Systems and Networking – Unit I

B.Sc. in Applied Computer Science and Artificial Intelligence

2021-2022

SAPIENZA
UNIVERSITÀ DI ROMA

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Who Am I?

Who Am I?

UniPI

Who Am I?

UniPI

UniVE

Who Am I?

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Yahoo! Labs

Who Am I?

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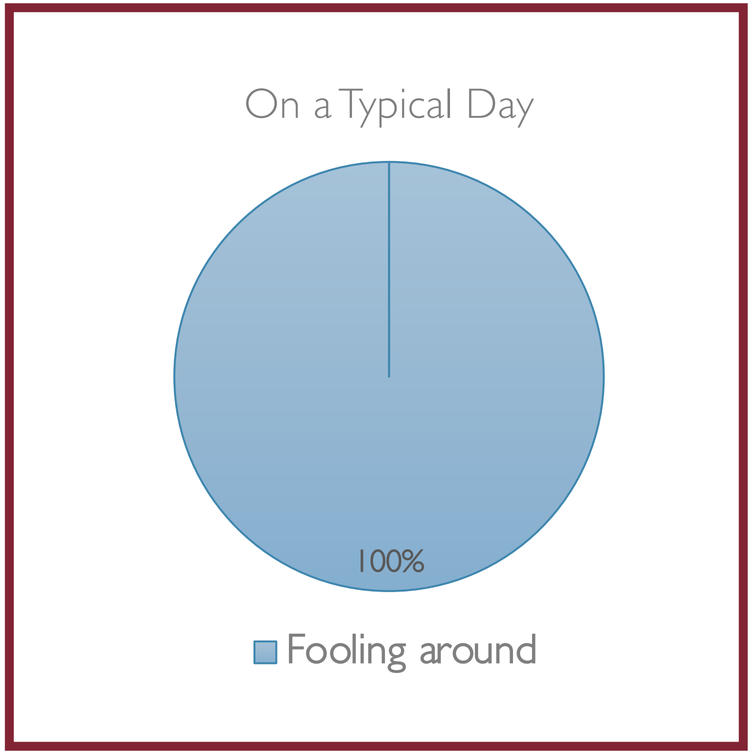
Sapienza

If A Day Of Mine Were A Pie…



Expectation

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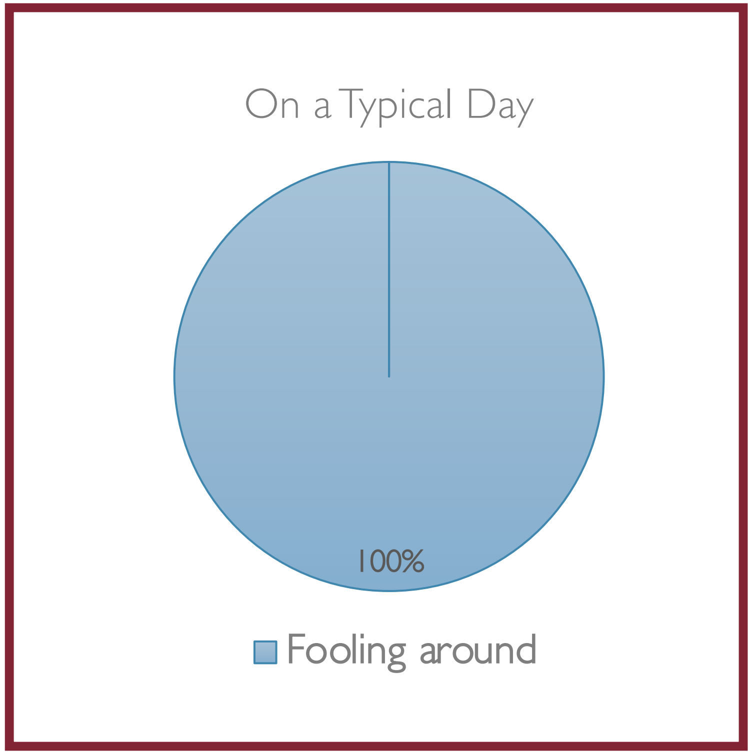
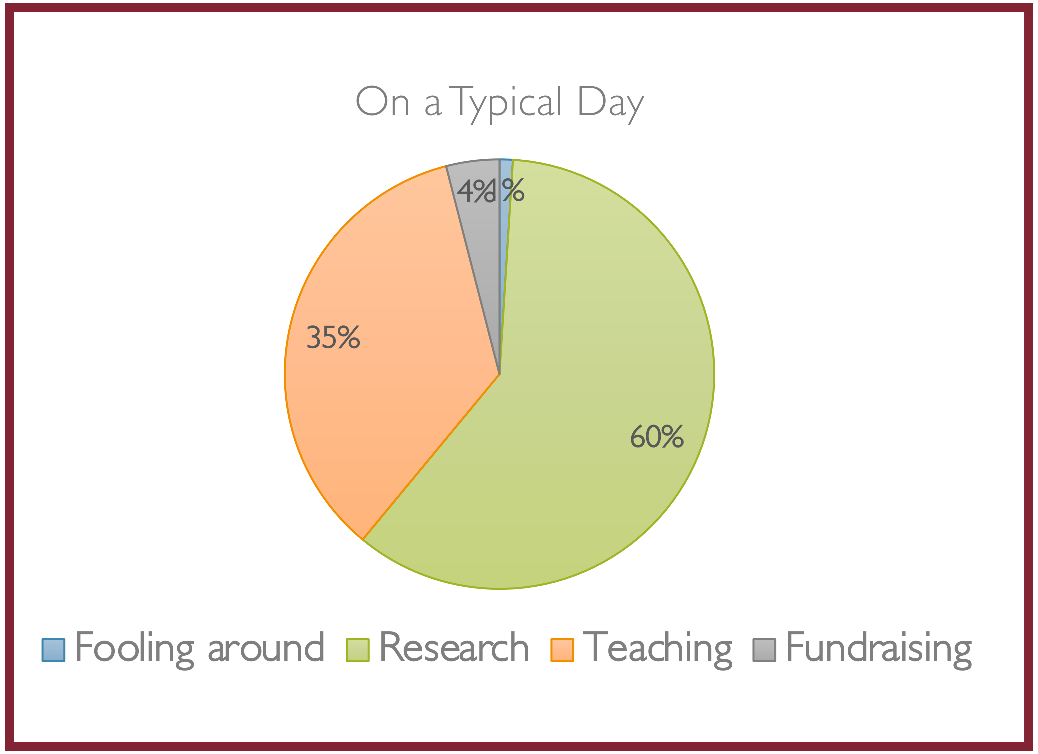


