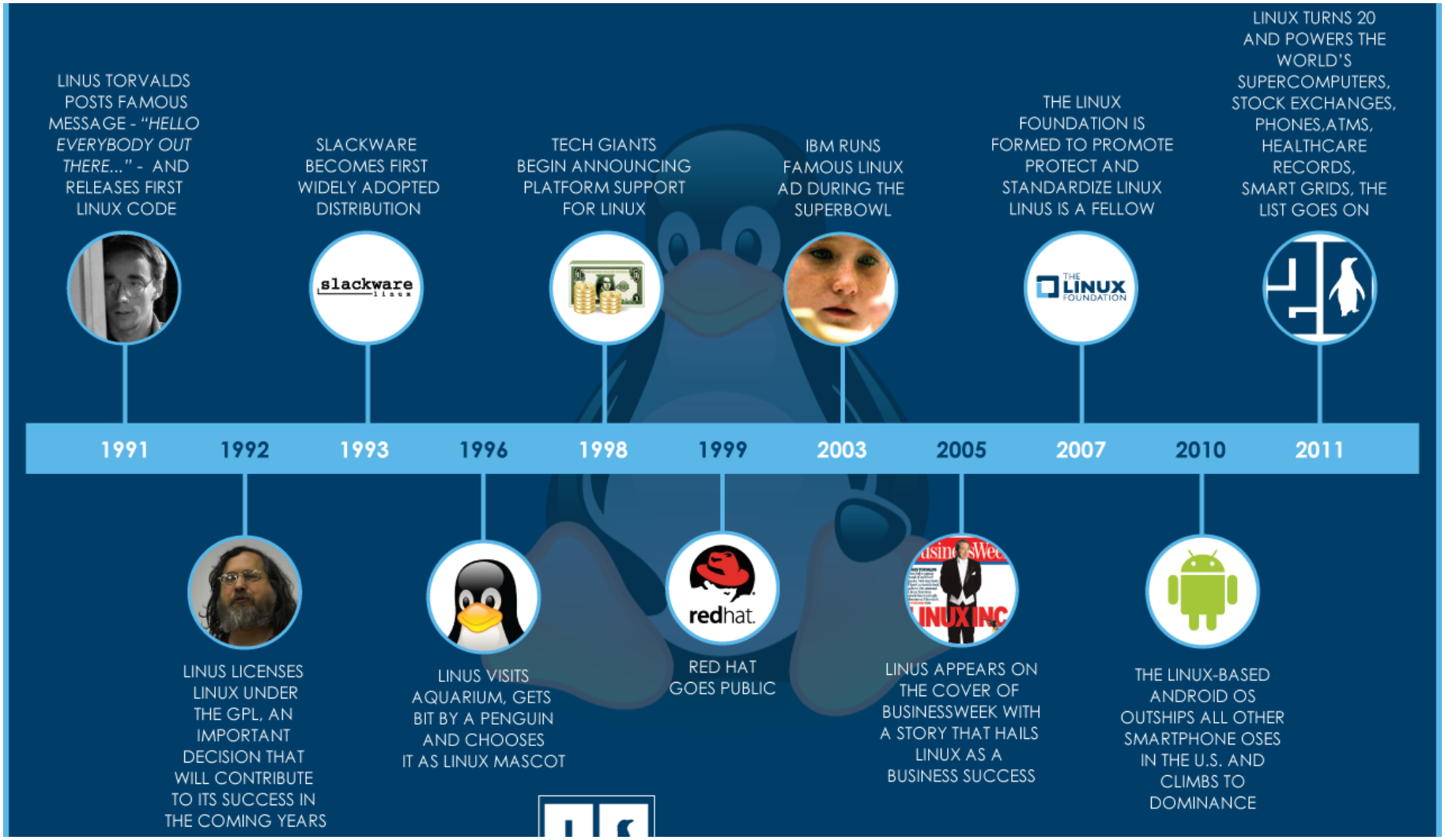
Linux history



Linux history



Linux history



Torvalds wrote the Linux based on the Unix

Linux's power is "Open source" and "Compatibility"