

Textbook

- “The Linux Programming Interface: A Linux and UNIX System Programming Handbook”, by Michael Kerrisk

THE LINUX PROGRAMMING INTERFACE

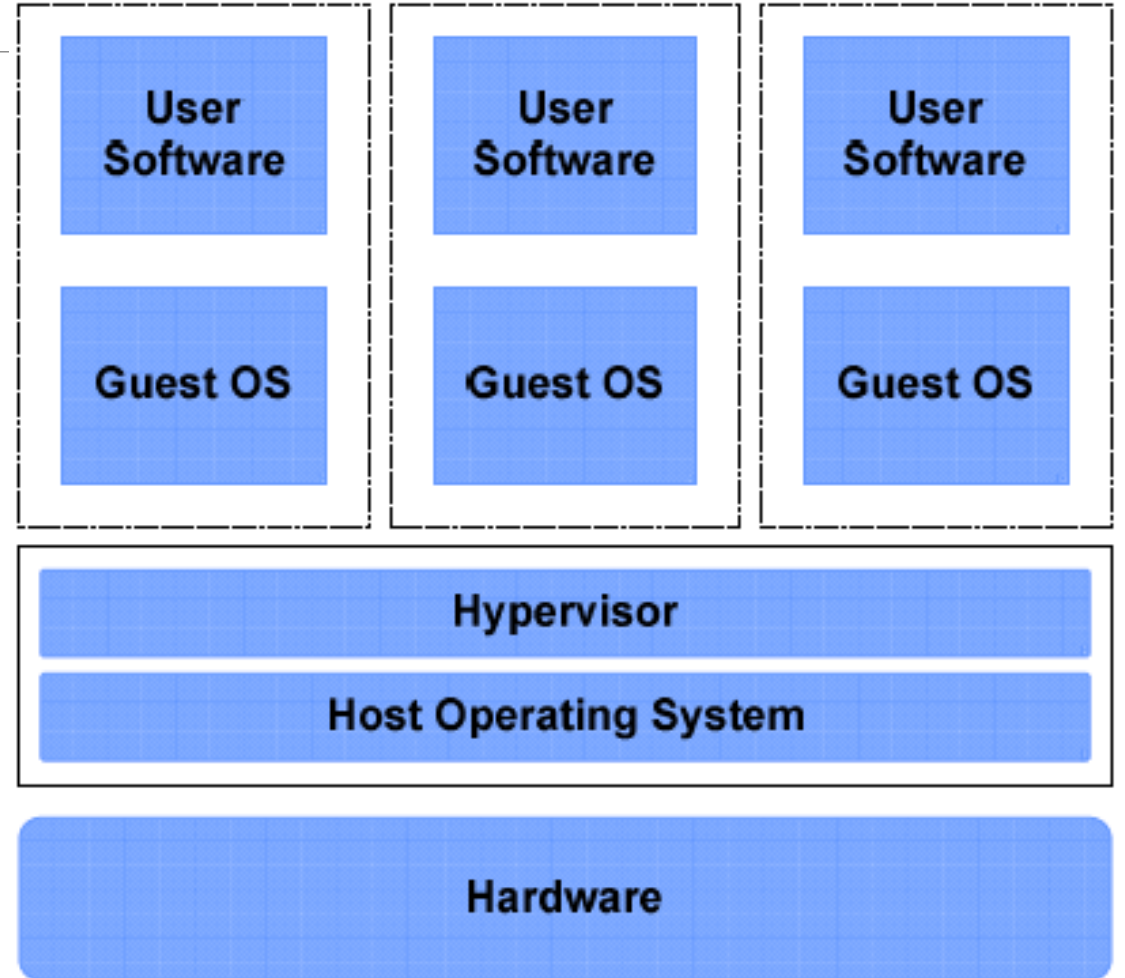
A Linux and UNIX[®] System Programming Handbook

MICHAEL KERRISK



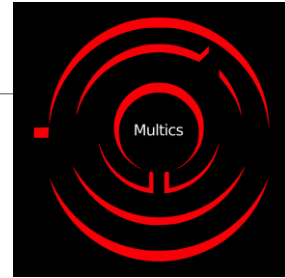
What is Virtualization?

- Virtualization is a framework or methodology of dividing the resources of a computer system into multiple execution environments.
- Platform virtualization is performed on a given hardware platform by **host software** (a control program), which creates a simulated computer environment, **a virtual machine (VM)**, for its guest software.



Multics

- Multics ("MULTiplexed Information and Computing Service") is an influential early time-sharing operating system based on the concept of a single-level memory.
- In 1964, Multics was developed as a cooperative project led by MIT along with General Electric and Bell Labs.



```
Remote Shell
Connection from: 188.100.2.59
Session #10 today, started at Wed 18 Mar 2020 22:34:42 UTC.

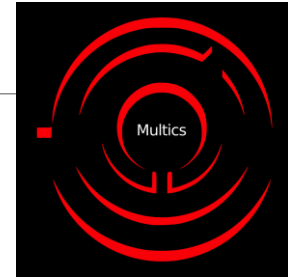
#####  ##  ##          ###          |  _  / \  |  \  |
#####  #####          ###  #  #    |  _  / \  |  \  |
##  #  #  #####  #####          ##  ##  ###  |  _  / \  |  \  |
#  #  #  #  ##  #  ##          ##  ##  #      |  _  / \  |  \  |
#  #  #  #  #  #  #  #####  ##  #####          #####
##  ##  #  #  #  #  #  #####  #####  #  #####  #
##  ##  #  #  #  #  #  #####  ##  #  #  #  #  #  #
##  ##  #  #  #  #  #  #  #  #  #  #  #  #  #  #
##  ##  #  #  #  #  #  #  #  #  #  #  #  #  #
#  #  #  #  #  #  #  #  #  #  #  #  #  #  #
#####  #  #  #####  #  #  #  #  #  #  #  #  #
#  #####  #  #  #####  #####  #  #  #  #  #  #
#  #  #  #  #  #  #  #  #  #  #  #  #  #
#  #  #  #  #  #  #  #  #  #  #  #  #

##  [ Type "enter Guest" or sign up at https://ban.ai/multics ]

Multics MR12.6f: BAN AI Systems (Channel a.h002)
Load = 9.0 out of 300.0 units: users = 9, 03/18/20 1834.7 edt Wed
```

