# Introduction to Operating Systems

## 1. Introduction

2026-11-13

USO Team

# Welcome

to the *Introduction to Operating Systems* class

**You will learn, understand and experiment**

- how operating systems work
- how basic POSIX (Linux) commands work
- how to use the Linux **command line**
- the history of Linux
- how use the development tools

**We expect**

- to come to class
- ask a lot of questions

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# Our team - Leads

**Lectures**

- Răzvan Rughiniș (CA)
- Mihai Carabaș (CB)
- Sergiu Weisz (CC)
- Alexandru Radovici (CD)
- Ioana Culic (AC)

**Team Leads**

- Alice Șuiu - Course tests
- Ionuț Mihalache - Homeworks
- Ștefan Jumărea - Practical Tests and Infra
- Andreia Ocănoaia - Labs

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# Team members

- Ana Gabriela Almăjanu
- Alexandru Răduță
- Alexandru-Nicolae Ocănoaia
- Vlad Cătănoiu
- Adelin-Costin Popa
- Diana Vulpoi
- Gabriel Pitic
- Rareș Sarmasag
- Maria Irina Gherman
- Catalin Cojocaru
- Rareș-Constantin Rîjniță
- Robert-Paul Pașca
- Andrei-Costin Carp
- Eduard-Ștefan Pană
- Amir Fallah-mirzaei
- Maria Sfîrăială
- Ştefăniţă-Alexandru Stoica
- Florin Postolache
- Andrei-George Nicola
- Elena-Luiza Olaru
- Maria-Teodora Popescu
- Aureliu Valentin Antonie
- Răzvan Vîrtan
- Răzvan Deaconescu
- Cătălin Pușcoci
- Daniel-Ioan Dinu
- Vlad-Iulius Năstase
- Ionuț Mihalache
- Vaduva Jan Alexandru
- Alice Suiu
- Resul Ebru
- Andreia Ocănoaia
- Alexandru Razvan Căciulescu
- Ștefan Jumărea
- Eric-Emanuel Tudorică
- Răzvan Voica
- Alex Cioloca
- Ana-Florentina Neacșu
- Darius-Florin Epure
- Maria-Alexandra Neacşu
- Cristian-Andrei Pomenea
- Alex-Ciprian Fechet
- Ştefan-Rareş Cazan
- Darius-Octavian Chifor
- Silviu-Adelin Stoican
- Robert-Alexandru Ghiță
- Ionuţ-Valentin Anghel
- Izabela-Maria Stoica
- Patrick David Covaci
- Ioana-Ruxandra Banu
- Ilinca Savu
- Victor Lișman
- Eva Cosma
- Irina Bradu
- Alexandru Iova
- Genan Omer

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# Outline

## Activities

- 12 Lectures
- 12 Labs

## Subjects

1. Intro to Virtual Machines
2. File, Folders and Path
3. Text Editors (vim, nvim or helix)
4. Users & Groups
5. Process Management
6. Linux Command Line (text processing)
7. Software Development
8. Source Code Repositories (git)
9. Shell Scripts (bash)
10. Networking

## Rules

- No AI access
- No *stackoverflow.com*
- DuckDuck GO search engine

## 4 homework assignments

> *that will help you prepare for the hands on tests*

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# Grading

| Part | Description | Points |
|---|---|---|
| Lecture tests | You will have a four lecture tests. | 0.5p |
| Homework | You will have 4 homework assignments to exercise you for the hands-on tests | 1p |
| Lab activity | Your lab activity will be graded. | 0.5p |
| Hands-on midterm | You will have a practical test covering the first 9 weeks (a Saturday in December) | 4p |
| Theoretical exam | You will have a quiz on Moodle with French grading (in the exams period). | 2.5p |
| Hands-on exam | You will have a practical test covering all the subjects (in the exams period). | 2.5p |
| **Total** | *You will need at least **2.5p during the semester and 5 points in total** to pass the subject.* | **11p** |

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# Notation

- *name* - this is a name
- **important** - this is important
- `command` - this is a command or a part of a source code

Code

```
$ command arguments
```

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# Notation

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$ command arguments
this is what the command wrote
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Code

```
$ command arguments
this is what the command wrote
$ command2 arguments placed \ # mind the \ that splits the command over multiple lines
           using multiple \
           lines
```

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# Notation

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Code

```
$ command arguments
this is what the command wrote
$ command2 arguments placed \ # mind the \ that splits the command over multiple lines
           using multiple \
           lines
```

> `$` signifies that the user can write a command, but is **not part of the command**.

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*If you can't explain it simply, you don't understand it well enough*

– Albert Einstein

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# Bibliography

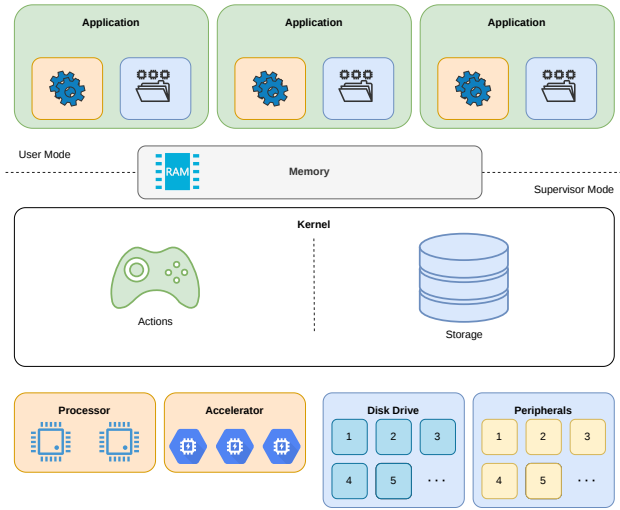

1. **Brian Ward**, *How LINUX Works*, 3rd Edition, No Starch Press, 2021
2. **Razvan Deaconescu, Razvan Rughinis, Mihai Carabas, Alexandru Radovici**, *Utilizarea Sistemelor de Operare*, Printech 2021, download


