Jin-Soo Kim
(*jinsoo.kim@snu.ac.kr*)

Systems Software &
Architecture Lab.

Seoul National University

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Introduction to Operating Systems

Why OS?

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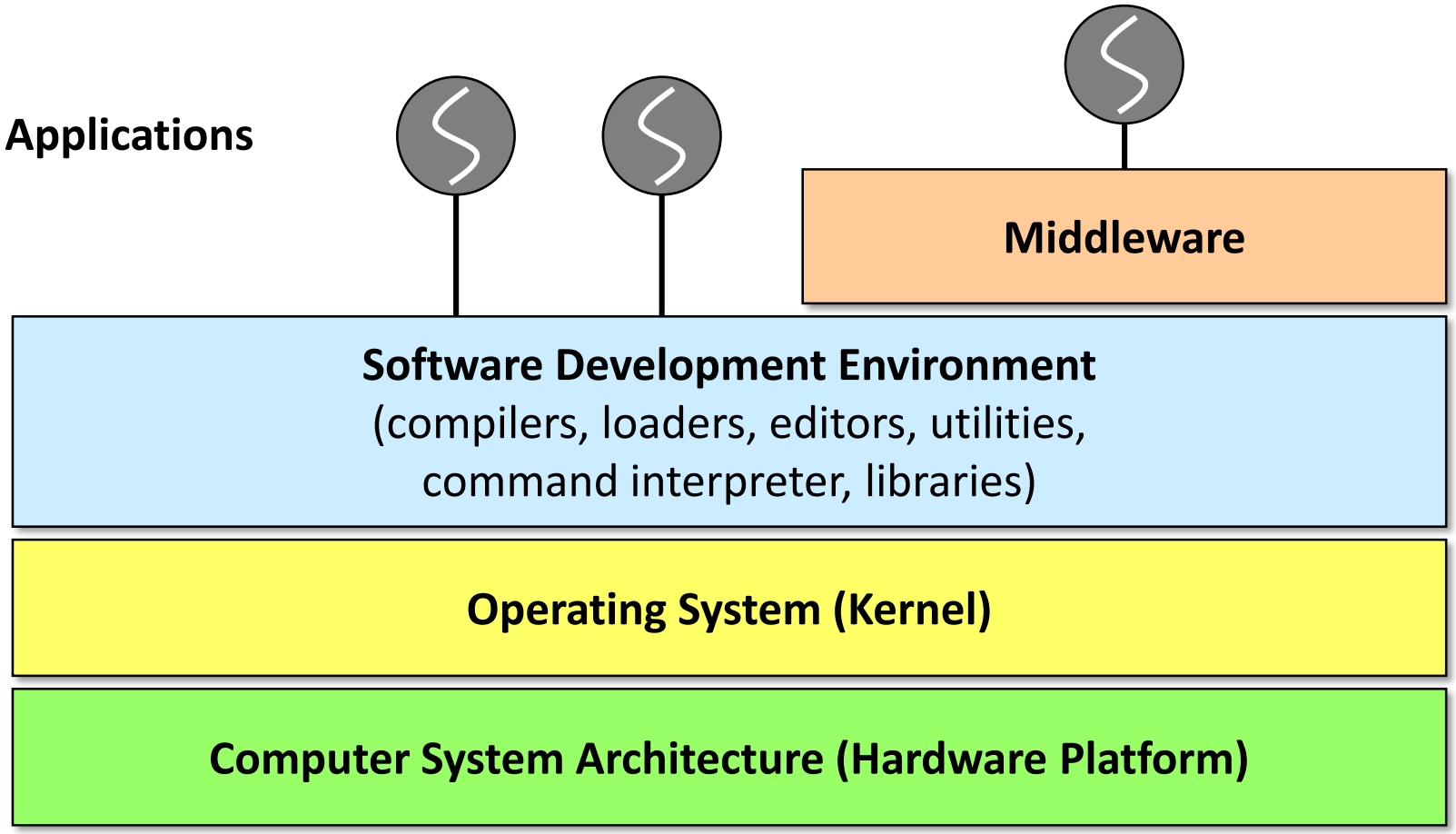
What is an OS?

- _____ that converts hardware into a useful form for _____



OS: Application View

- OS provides an execution environment for running programs

- OS provides a(an) _____ view of the underlying computer system
  - What are the correct abstractions?
  - How much of hardware should be exposed?