Multics Failure

- In 1969, Bell withdrew from the project as it became clear it would not deliver a working system in the short term.
- In 1970, GE decided to exit the computer industry entirely and sold the division to Honeywell.
- Nathan Gregory writes that “*Multics has influenced all modern operating systems since, from microcomputers to mainframes*”.
- Novel Ideas:
 - Dynamic linking.
 - Hierarchical file system.
 - Single-level store for data access.
 - ...



```
Remote Shell
Connection from: 188.100.2.59
Session #10 today, started at Wed 18 Mar 2020 22:34:42 UTC.

#####  ##  ##          ###          | _ / \ | \ | |
#####  #####          ###  #  #    | _ \ / \ | \ | |
##  #  #  #####  #####          ##  ##  ### | _ / \ | \ | |
#  #  #  #  ##  #  ##          ##  ##  #    | _ / \ | \ | |
#  #  #  #  #  #  #  #####  ##  #####          #####
##  ##  #  #  #  #  #  #####  #####  #  #####
##  ##  #  #  #  #  #  #####  ##  ##  ##  #  #####
##  ##  #  #  #  #  #  ##  ##  ##  ##  #  #####
##  ##  #  #  #  #  #  ##  ##  ##  ##  #  #####
#  ##  #  #  #  #  #  ##  ##  ##  ##  #  #####
#  #  #  #  #  #  #  ##  ##  ##  ##  #  #####
#####  #  #####  ##  ##  ##  ##  ##  ##  #####
#  #####  ##  #####  #####  #  ##  ##  #####
#  ##          ##          ###          #####
#  [ Type "enter Guest" or sign up at https://ban.ai/multics ]

Multics MR12.6f: BAN AI Systems (Channel a.h002)
Load = 9.0 out of 300.0 units: users = 9, 03/18/20 1834.7 edt Wed
```

Bell Labs

- In 1880, when the French government awarded Alexander Graham Bell the Volta Prize of 50,000 francs for the invention of the telephone. He used the award to fund the Volta Laboratory ("Alexander Graham Bell Laboratory").
- In 1889, *American Telephone & Telegraph Company (AT&T)* and its own subsidiary company took control of American Bell and the Bell System.
- Innovations at Bell labs:
 - Transistor.
 - Laser.
 - Information theory.
 - C, C++, AWK, and others.
 - Unix.
- Nine Nobel Prizes have been awarded for work completed at Bell Laboratories.



Unix Creation

- Ken Thompson and Dennis Ritchie developed Unix in Bell Labs on DEC PDP-7 machine.



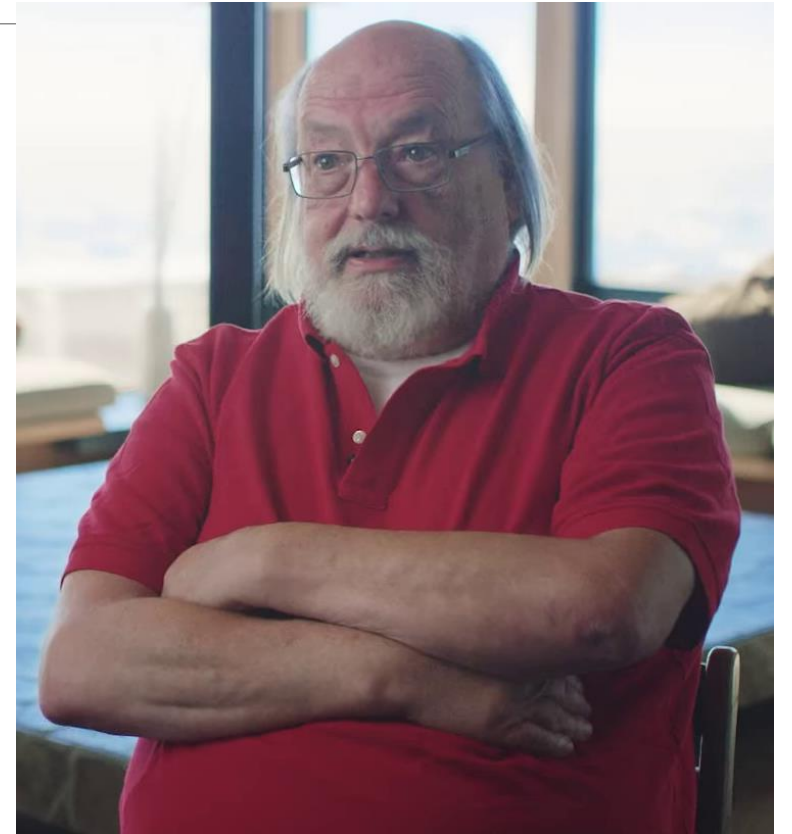
DEC PDP-7

- The PDP-7 was an 18-bit minicomputer produced by Digital Equipment Corporation (DEC) as part of the PDP series (1965).
- Price: US\$72,000 (equivalent to \$668,604 in 2022).
- Weight: 500 KG.
- Memory: 4K words (9.2 KB).
- Display: Printer.
- Input: Keyboard.



Unix First Version

- Ken Thompson wrote UNIX in 3 weeks in his wife vacation 😊.
- He wrote:
 - Editor.
 - Assembler.
 - Kernel.



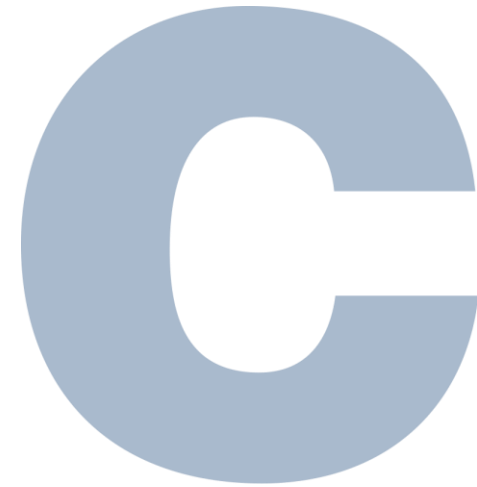
Rewriting Unix on PDP-11

- As UNIX was written in assembly, Ken Thompson needs to rewrite it again on the PDP-11.