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# Operating System

*the purpose of an OS*

# The *Core Role* of an Operating System



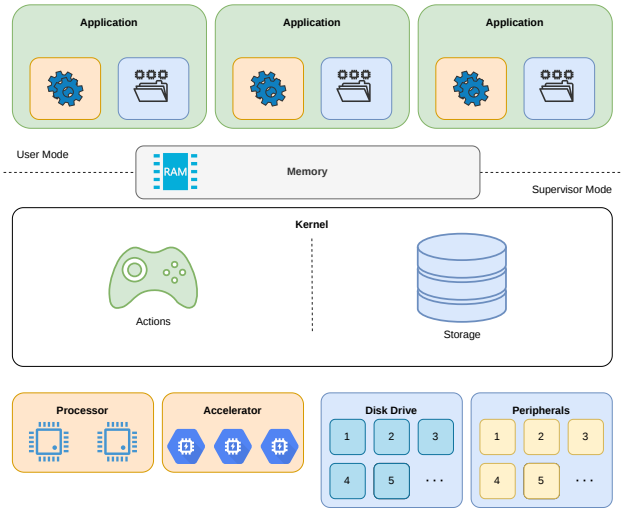

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# The *Core Role* of an Operating System



**Allow Portability**

- provides a hardware independent API
- applications should run on any hardware




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# The *Core Role* of an Operating System

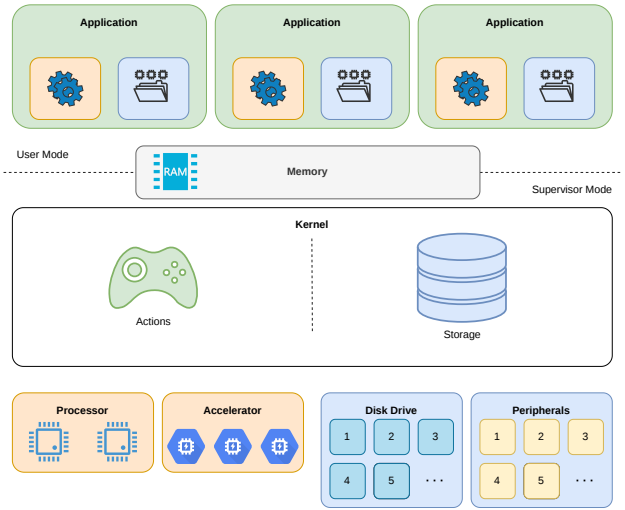


**Allow Portability**

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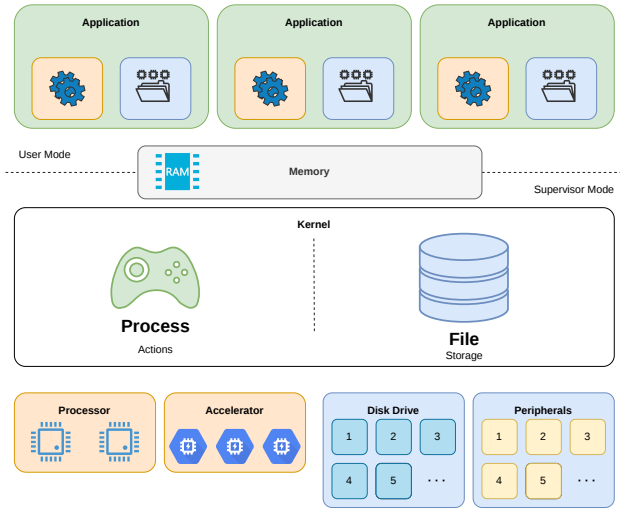
**Resources Management and Isolation**

- allow applications to access resources
- prevent applications from accessing hardware directly
- isolate applications




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# Desktop and Server Operating Systems - abstractions

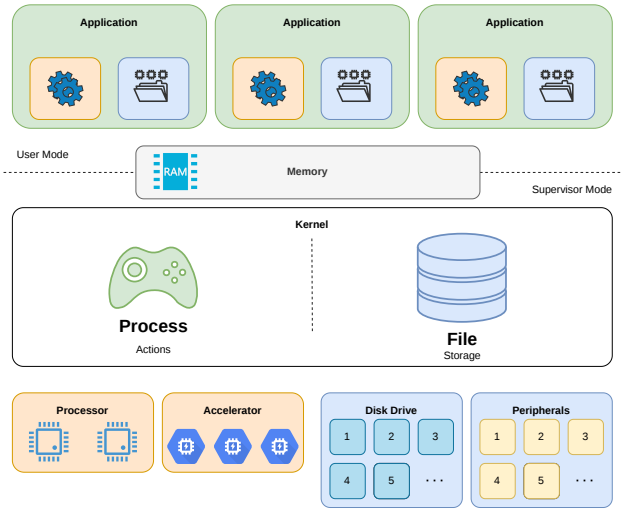



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# Desktop and Server Operating Systems - abstractions

**Actions**

- *Applications*
- use the *Processor* and *Accelerators* (GPU, Neural Engine, etc)




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# Desktop and Server Operating Systems - abstractions

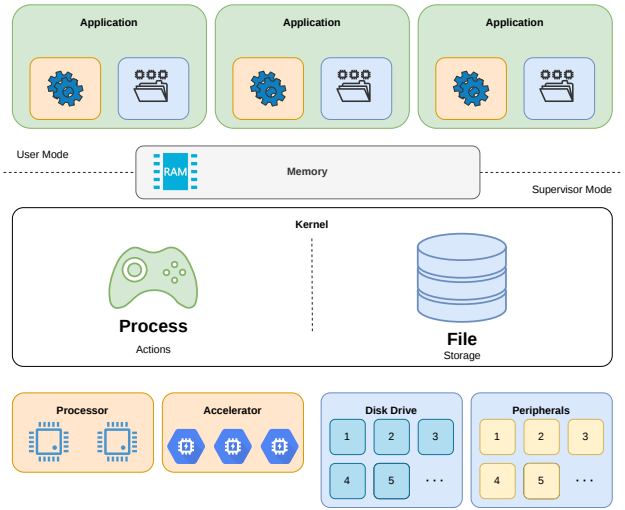


**Actions**

- *Applications*
- use the *Processor* and *Accelerators* (GPU, Neural Engine, etc)

