

# **Systems 3**

## **Principles**

Marcel Waldvogel

Department of Computer and Information Science  
University of Konstanz

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# Timetable

- Lecture: Thursday (15:15) && Friday (11:45)
  - Marcel Waldvogel ([marcel.waldvogel@uni.kn](mailto:marcel.waldvogel@uni.kn))
- Exercise: Thursday (8:15 || 11:45 || 17:00)
  - Klaus Herberth ([klaus.herberth@uni.kn](mailto:klaus.herberth@uni.kn))
  - Christian Löhle ([christian.loehle@uni.kn](mailto:christian.loehle@uni.kn))

# Exam Admission

- Work in a group of two students
- Your solutions to every exercise need to show serious deliberation
- You are allowed to have two failures (three strikes and out)
- If you get 50% in total you will get a 0,3 exam bonus

# Teaching materials

are available via git<sup>1</sup> on GitLab<sup>2</sup>. One member of the group forks the repository<sup>3</sup> into his personal space and

- **grants access** to the other member (at least ‘Developer’),
- **shares** it with the tutors (at ‘Owner’ or ‘Master’ level).

You can then browse all files in the repository, which includes instructions on how to clone it into a local repository.

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<sup>1</sup><https://git-scm.com/>

<sup>2</sup><https://git.uni.kn>

<sup>3</sup><https://git.uni-konstanz.de/disy/lectures/systeme-3-2019>

# Chapter Goals

- Operating Systems<sup>4</sup>: What and why?
- What are their functions and how did they evolve?
- First insights into structure and processes.
- Does the CPU<sup>5</sup> control the OS or vice versa?

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<sup>4</sup>OS

<sup>5</sup>Central Processing Unit aka<sup>6</sup>processor

<sup>6</sup> "also known as"

# What is an Operating System?

- Where do we find them?
- What do they do there?
- What are common operating systems (OS)?

# What does an Operating System do?

## Traditional goals

### Hardware abstraction

- 1 Simplify application development
- 2 Portability
- 3 ...

### Resource management

- 1 Share CPU among multiple processes
- 2 Share network cards among multiple services
- 3 ...

# What does an Operating System do?

Today: Communications gateway

## Enable communications

- 1 Between processes
- 2 Between systems

## Restrict/select communications

- 1 Not everyone should be able to interfere with everything
- 2 Only when a process is ready
- 3 Only what a process expects

Hardware abstraction, resource management, and communications are independent dimensions (more or less).