- Typical OS abstractions
  - Processors → Processes, Threads
  - Memory → Address space (virtual memory)
  - Storage → Volumes, Directories, Files
  - I/O Devices → Files (+ ioctls)
  - Networks → Files (sockets, pipes, …)

OS: System View

- OS manages various resources of a computer system

- Sharing
- _____
- Fairness
- Efficiency
- …

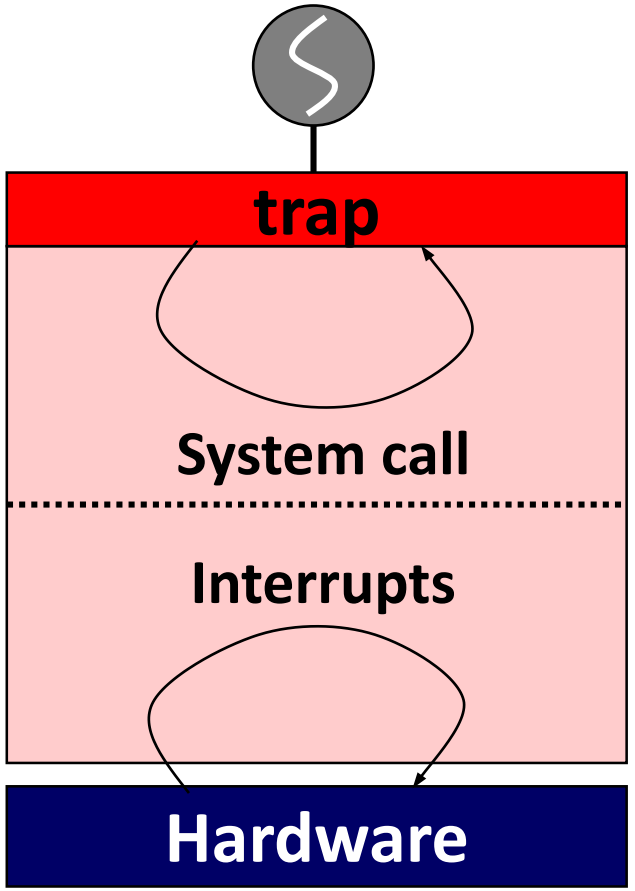
Resources

- **CPU**
- **Memory**
- **I/O devices**
- **Queues**
- **Energy**
- **…**

OS: Implementation View

- OS is highly-concurrent, _____ software

- Two kinds of events
  - System calls
  - Interrupts

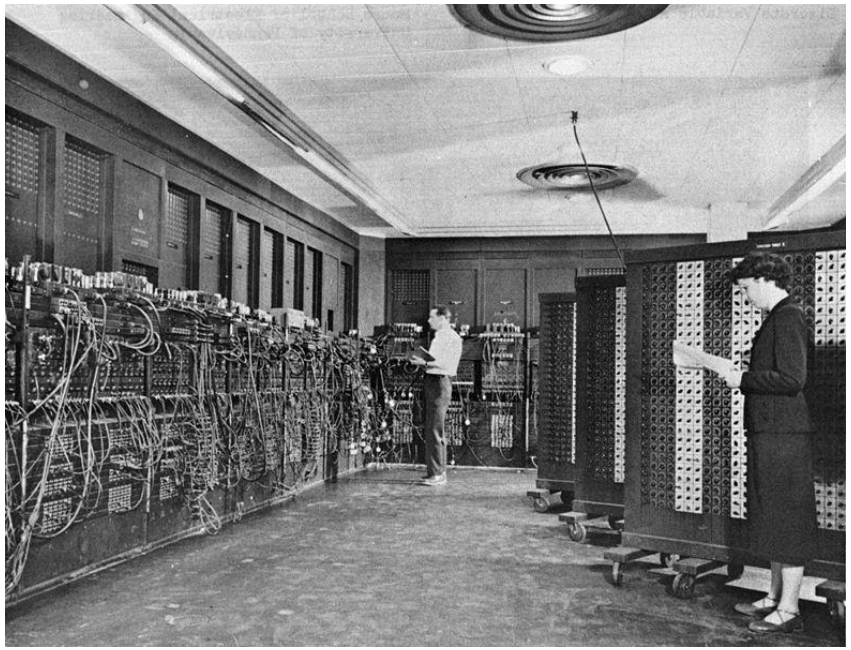


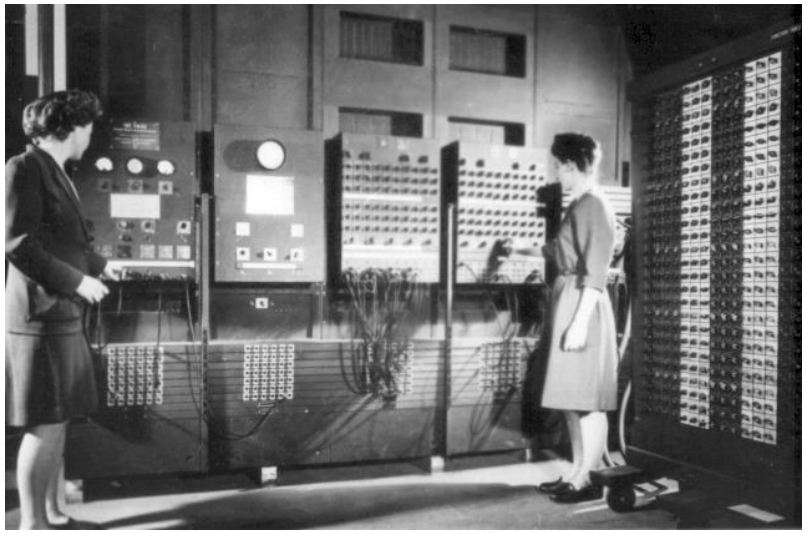
Three Pieces

- Virtualization