**Data**

- everything is a file
- peripherals are viewed as files (*POSIX*)
  - `/dev/input/keyboard` - keyboard
  - `/dev/fb` - screen (framebuffer)
  - `/dev/sda` - Disk Drive A (first)




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# Embedded Operating Systems

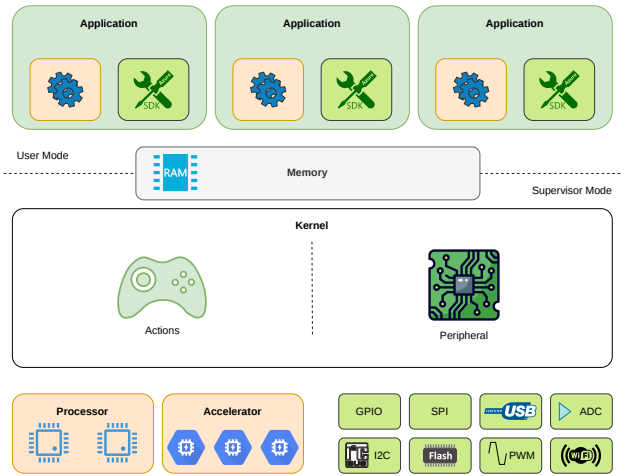
**Actions**

- Simple *applications*
- use the *Processor* and *Accelerators* (Crypto Engines, Neural Engine, etc)

**Peripheral**

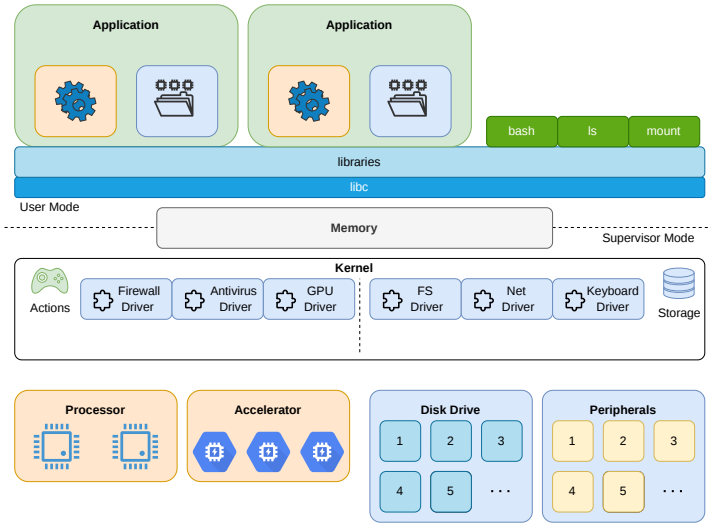
- provide a hardware independent API
- prevent processes from accessing the peripheral

*usually* the applications and the kernel are compiled together into a **single binary**




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# The OS Stack




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# Application Examples

| What it does | Windows | Linux | macOS |
|---|---|---|---|
| Desktop | `explorer.exe` | `nautilus` | Finder |
| Applications | `taskbar.exe` | `gnome-shell` | Dock |
| Files | `explorer.exe` | `nautilus` | Finder |
| Settings | `start ms-settings:` | `gnome-control-center` | System Settings |
| Commands | `cmd.exe` or `powershell.exe` | `bash` or `zsh` | `bash` or `zsh` |
| Documents | `powerpoint.exe` | `libreoffice` | Pages |
| Edit Code | `code.exe` | `code` | `code` |
| Terminal[1] | *handled by the OS* | `ptyxis` | Terminal |

[1]Third party recommendations for Linux and macOS are Kitty, Alacritty and Ghostty

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# Where can we see the core of the OS

# Where can we see the core of the OS

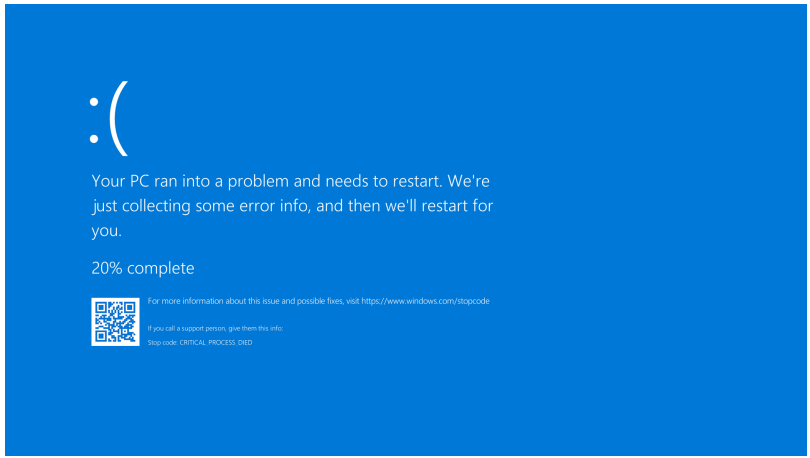
```
Booting Linux on physical CPU 0x0
Linux version 4.1.0-rc1-00016-g5704046-dirty (ags@trochilidae) (gcc version 4.9.
3 20141031 (prerelease) (Linaro GCC 4.9-2014.11) ) #68 Sat May 16 10:51:07 CEST
2015
CPU: ARMv7-M [410fc241] revision 1 (ARMv7M), cr=00000000
CPU: unknown data cache, unknown instruction cache
Machine model: VF610 Cortex-M4
Built 1 zonelists in Zone order, mobility grouping on.  Total pages: 12192
Kernel command line: console=ttyLP2,115200 clk_ignore_unused init=/linuxrc rw
PID hash table entries: 256 (order: -2, 1024 bytes)
Dentry cache hash table entries: 8192 (order: 3, 32768 bytes)
Inode-cache hash table entries: 4096 (order: 2, 16384 bytes)
Memory: 46800K/49152K available (895K kernel code, 52K rwdata, 312K rodata, 64K
init, 165K bss, 2352K reserved, 0K cma-reserved)
Virtual kernel memory layout:
    vector  : 0x00000000 - 0x00001000   (   4 kB)
    fixmap  : 0xffc00000 - 0xfff00000   (3072 kB)
    vmalloc : 0x00000000 - 0xffffffff   (4095 MB)
    lowmem  : 0x8c000000 - 0x8f000000   (  48 MB)
      .text : 0x0f000080 - 0x0f12e050   (1208 kB)
      .init : 0x8c00a000 - 0x8c00d000   (  12 kB)
      .data : 0x8c008000 - 0x8c018060   (  65 kB)
       .bss : 0x8c018060 - 0x8c041630   ( 166 kB)
```