# Gen1 ~1950: Tubes, plugboards, core memory

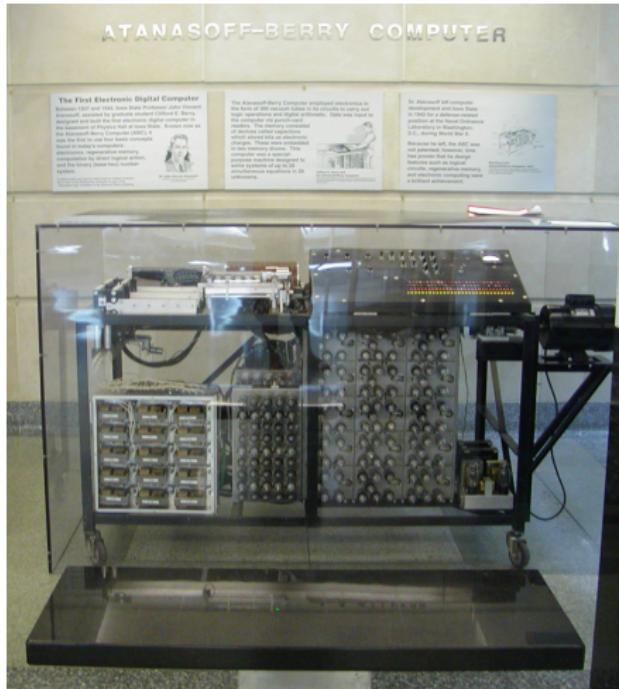
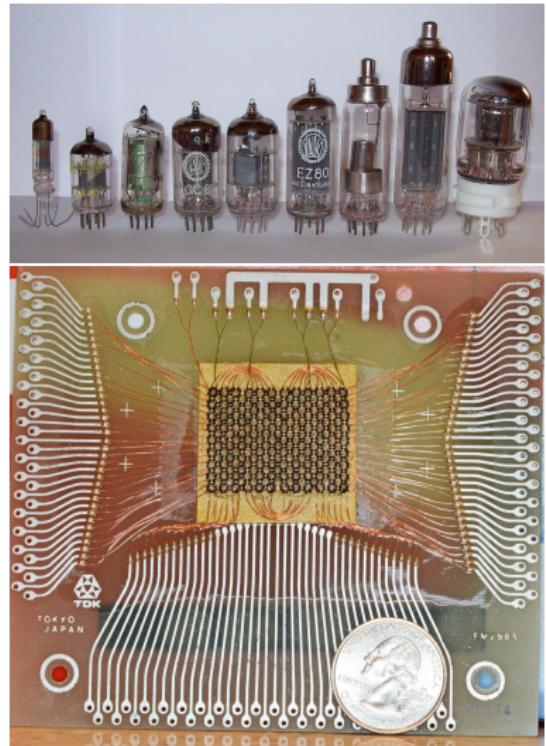
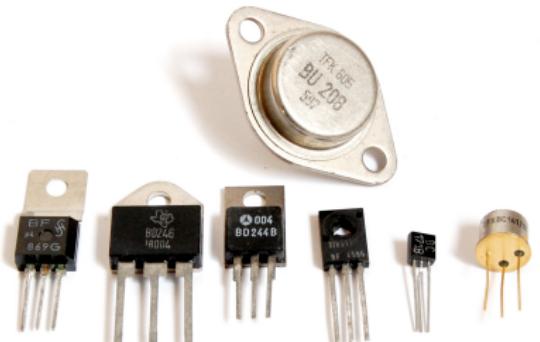


Photo credits: Wikipedia users Manop, CC BY-SA 3.0; Stefan Riepl (Quark48), CC BY-SA 2.0 de; Bubba73 (Jud McCranie), CC BY-SA 4.0.



# Gen2 ~1960: Transistors and batch systems



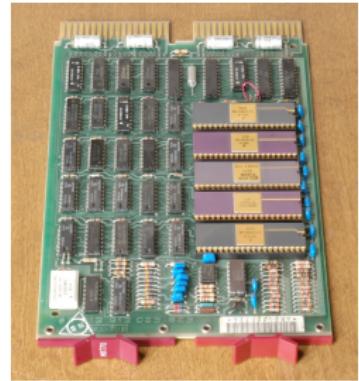
## Batch processing

Programs can be run quickly one after another to reduce turn-around time and increase utilization.

Today used for e.g. HPC/Supercomputing, end-of-day processing.

Photo credits: Wikipedia users [Benedikt.Seidl](#), public domain; [Grkauls](#), public domain.

# Gen3 ~1970–1980: ICs and multiprogramming



## Multiprogramming

Multiple programs (of different users) can be run seemingly in parallel.  
Today used for e.g. personal computers, mobile devices, even IoT.

Photo credits: Wikipedia users [Stefan.Kögl](#), CC BY-SA 3.0; Retro-Computing Society of Rhode Island, CC BY-SA 3.0 (2).

# Gen4 1980+: Personal computers



## Single-user

Computers were getting cheap enough to be used by single users, instead of using terminals to a central computer. First without networking.

Today many devices are used by mostly a single user, but still run multi-user operating systems. Reasons: Security, compatibility, . . .

Photo credits: Wikipedia users Hydrargyrum, CC BY-SA 3.0; Ruben de Rijcke, CC BY-SA 3.0; Rama, CC BY-SA 2.0 fr.

# Gen5 1990+: Mobile devices etc.



## Mobile

Faster processors, higher integration, cheaper prices, and lower power consumption made computers more portable and almost ubiquitous (IoT).

Wireless/mobile networking, cloud computing, isolation between processes of the same user (sandboxing), virtualization.

Photo credits: Wikipedia users Snowmanradio, CC BY-SA 3.0; Blake Patterson from Alexandria, VA, USA;  
Source ([WP:NFCC#4](#)), Fair use.