  - How to make each application believe it has each resource to itself?
- Concurrency
  - How to handle concurrent events correctly and efficiently?
- Persistence
  - How to make information survive power loss?

1G (1945-55)

- Vacuum tubes and plugboards
  - No OS
  - No programming languages
  - No assembly languages

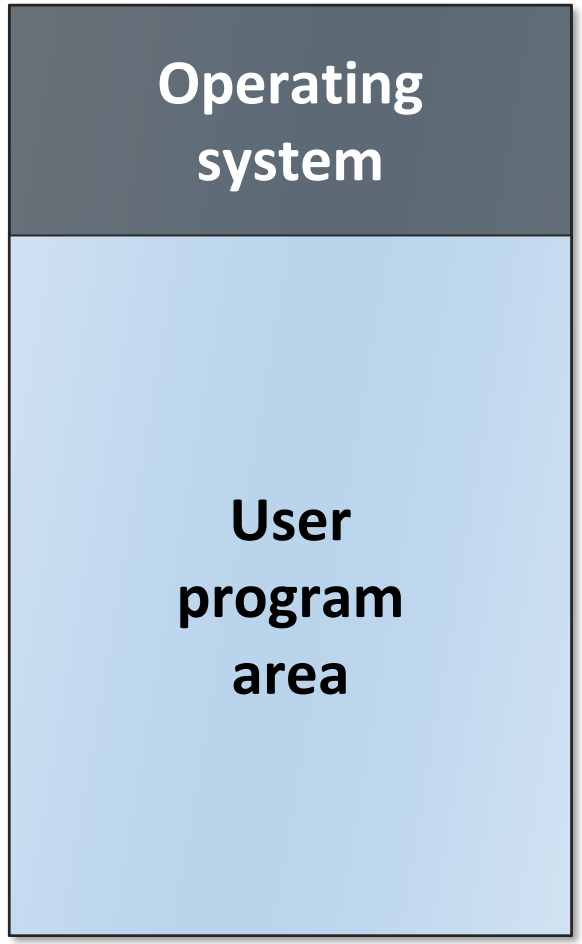




ENIAC (Electronic Numerical Integrator And Computer), 1946

2G (1955-65)

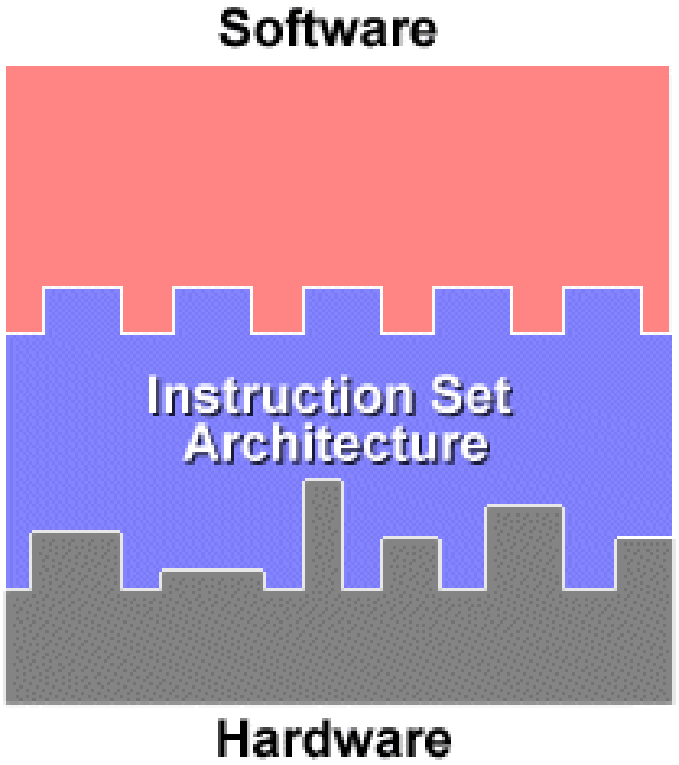
- Transistors and mainframes
- _____ systems
  - One job at a time
  - Card readers, tape drives, line printers
- OS is always resident in memory and merely transfers a control (just a library)
- CPU is underutilized due to the bottleneck in I/O