**During Boot**

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# Where can we see the core of the OS




**Blue Screen (BSoD)**

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# Where can we see the core of the OS



```
Waiting for driver initialization.
Scanning and configuring dmraid supported devices
Scanning logical volumes
  Reading all physical volumes.  This may take a while...
  Found volume group "VolGroup00" using metadata type lvm2
Activating logical volumes
  2 logical volume(s) in volume group "VolGroup00" now active
Trying to resume from /dev/VolGroup00/LogVol01
No suspend signature on swap, not resuming.
Creating root device.
Mounting root filesystem.
kjournald starting.  Commit interval 5 seconds
EXT3-fs: mounted filesystem with ordered data mode.
Setting up other filesystems.
Setting up new root fs
no fstab.sys, mounting internal defaults
Switching to new root and running init.
unmounting old /dev
unmounting old /proc
unmounting old /sys
type=1404 audit(1381844547.109:2): enforcing=1 old_enforcing=0 auid=4294967295 s
es=4294967295
Unable to load SELinux Policy. Machine is in enforcing mode. Halting now.
Kernel panic - not syncing: Attempted to kill init!
_
```



**Linux Kernel Panic**

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# Where can we see the core of the OS



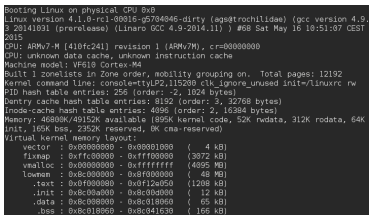



**macOS Kernel Panic**

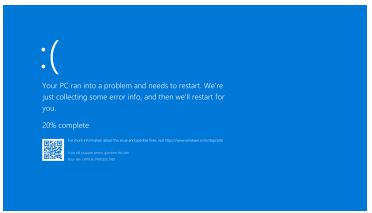
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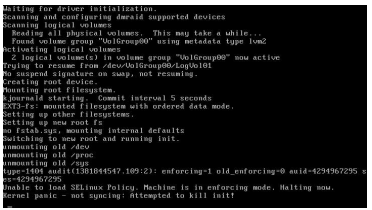
## During Boot

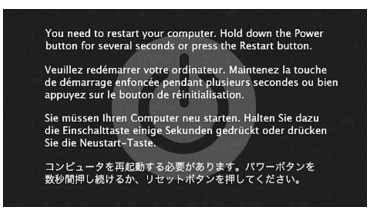



## Blue Screen (BSoD)




## Kernel Panic




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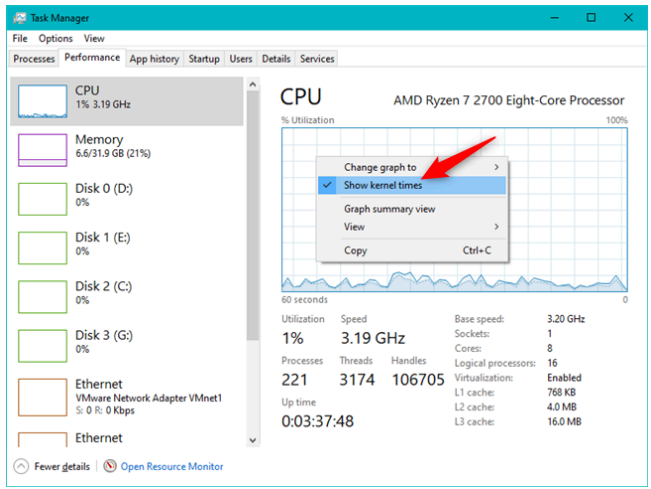
# The Kernel

- is a collection of applications that *usually* run in privileged mode
- one *main application* and several *utilities apps*

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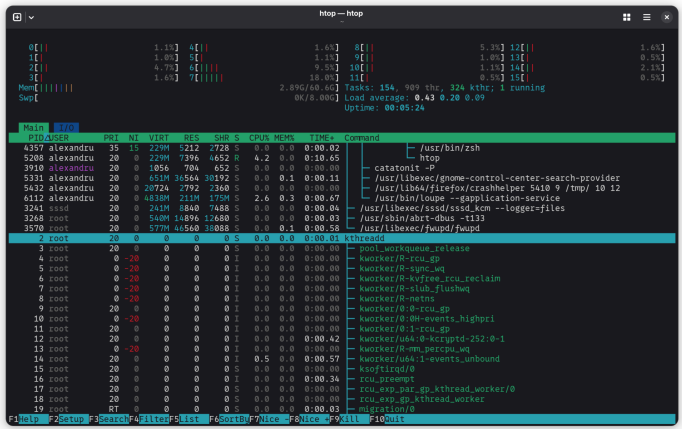



**Windows Task Manager**

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# The Kernel

- is a collection of applications that *usually* run in privileged mode
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htop

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# Virtual Machine

*run an OS within an application*

# The Idea

*run an operating system within an application*

Why?