# OS History

## 1960s

**CTSS** Time-sharing (processes)

**VM/CMS** Virtualization (isolation)

**Multics** Single-level store, hierarchical file system, dynamic linking, IPC, hot-swapping

## 1970s

**Unix** ← Multics; modularity (everything is a file, user-level shell, byte stream, text files, pipes), portability, documentation

**CP/M** (← Unix); OS modularity (BIOS, BDOS, CCP), drive letters, OS for microcomputers/personal computers, Ctrl-Z for EOF

**VMS** File versions, file databases, multiprocessing/partitioning  
Networking, email

# OS History (cont'd)

## 1980s

**MS-DOS** ← CP/M

**MINIX** ← Unix; teaching

**GNU** Unix as free software<sup>7</sup>

**Mach** Micro-kernel (modularity in the kernel)

**GUI** Xerox, Apple, Digital Research/Atari, Amiga, Microsoft, X11

**Networking** Multiple protocols; “OSI”; TCP/IP, WWW

## 1990s

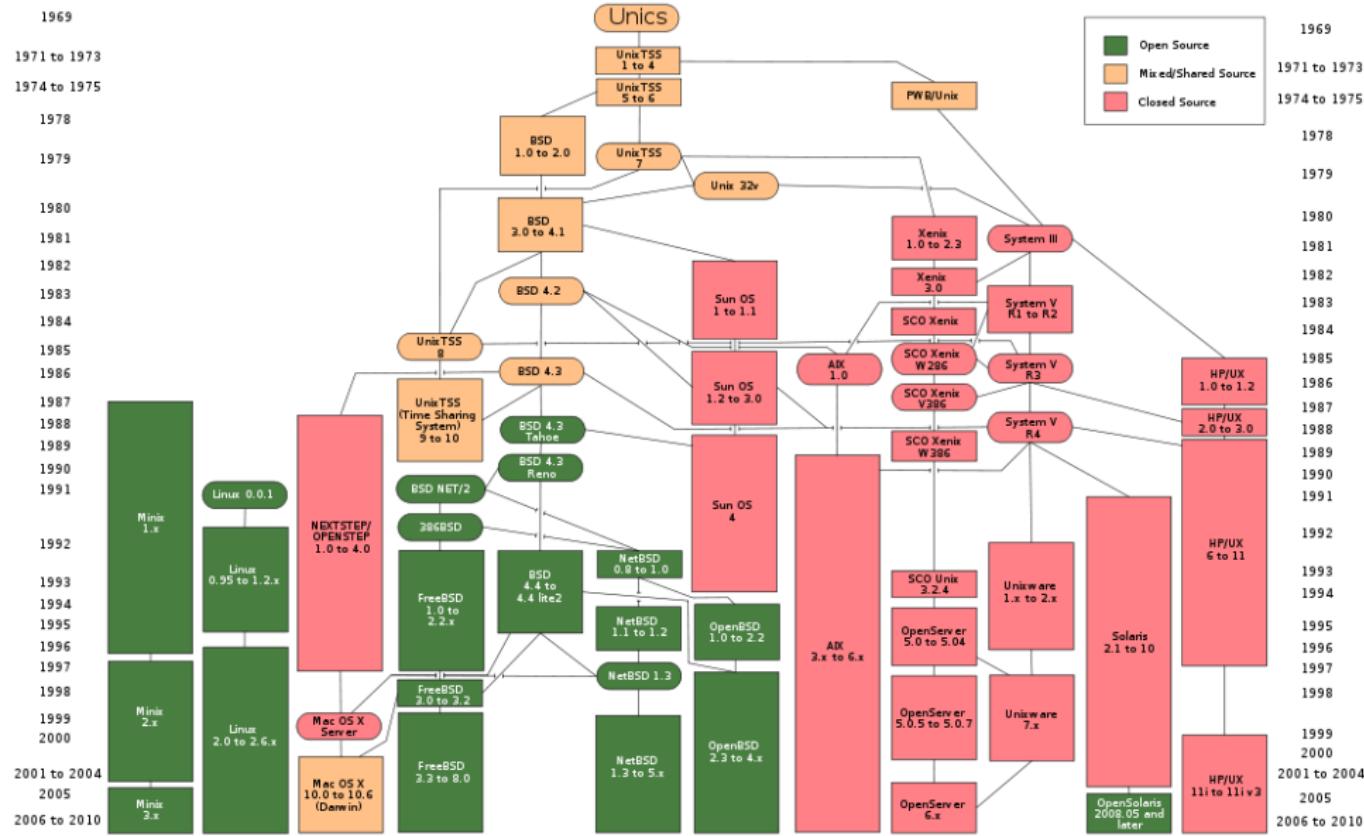
**Linux** Free software Unix-compatible kernel<sup>8</sup>