3G (1965-80)

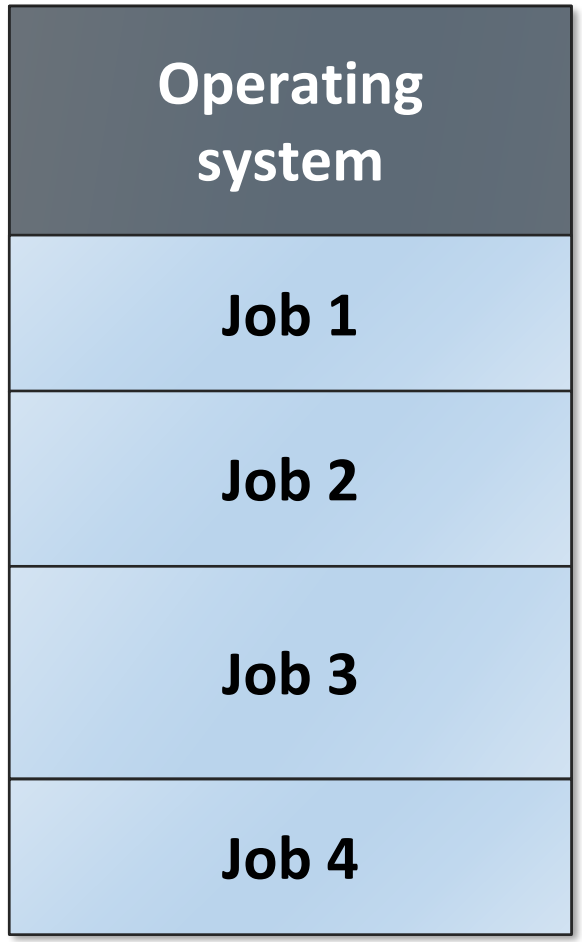
- Architectural advances
  - Integrated Circuits (ICs): better price/performance
  - Disk drives
  - On-line terminals

- Established the notion of "Computer Architecture"
  - IBM System/360 Family



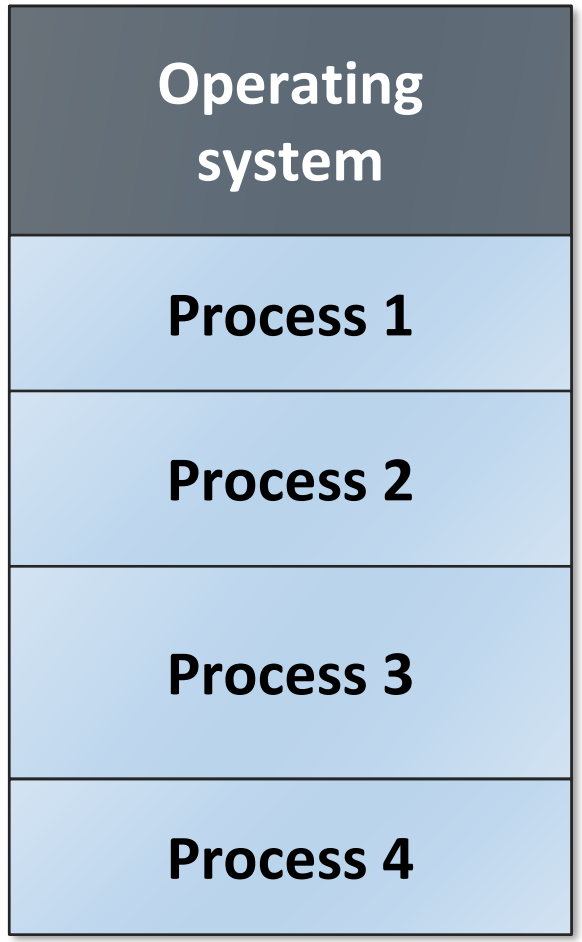
3G (1965-80)