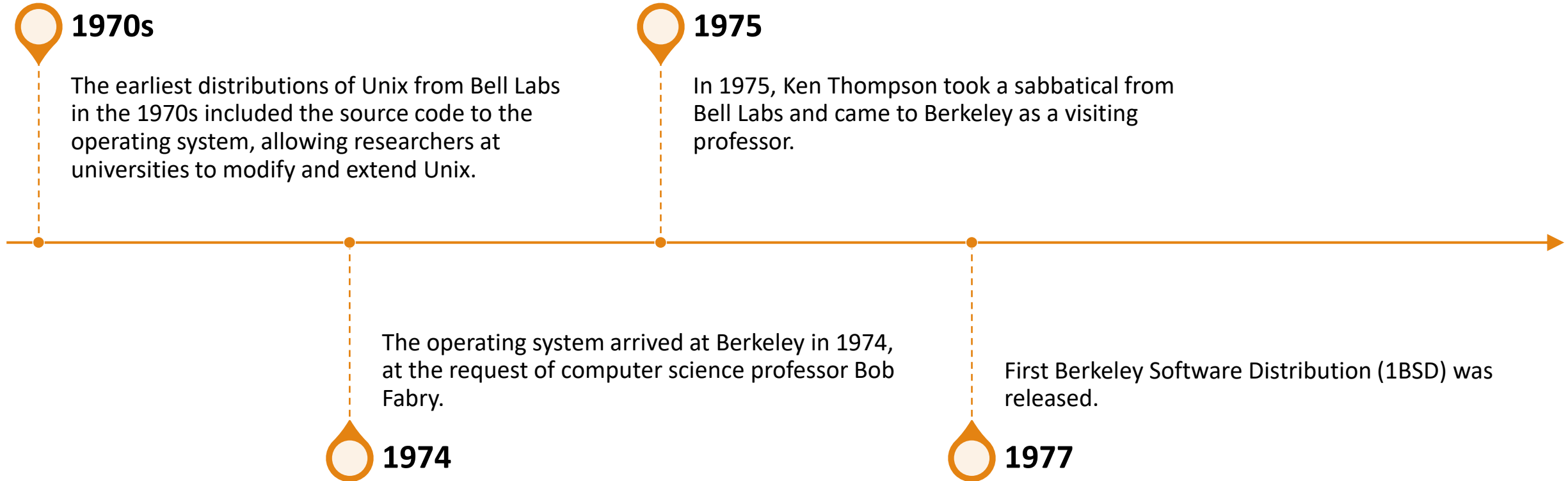


Inventing C language

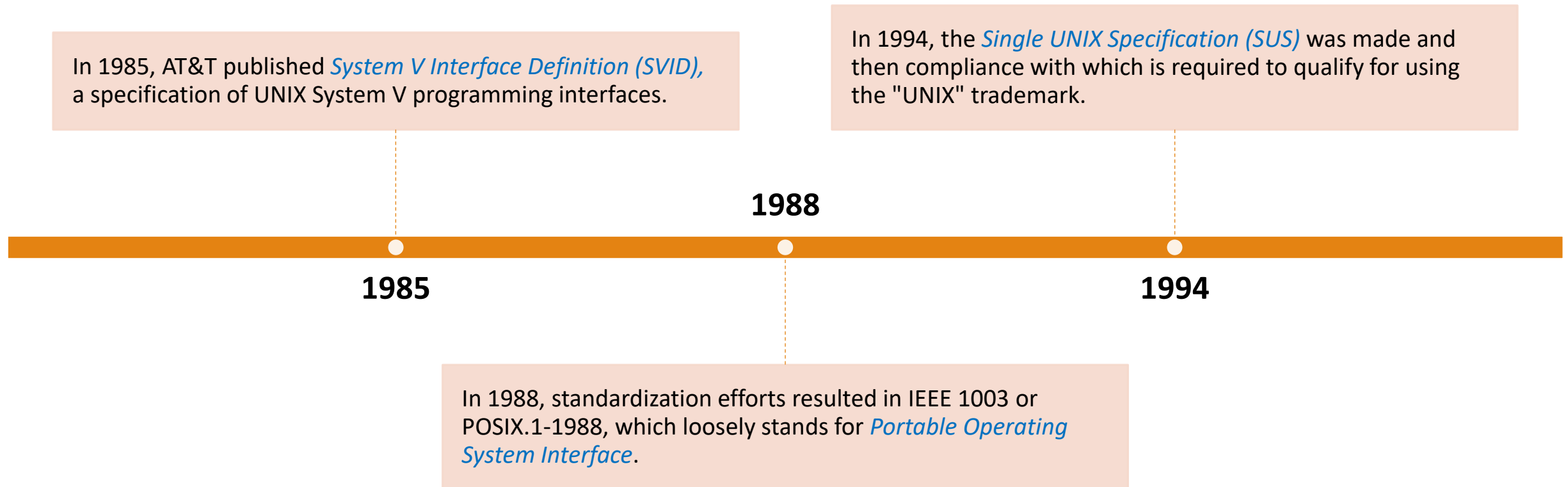
- Dennis Ritchie developed C language as a successor to B language (created by Ken Thompson).
- Then, Unix was ported to the C language.



Unix in UC Berkeley

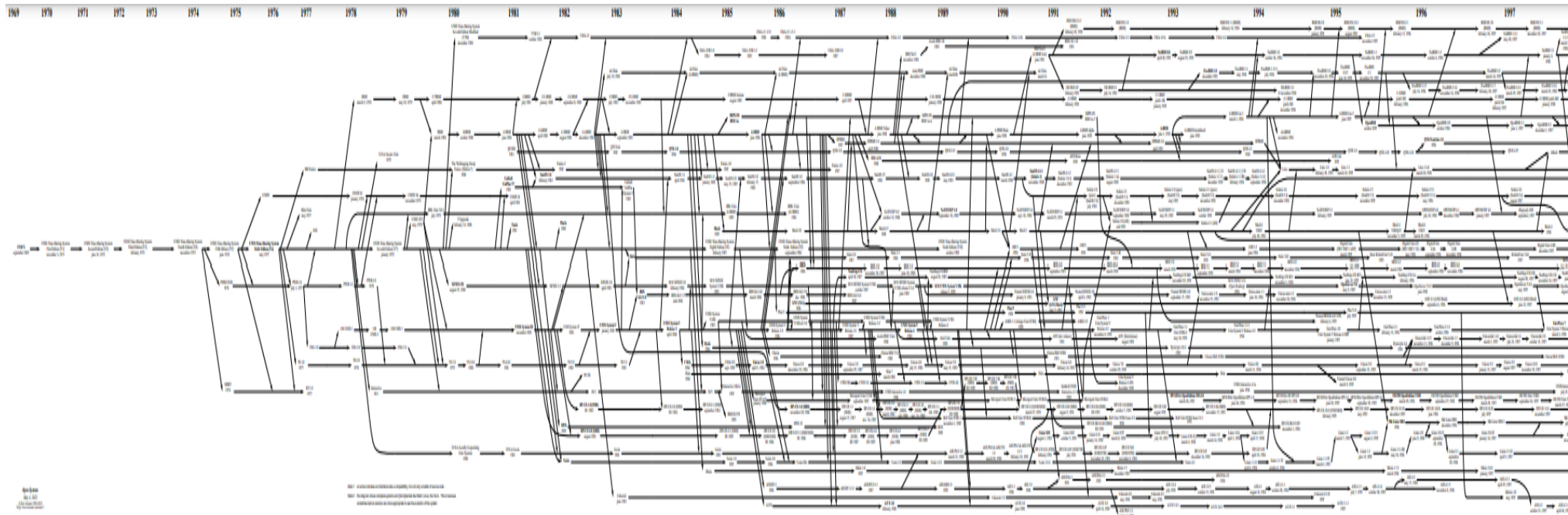


Unix standardization efforts



Unix Evolution

<https://www.levenez.com/unix/>



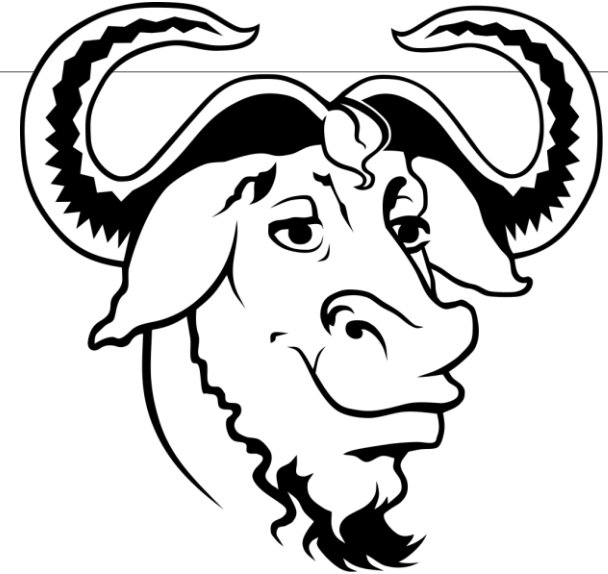
GNU

The GNU Project is a free software, mass collaboration project announced by [Richard Stallman](#) on September 27, 1983.