**Browser** Browser as GUI

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<sup>7</sup>user-level software, kernel (**Hurd**) stalled

<sup>8</sup>User-level tools from GNU project, hence, often called *GNU/Linux* in combination



# Market shares

## Mobile

- Android (76%) ← Linux
- iOS (22%) ← Unix

## Tablet

- iOS (73%) ← Unix
- Android (27%) ← Linux

## Desktop

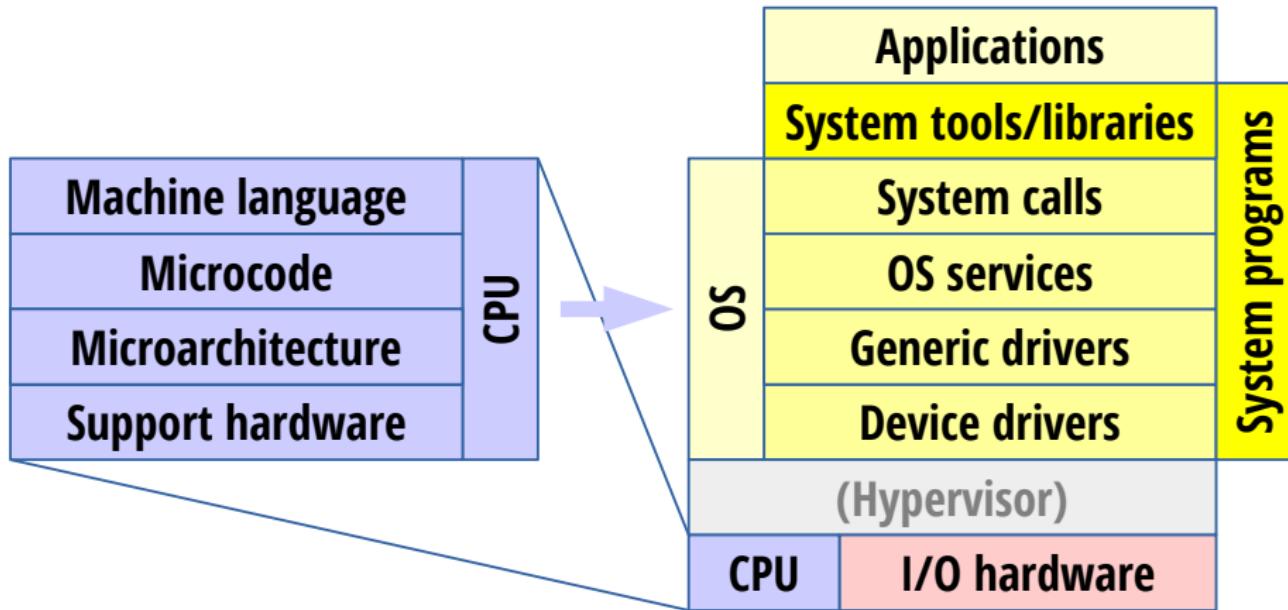
- Windows (80%) ← MS-DOS, VMS
- OS X (15%) ← Unix
- Linux (2%) ← Unix

## Server

- Cloud: Linux 90%
- Home router: Linux ~100%
- HPC: Linux ~100%
- Web servers: Linux 70...97%
- IoT: Linux 72%
- Business: Windows-mostly(?)

Source: Clients StatCounter, September 2019; servers MakeUseOf, March 2018, James Playfair on Quora, IT Pro Today/Eclipse Foundation

# The Modern Computer System



- 1 A main program that initializes the system and the first process(es)
- 2 A set of service procedures that carry out the process' system calls
- 3 A set of utility procedures that help the service procedures

# The Process

## Properties

- Environment for user programs
- Unit for the OS to manage running programs (=processes)
- Created by other processes

Most programs are written to run in processes. It becomes our little world with which we interact with the OS using system calls. The OS remains a black box with a defined API.