- _____ systems
  - Increase CPU utilization
  - IBM OS/360 (1964)
- OS features
  - Job scheduling
  - Memory management
  - CPU scheduling
  - Concurrency
  - Protection
  - Spooling (Simultaneous Peripheral Operation On-Line)



3G (1965-80)

- _____ systems
  - Improve response time
  - MIT CTSS (1961), Multics (1965), Unix (1969)
- OS features
  - Sophisticated CPU scheduling
  - Virtual memory and swapping
  - File system
  - Synchronization
  - Interprocess communication (IPC)
  - Interactive shell
  - More protection, …



4G (1980-)

- Architectural advances
  - Microprocessors (LSIs & VLSIs): 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
  - Mobile / Networked / Distributed
  - Virtualization, etc.

OS History

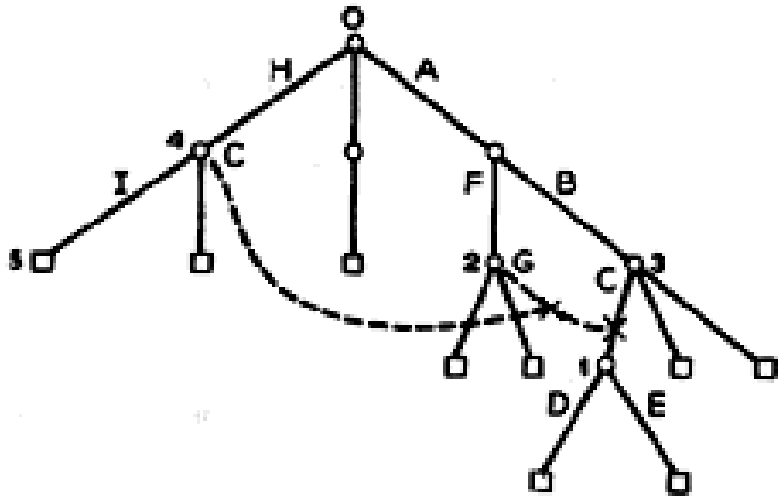
- CTSS (1961, MIT)
  - Compatible Time-Sharing System
- OS/360 (1964, IBM)
- MULTICS (1965, MIT, Bell Labs, GE)
  - MULTiplexed Information and Computing Service
- Unix (1969, Bell Labs)

Multics

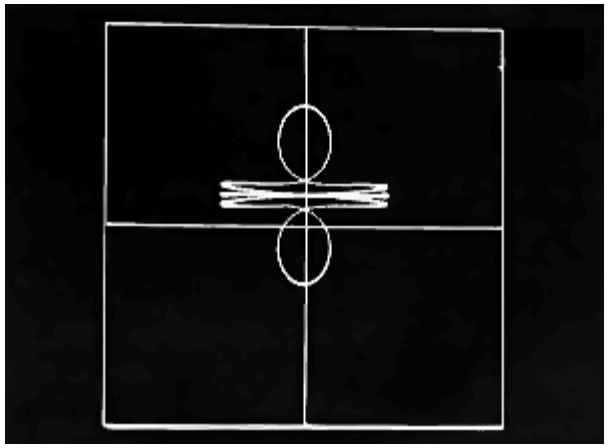
- Multiplexed Information and Computing Service
- A time-shared, multi-processor mainframe "computing facility"
- Originally started by MIT, GE, and Bell Labs in 1965
  - For GE-645, a 36-bit system
  - Bell Labs quit in 1969 and built Unix
  - GE's computer business, including Multics, was taken over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

Multics Innovations

- Hierarchical file system
  - ACLs, long names, hard & symbolic links, quota, …
- Virtual memory (segmentation and paging)
- User-level command shell
- Dynamic linking, shared memory
- Implementation in high-level language (PL/1)
- Mapping of logical disk volumes onto physical volumes
- Support for BCPL, APL, Fortran, Lisp, C, Cobol, Algol, Pascal, …
- Multics Relational Data Store (MRDS), Spreadsheets
- Rated B2 by NCSC (National Computer Security Center)



Unix



"… When BTL (Bell Telephone Laboratories) withdrew from the Multics project, they needed to rewrite an operating system in order to play space travel 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, Addison-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."