- Debug operating systems
- Run software that is not compatible with the OS your computer runs
- Securely share a server

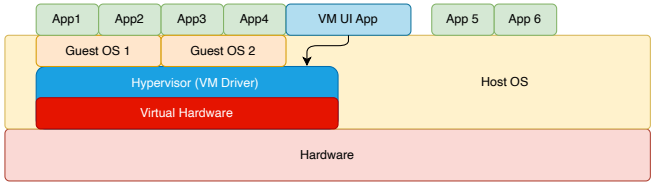
Virtualization Software

- VirtualBox
- VMWare
- QEMU

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# Simulation / Emulation

simulate all the hardware - very slow



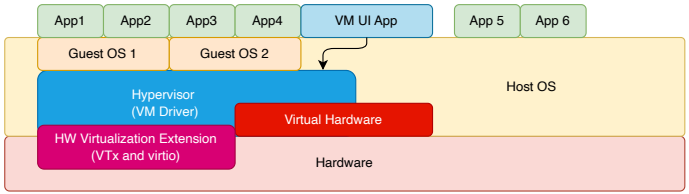

QEMU

- is able to simulate most of the available architectures
  - most used `x86`, `AMD64`, `arm`, `aarch64`, `powerpc`, `risc-v`

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# Virtualization

Use a part of the available hardware, emulates as if the system was running alone on the hardware

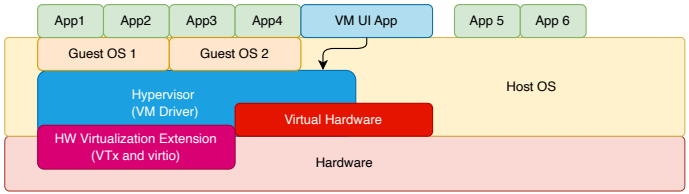



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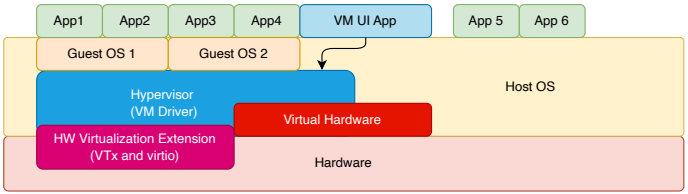



- Requires VT-x (Intel), AMD-V (AMD) or VHE (ARM)
-

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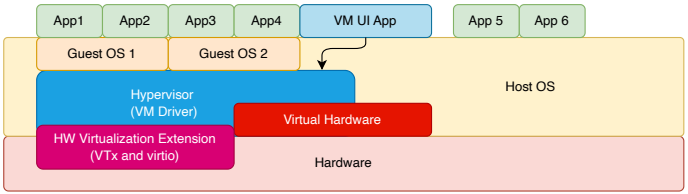



- Requires VT-x (Intel), AMD-V (AMD) or VHE (ARM)
- The guest OS has to be built for the same CPU architecture as the host OS
  - *Intel / AMD* is x86_64 (`amd64`)
  - *Apple Silicon* is ARM64 (`aarch64`)

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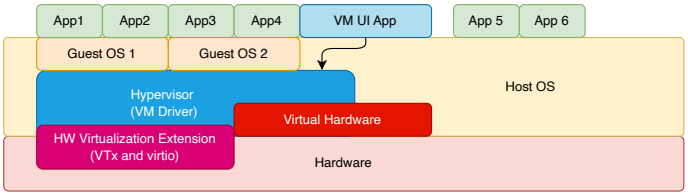
## Hypervisors

- VMWare
- VirtualBox
- QEMU using `hyper-v`, `KVM` or *Hypervisor.framework*

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# Virtualization

Use a part of the available hardware, emulates as if the system was running alone on the hardware




## Hypervisors

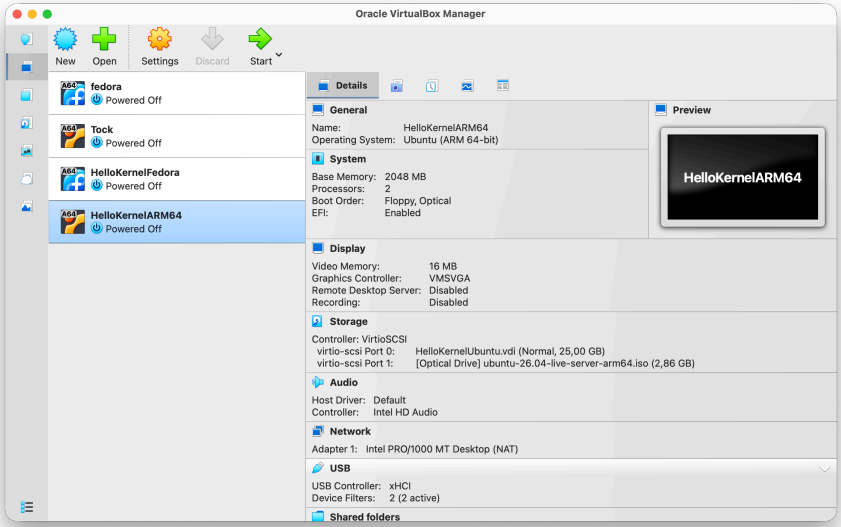
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  - *Apple Silicon* is ARM64 (`aarch64`)

> Make sure you download a Linux version for `amd64` or `aarch64`

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# VirtualBox Machine Settings