A recursive acronym meaning ***"GNU's not Unix!"***

The GNU General Public License (GNU GPL or simply GPL) is a series of widely used free software licenses that guarantee end users the four freedoms on the software:

- Run.
- Study.
- Share.
- Modify.



The Creation of Linux

Surrounding conditions:

- Hardware evolved and Intel created X86.
- Internet evolved and mailing lists were popular.
- In 1987, MINIX, a Unix-like system intended for academic use, was released by Andrew S. Tanenbaum.

Linus Torvalds wrote the first kernel version in 1991.



Linux Statistics

47% of professional developers use Linux-based operating systems. (Statista)

Linux powers 39.2% of websites whose operating system is known. (W3Techs)

Linux powers 85% of smartphones. (Hayden James)

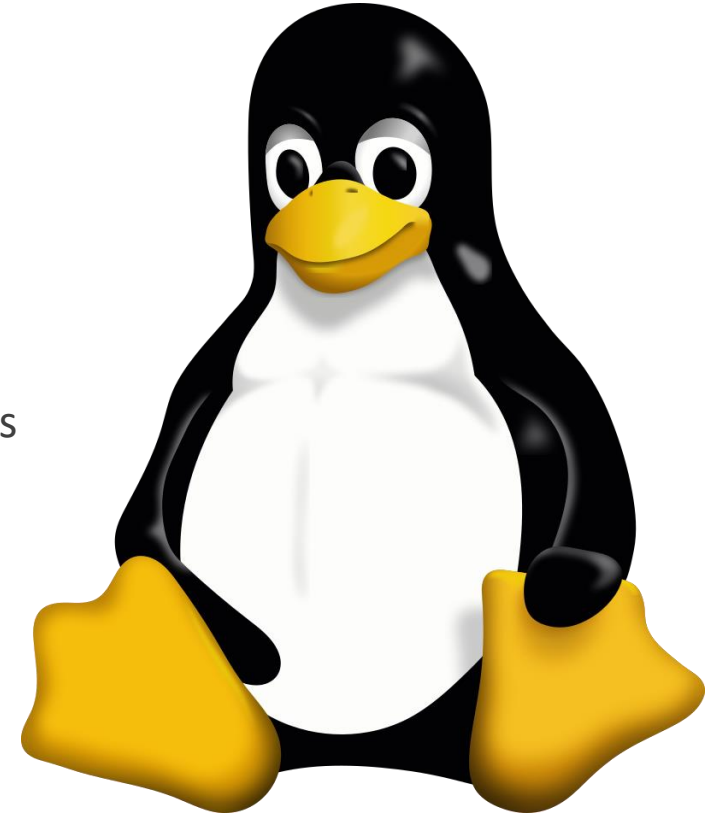
Linux, the third most popular desktop OS, has a market share of 2.09%. (Statista)

The Linux market size worldwide will reach \$15.64 billion by 2027. (Fortune Business Insights)

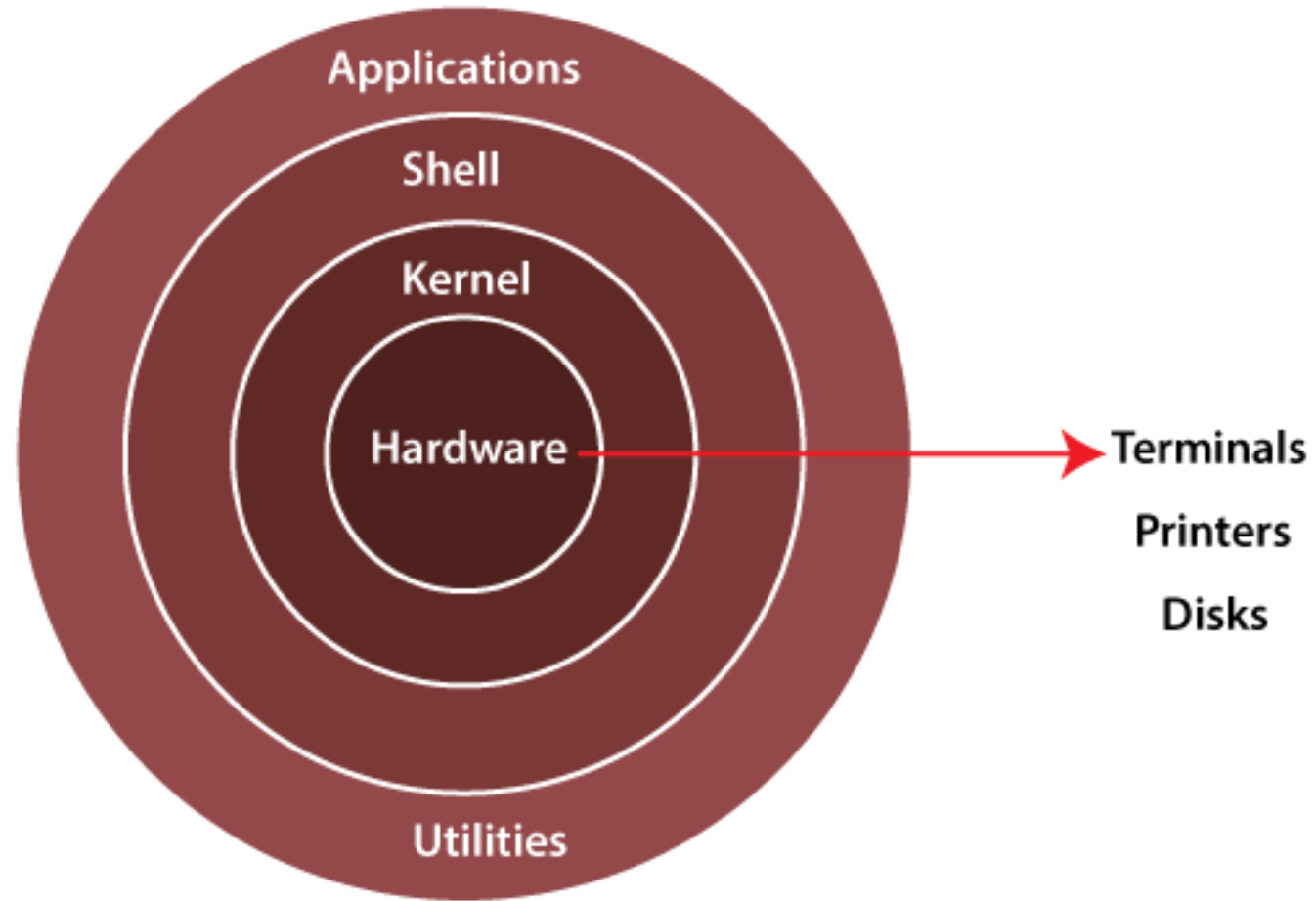
The world's top 500 fastest supercomputers all run on Linux. (Blackdown)