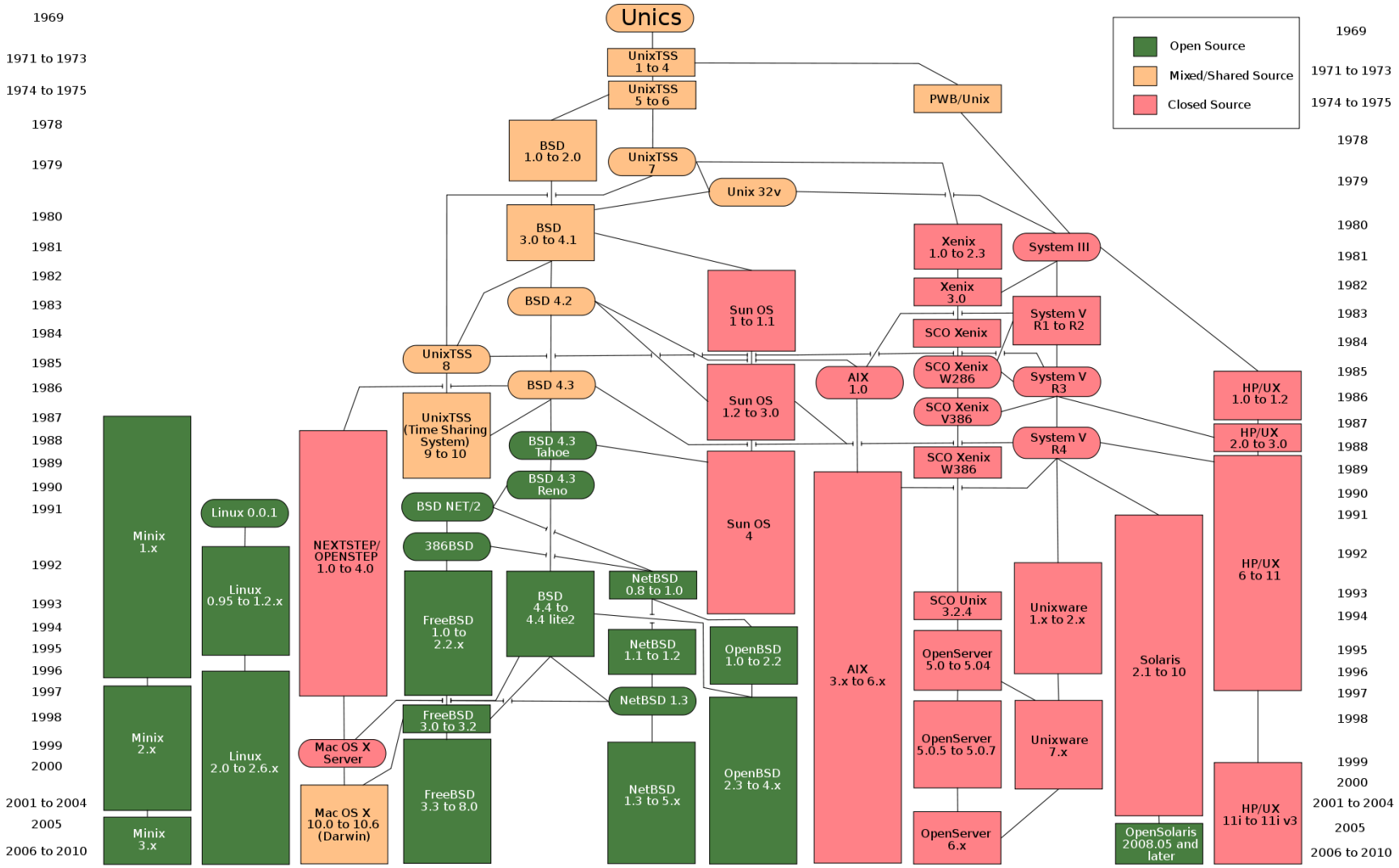
– Ken Thompson

Unix Features

- Hierarchical file system
  - 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

AT&T Archives: The UNIX Operating System
https://www.youtube.com/watch?v=tc4ROCJYbm0

Unix Family Tree



Source: http://en.wikipedia.org/wiki/History_of_Unix

Summary: Multics vs. Unix

- Multics
  - Top-down approach
  - 150 MY for design and system programming, another 50 MY for improvements
  - Too complicated, too costly hardware
  - Many novel ideas had a great impact

- Unix
  - Bottom-up approach
  - 2 MY: Simplicity, elegance, and ease of use
  - Low cost hardware, university adoption
  - The root of the modern operating systems