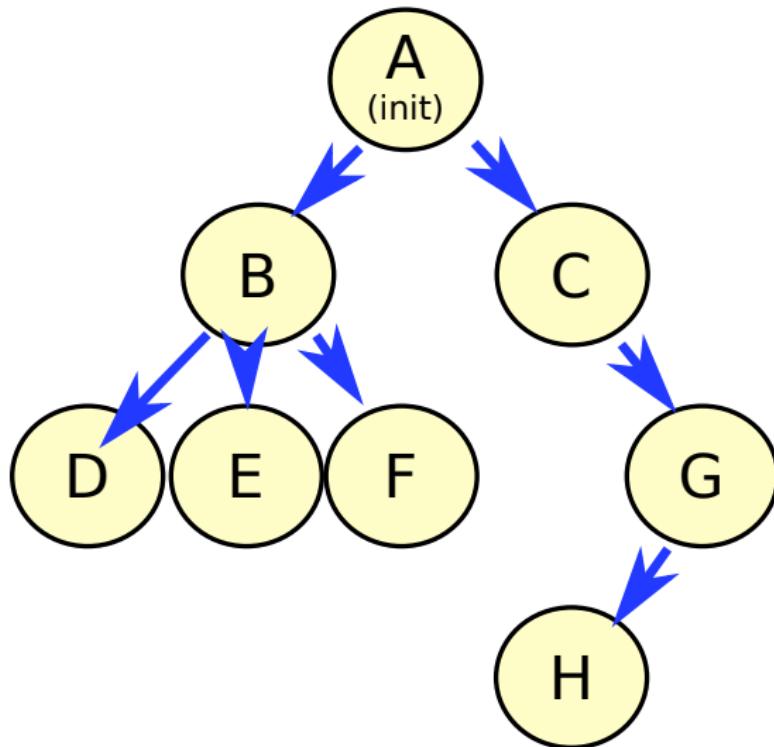
## Process vs. program

**Program** The (static) code to be executed.

**Process** The environment for running a program (processor state, OS state (open files etc.), ...)

Multiple processes may run the same program at the same time.  
On Unix, a single process may run multiple programs in turn.

# Process Tree



# System Calls

## OS is a black box

- How to get into this box?

## Entry options

- Function call opcode? (**Defeats isolation!**)
- Special opcode for system calls! (**Gatekeeper**)

## Goals for separation

- Isolation
- Security
- Abstraction

→ How can we call into an isolated environment **with elevated rights?**

# System Calls

## Example system calls

**Files** open(), close(), read(), write()

**Processes** fork(), exec(), exit(), getpid(), getppid()

**Networking** socket(), bind(), listen(), accept(), ← Files

**Memory** brk(), sbrk(), mmap(), munmap(). **Not** malloc(), free()!

**IPC** pipe(), shmat()

**Resources** setrlimit()

**Users** getuid(), setuid(), getgid(), setgid()

# Schedule

Week	Thursday	Friday
0	Principles	<b>C Basics</b>
1	<b>Pointers</b>	—
0	Principles	<b>C Introduction</b>
1	<b>C Basics</b>	<b>Pointers</b>
2	I/O	Memory
3	<b>Memory in C</b>	Memory Expansion
4	Process Model	Process Synchronization
5	<b>Threads</b>	Scheduling
6	<b>Big Programs</b>	Filesystem
7	OS Structure	OS Design
8	Vulnerabilities	Cryptography
9	<b>Libraries</b>	Virtualization
10	Meltdown	Security
11	Data security	Privacy
12	Defensive programming	Spare
13	Review	Q&A
14	Exam	—

# Literature

- Andrew S. Tanenbaum, Albert S. Woodhull. *Operating systems: design and implementation*. Uni-KN kid 346/t16a + lbs 843/t16b
- Brian W. Kernighan, Dennis M. Ritchie. *The C Programming Language*. Uni-KN kid 248 k27.
- Peter van der Linden. *Expert C Programming — Deep C Secrets*. Uni-KN kid 248 v16.