96.3% of the top one million web servers are running Linux. (ZDNet)

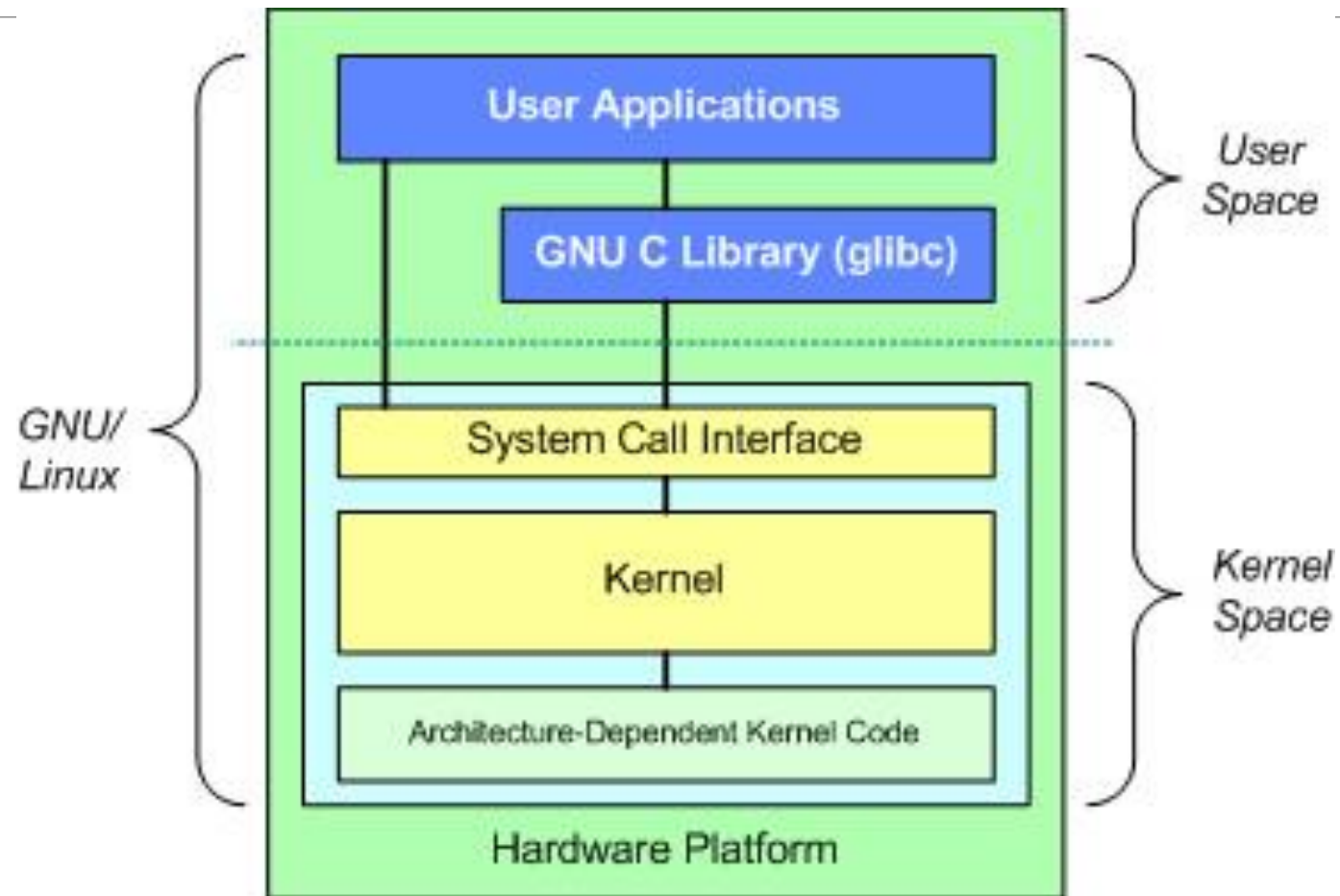
Today, there are over 600 active Linux distros. (Tecmint)