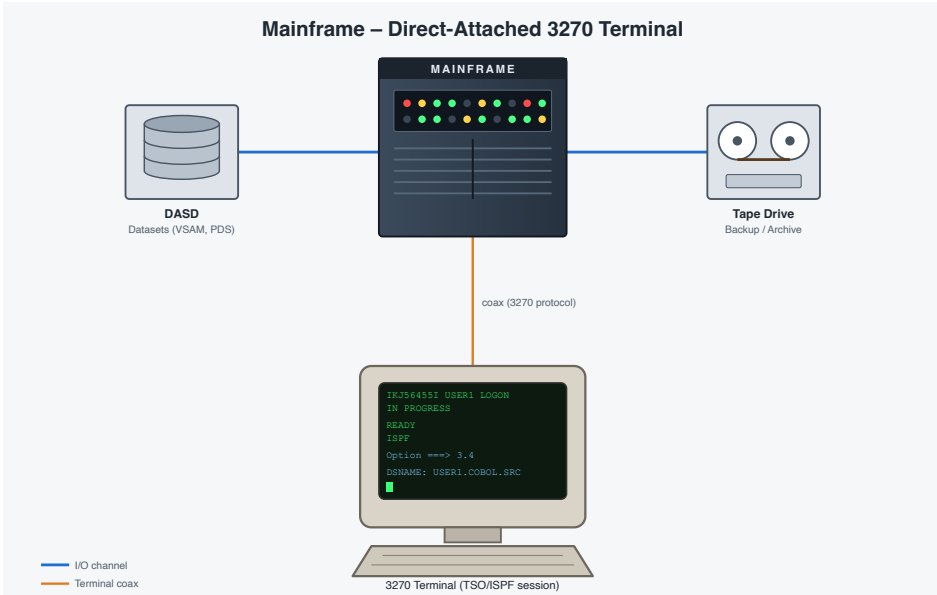



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# Distribution

*what an OS is from the user's point of view*

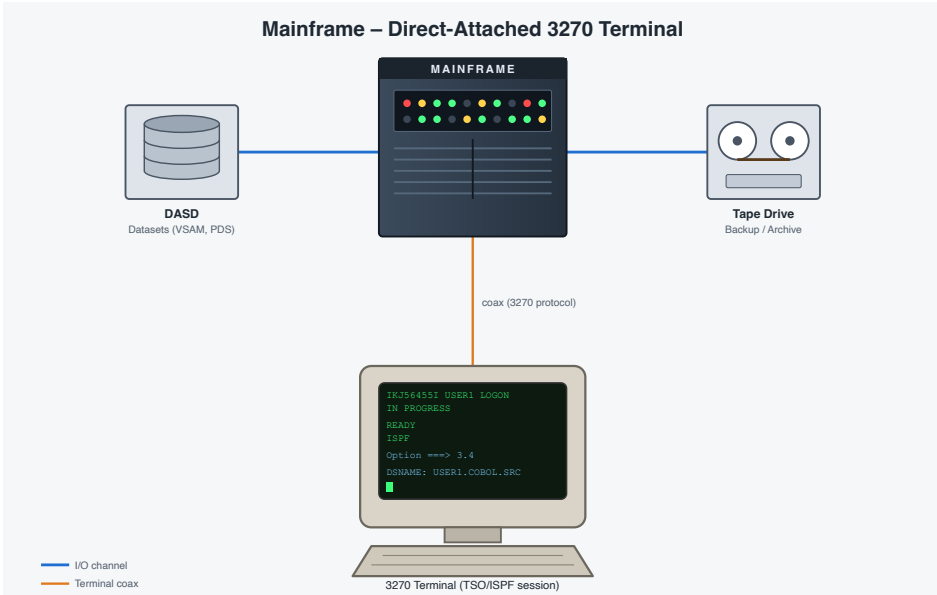
# Meet the *Mainframe*




**Size:** a full room
**IO:** remote terminal
**Users:** single
**Programs:** one batch job

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# Meet the *Mainframe*



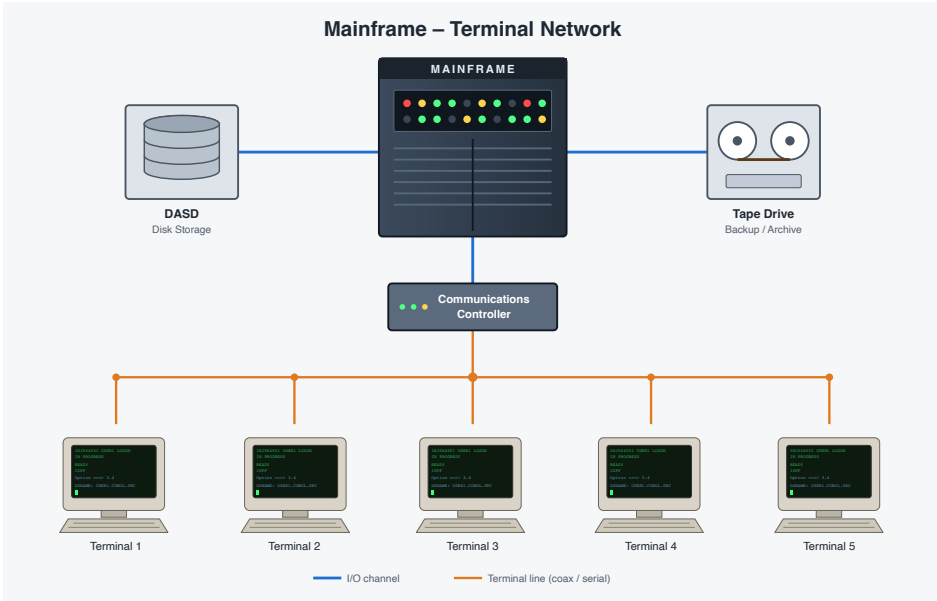

**Size:** a full room
**IO:** remote terminal
**Users:** single
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Waste of compute power

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# Meet the *Mainframe*




**Size:** a full room
**IO:** remote terminals
**Users:** multiple
**Programs:** multiple

Waste of compute power

The need for an Operating System

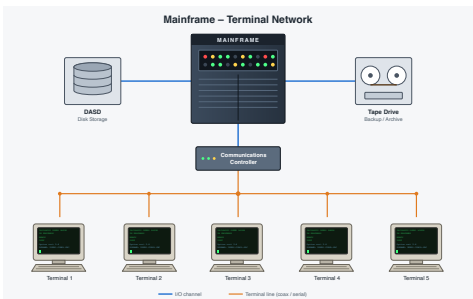
*UNIX*

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# UNIX

Mainframes provide a lot of hardware

- need to be shared by several users
- each user has a terminal connected to the mainframe
- run several programs in parallel