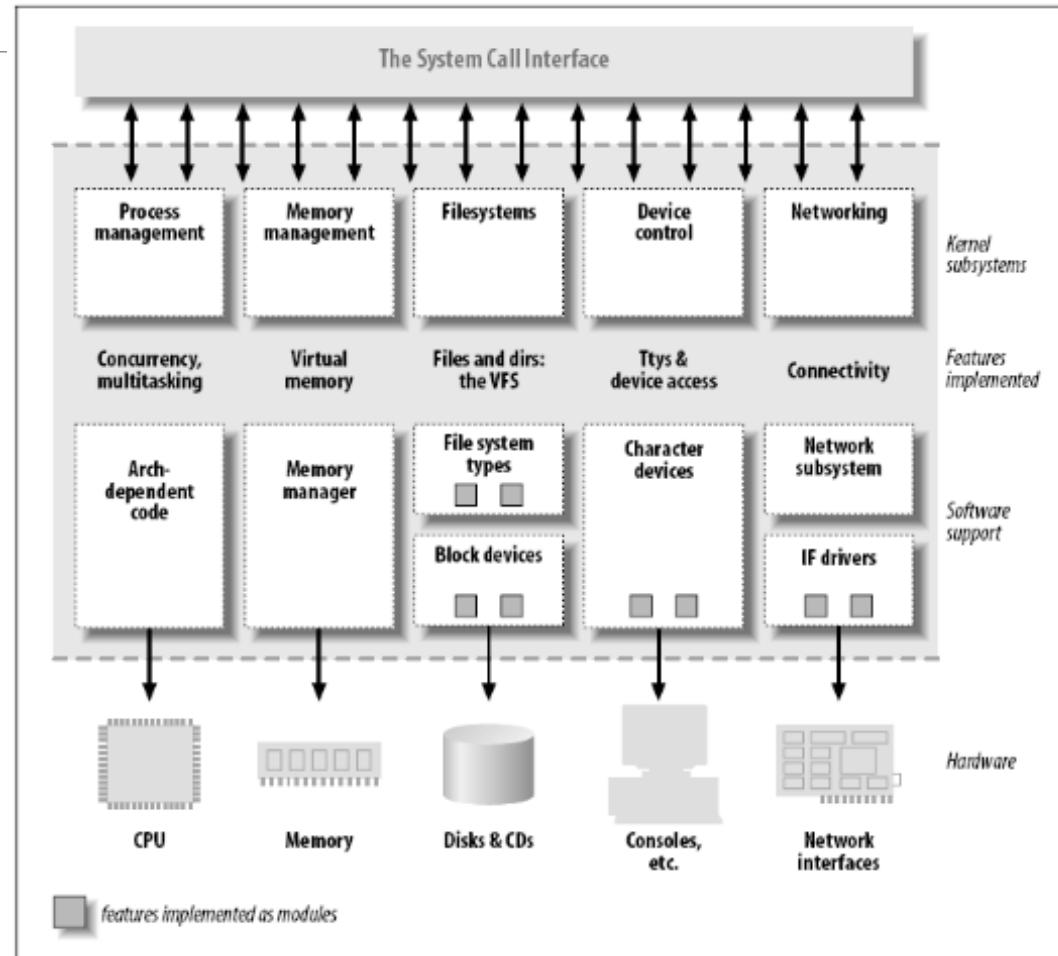
Linux OS



Kernel Space vs User Space



Linux Kernel

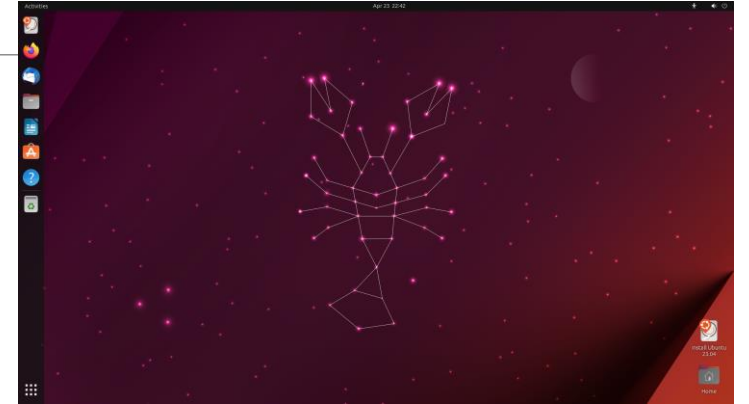
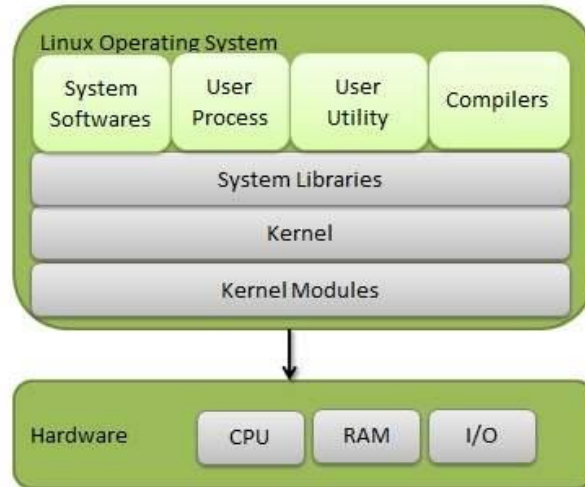


Linux Distributions

- A Linux distribution is an OS made through a software collection that contains a Linux kernel, GNU libraries and tools, other software, a window system, documentation, a desktop environment, and a window manager.

Examples:

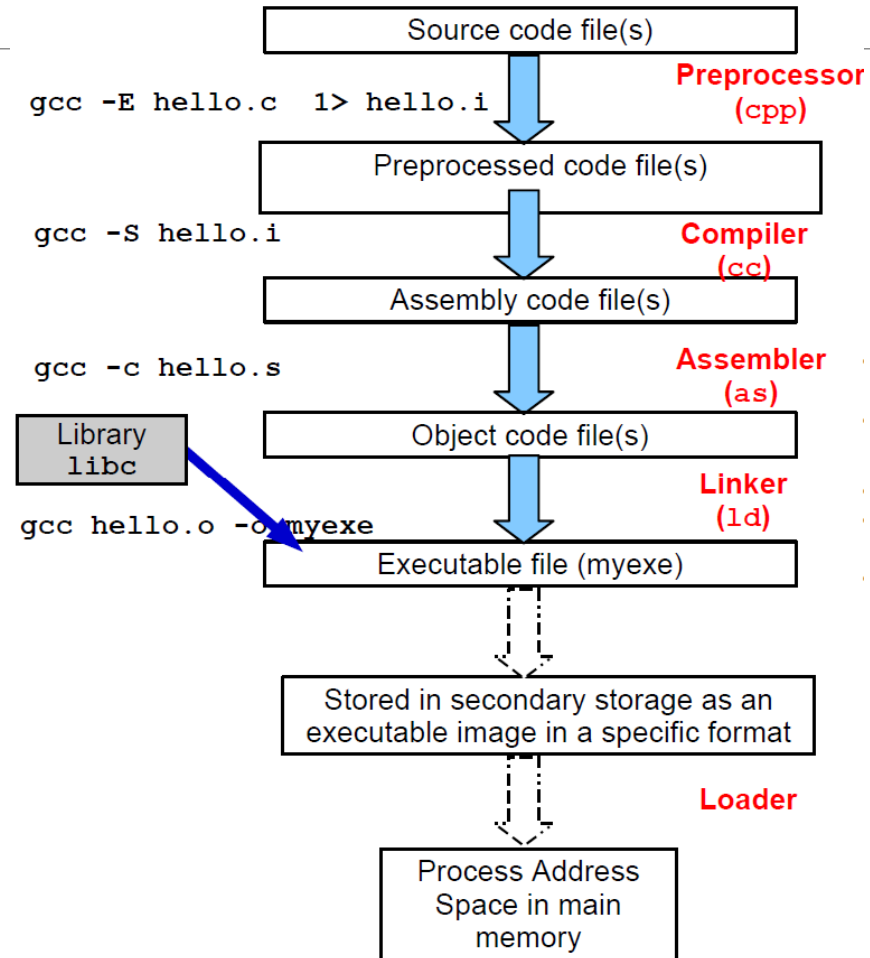
- Ubuntu
- Linux Mint
- Debian
- Red Hat Enterprise / CentOS
- Fedora
- Arch Linux
- **Yocto**



Basic Commands

- Navigation (pwd, cd, mkdir, ls, ..).
- Getting help (help, man, ..).
- Copy and rename files.
- Creating directories.
- Viewing files.
- Editing files.
- I/O redirection.
- Pipes.
- History.

Build Process



ELF Format

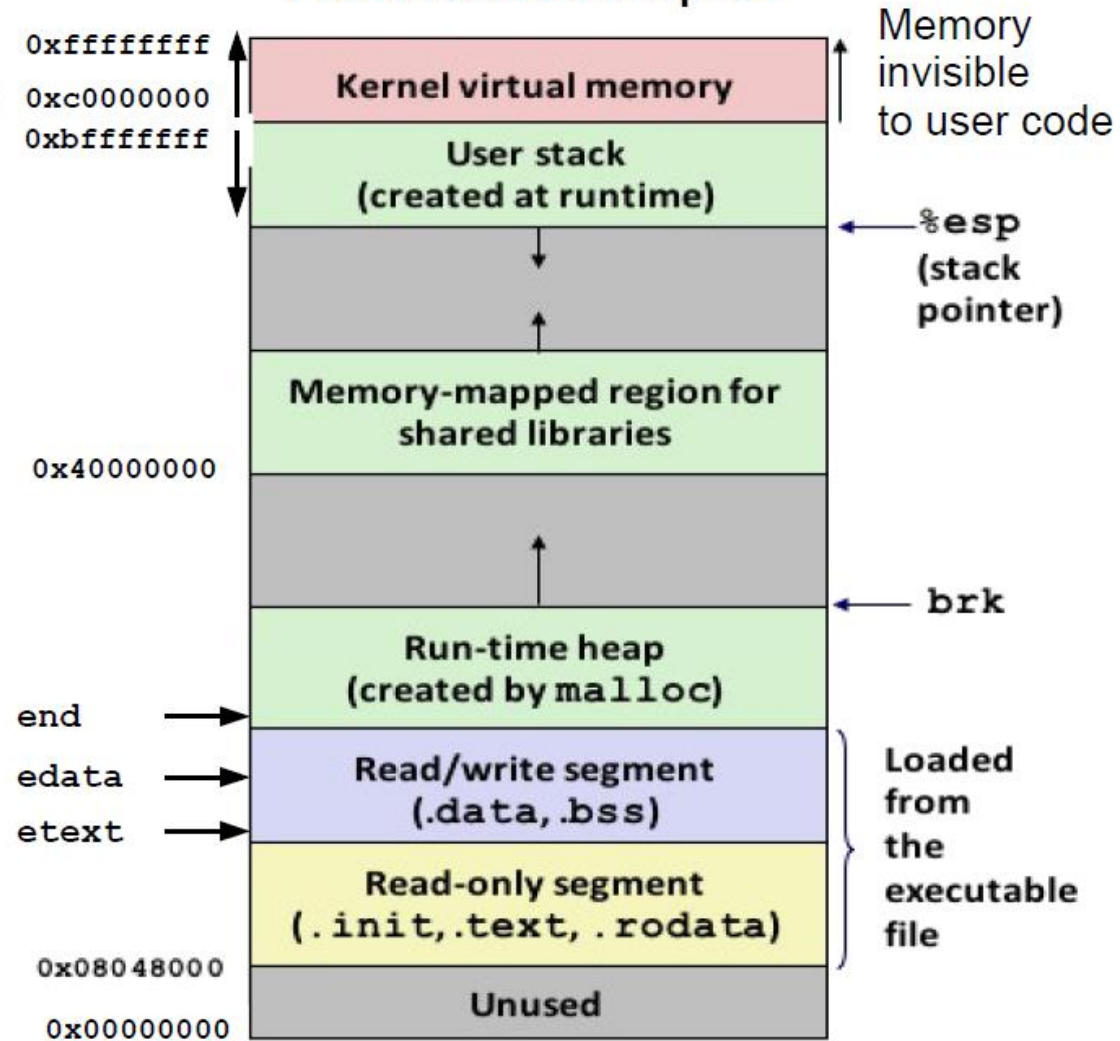
ELF header
Program header table (required for executables)
.init section
.text section
.rodata section
.data section
.bss section
.symtab
.debug
.line
.strtab
Section header table (required for relocatables)

Execution View

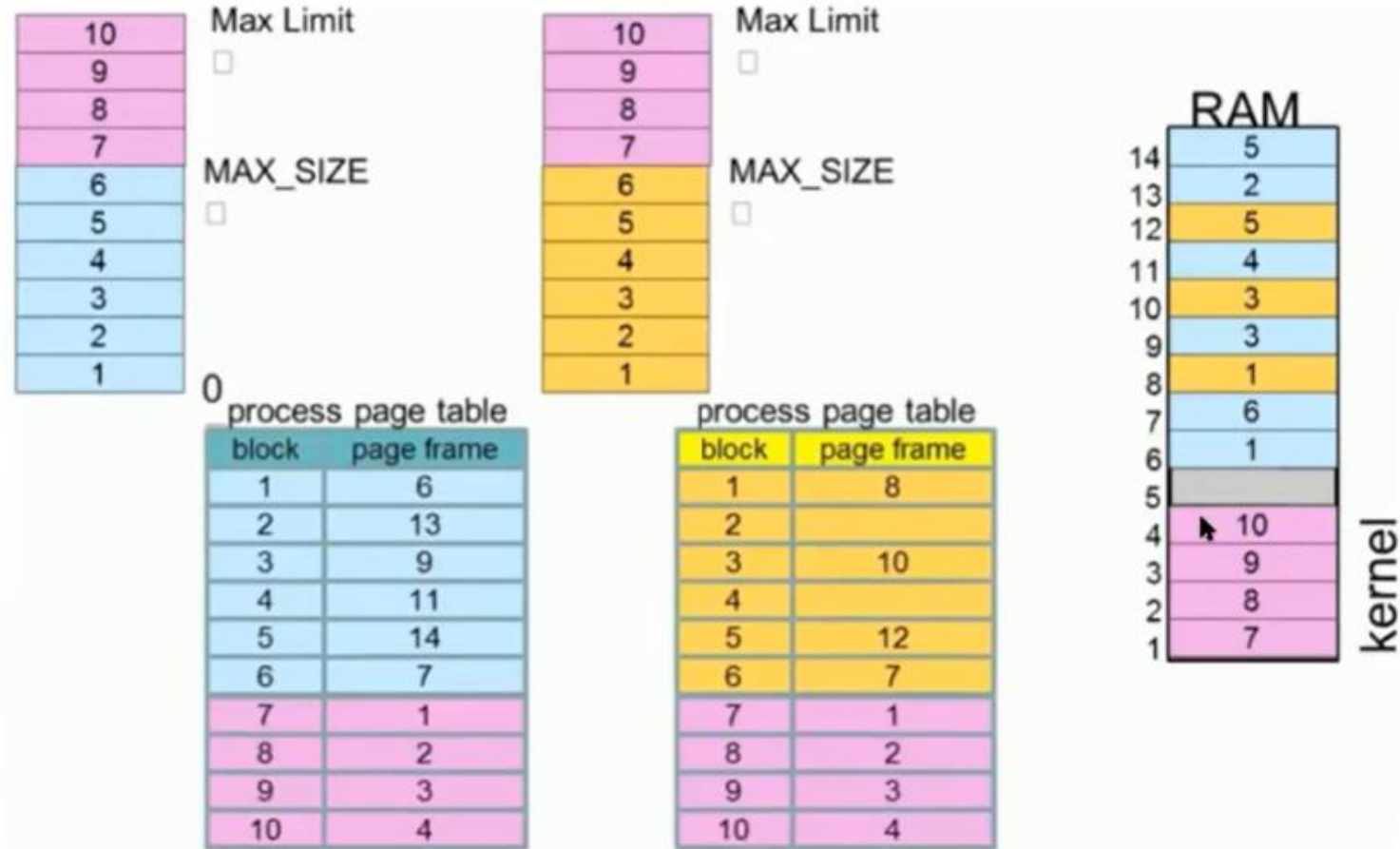
Executable Object File

ELF header
Program header table (required for executables)
.init section
.text section
.rodata section
.data section
.bss section
.symtab
.debug
.line
.strtab
Section header table (required for relocatables)