Ken Thompson & Dennis Ritchie (Bell Labs, AT&T)



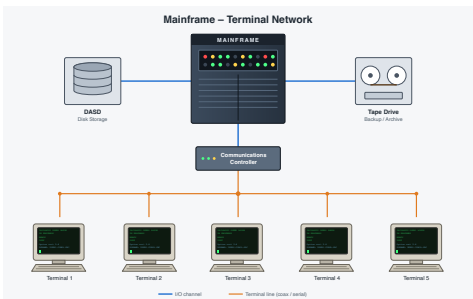

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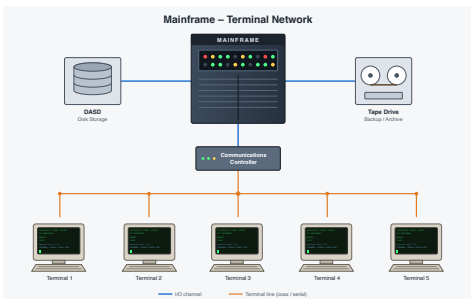

- Denis Ritchie writes C
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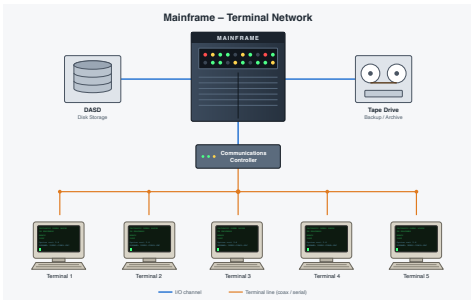

- Denis Ritchie writes C
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# UNIX

Mainframes provide a lot of hardware

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🔒 Is open source up to version *UNIX System III*

Ken Thompson & Dennis Ritchie (Bell Labs, AT&T)




- Denis Ritchie writes C
- together with Ken Thompson use C to write UNIX.

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# The POSIX Standard

*Portable Operating System Interface* (ISO 9945)

Defines:

- how an OS should work (*everything is a file*)
- how the C API looks like (ex `stdio.h`, `unistd.h`)
- what commands (basic software) should be available

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  - *in C/C++ source code format only*

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**When UNIX became closed source ->**

UC **Berkeley Software Distribution (BSD)**

| FreeBSD | Darwin | OpenBSD | NetBSD |
|---|---|---|---|
|  |   |  |   |

New kernels

| Minix | Linux | RedoxOS[1] |
|---|---|---|
|  |  |  |

[1]Partially POSIX compliant

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# GNU Software

Basic *UNIX* commands and software **rewritten**

- 
- 
- 

- 

*Richard Stallman* (MIT)





His vision is that software should be:

- free to share and modify
- GPL and LGPL licenses
  - allows selling and modifying
  - modified code must be relicensed under GPL

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  - `flex` / `yacc`
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- C Compiler -> GNU Compiler Collection (`gcc`)
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  - `flex` / `yacc`
- X Windows System (`x11`)

**Modern Software**

- *coreutils* are being rewritten in Rust (*uutils*)[1]
- `gcc` is being slowly replaced by LLVM
- `x11` is being replaced by Wayland

*Richard Stallman* (MIT)





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[1] Used by Ubuntu starting with 26.04

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# The Linux Kernel



***Linus Torvalds* (University of Helsinki)**

- did not agree with A. Tannenbaum about how Minix should work
-

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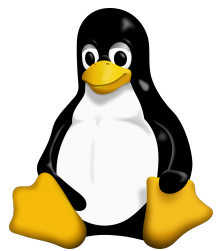
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- wrote his own 👩‍💻 *POSIX compliant* OS, called it Linu**x**

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# The Linux Kernel



- is the actual operating system
- invisible to the user
  - except when it boots 🏁 and panics 😱
- 25 mil line of code (LOC)
- manages all the system resources



Meet *Tux*

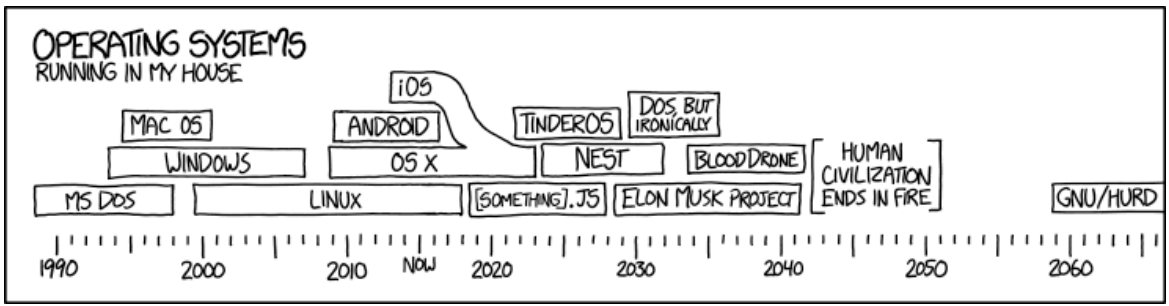
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# GNU/Linux = ❤️