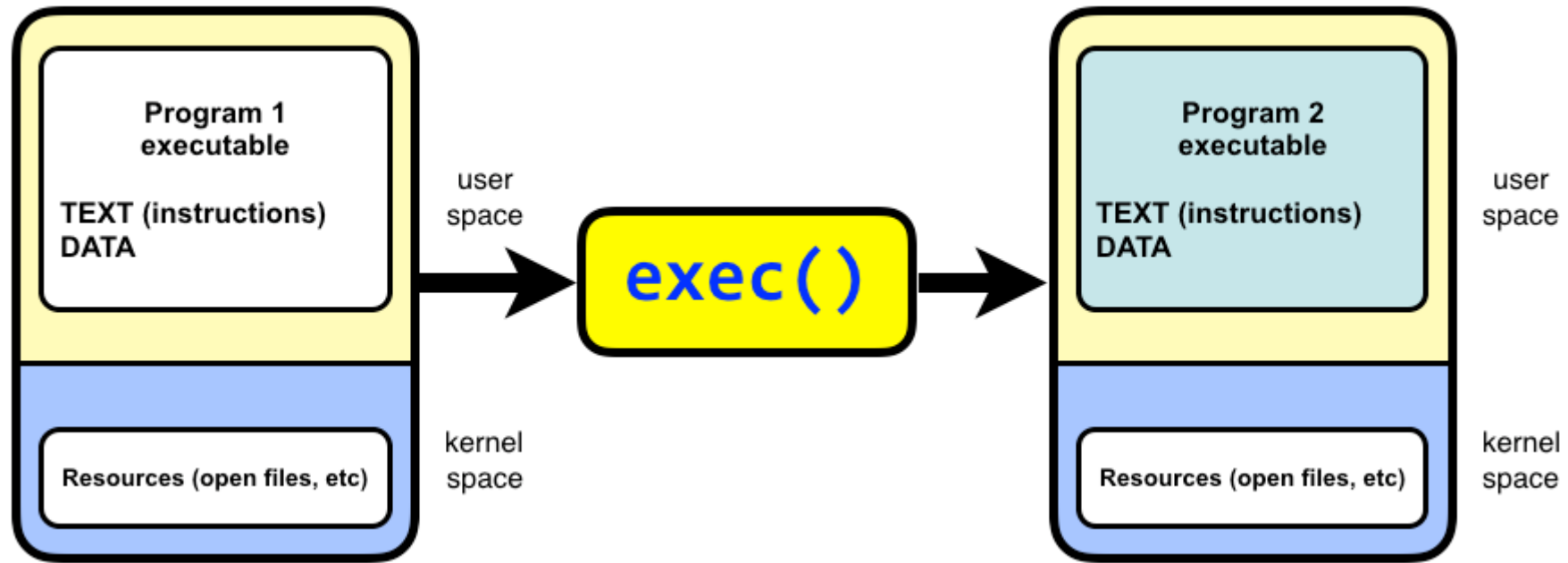
Process Address Space



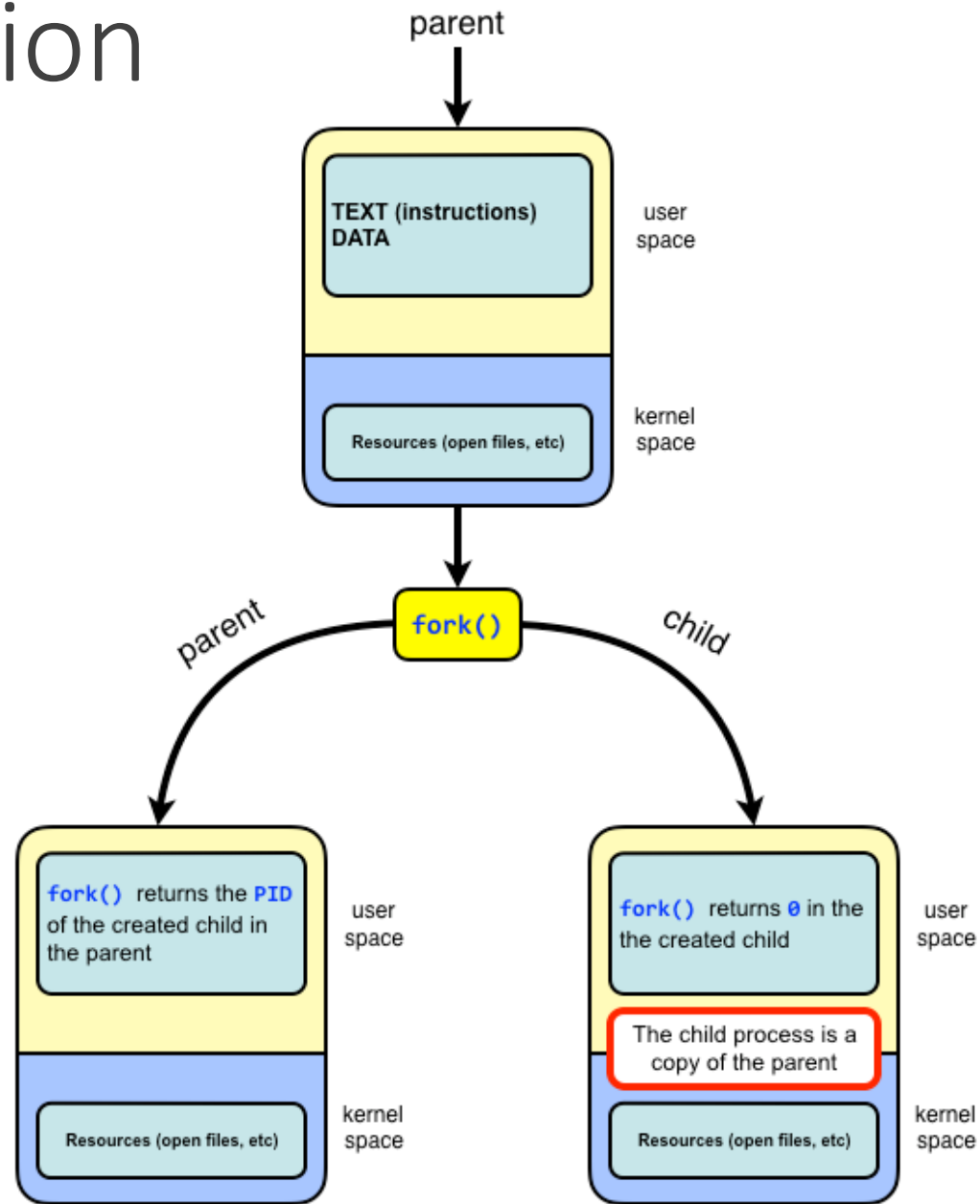
Virtual address



Program Execution



Process Creation



Executing Programs in a New Process