GNU Software on top of the Linux kernel

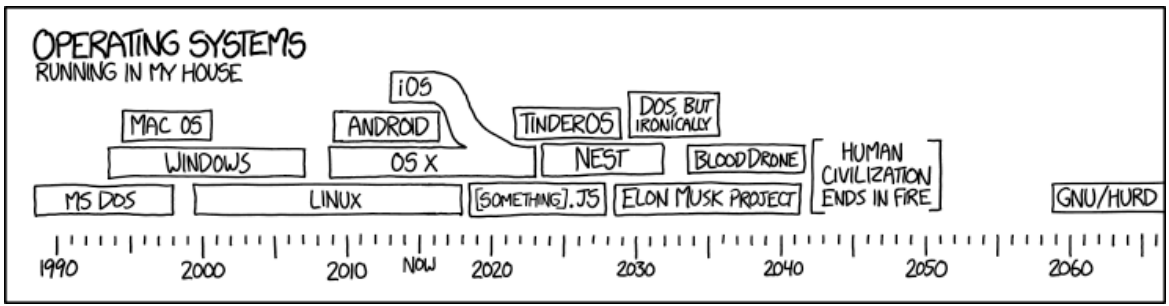



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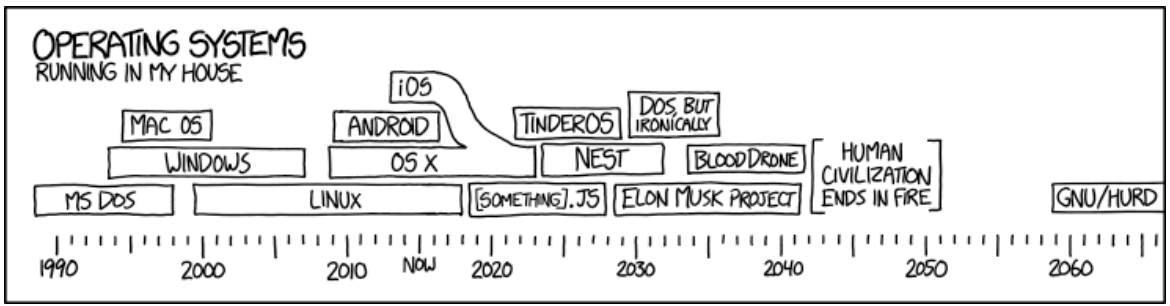



- GNU Hurd 👷🚧🏗️ (*work in progress for many many years*)
-

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# GNU/Linux = ❤️

GNU Software on top of the Linux kernel




- GNU Hurd 👷🚧🏗️ (*work in progress for many many years*)
- The Linux kernel 🐧 still is the *temporary replacement*

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# Base Distributions

The main Linux distributions that started it

*Took the Linux kernel, added the GNU libraries and tools and wrote a package manager to install software*

| | Name | Tagline | Package Format | Package Manager | Release Year |
|---|---|---|---|---|---|
|  | Slackware | *Oldest distribution* | `tgz` | `pkgtool` | 1993 |
|  | Debian | *Free Software* | `deb` | `apt` / `dpkg` | 1993 |
|  | Red Hat Linux | *Enterprise* | `rpm` | `dnf` / `rpm` | 1995 |

These are the base for most of the modern distributions that we have today.

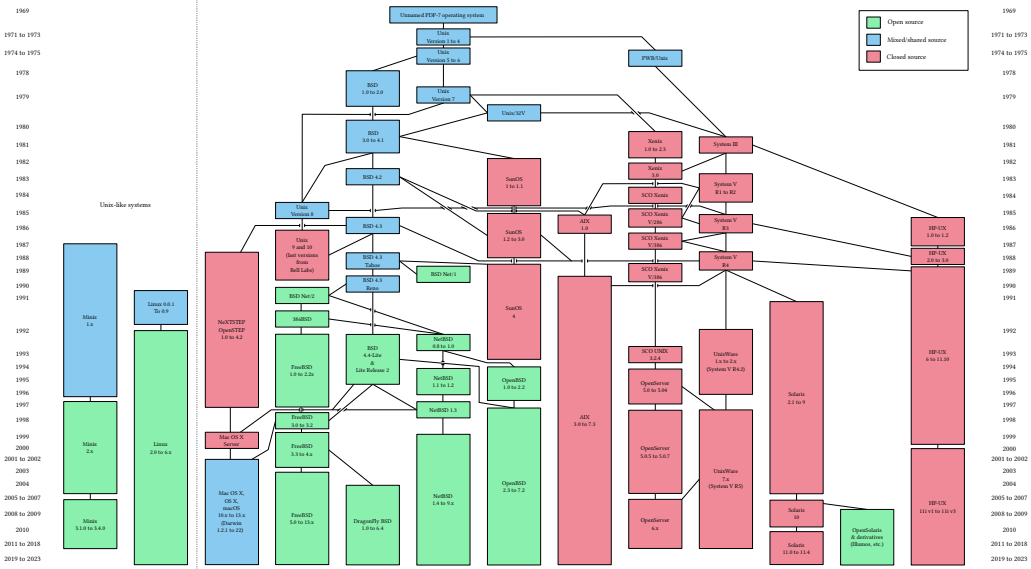
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# Modern Distributions

| | Name | Tagline | Parent | Package Format | Package Manager | Release |
|---|---|---|---|---|---|---|
|  | SUSE Linux | *Enterprise-grade Linux* | *Originally Slackware, later RPM-based* | `rpm` | `zypper`, `yast` | 1994 |
|  | ArchLinux | *Minimal Linux* | N/A | `pkg.tar.zst` | `pacman` | 2002 |
|  | Fedora | *Desktop Linux* | *Red Hat Linux renamed* | `rpm` | `dnf` / `rpm` | 2003 |
|  | Ubuntu | *Linux for Humans* | Debian | `deb` and `snap` | `apt` / `dpkg` and `snap` | 2004 |
|  | openSUSE | *Stable, usable Linux for everyone* | SUSE Linux | `rpm` | `zypper`, `rpm` | 2005 |

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# POSIX Distributions *Tree*




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# Most Used Linux Distribution?

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# Most Used Linux Distribution?



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# Non GNU Distributions

They use Linux, but most of the software is not from GNU

| | Distribution | Tagline | Parent | Package Format | Package Manager | Release Year |
|---|---|---|---|---|---|---|
|  | Android | *Mobile Linux platform* | Linux kernel (AOSP) | `.apk` (only Android apps) `.aab` (only Android apps) `.apex` (libraries) | AOSP tools (not typical package manager) | 2008 |
|  | ChromeOS | *The cloud-first OS* | Gentoo Linux | Custom (`.crx`, `.apk`, others) | `portage`, `cros_sdk`, Flatpak (via Crostini) | 2011 |

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# We talked about

- What an Operating System is
- The Operating System Stack
- Virtual Machines
- History of Linux
- Distributions

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