Expectation

vs.



Reality

Research On What?

HERCOLE Lab

Research On What?

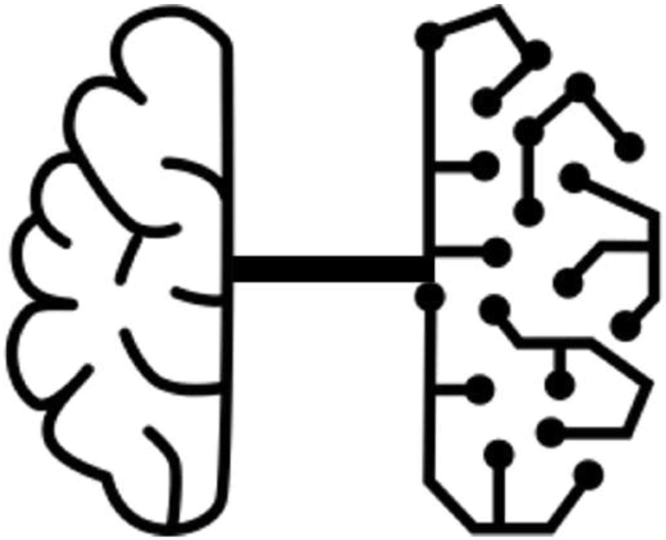
Human-Explainable

HERCOLE Lab

Research On What?

Robust

Human-Explainable



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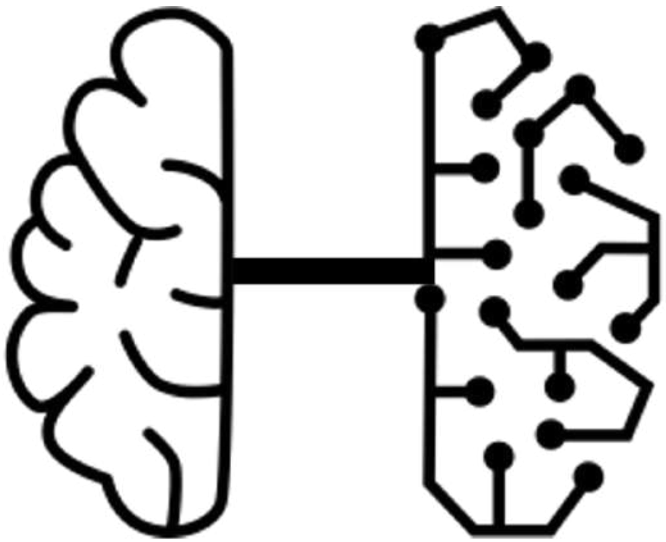

COllaborative

HERCOLE Lab

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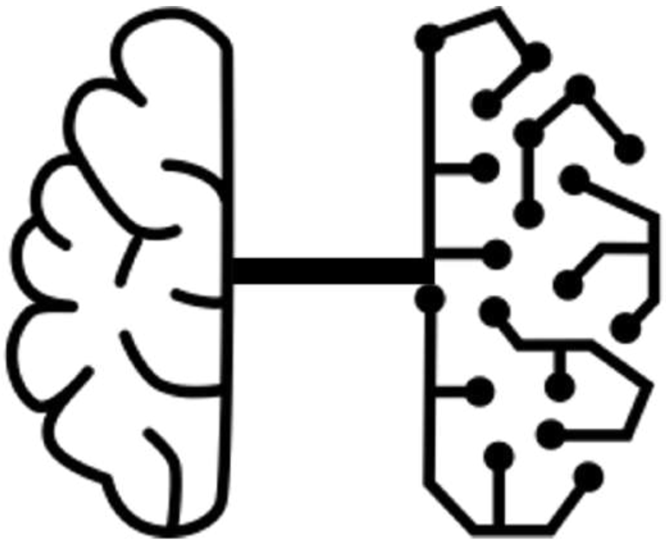

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LEarning

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Check out the lab's

[home page](#)

(still under construction, sic!)

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Meanwhile you can follow us on Twitter [@HercoleLab]

Useful Information

Class schedule

- Wednsesday: 11 a.m. - 1 p.m.
- Thursday: 8 a.m. - 11 a.m.

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Contacts

- email: tolomei@di.uniroma1.it
- website: https://github.com/gtolomei/systems-and-networking
- moodle: https://elearning.uniroma1.it/course/view.php?id=13817
- zoom: https://uniroma1.zoom.us/meeting/register/tZMkcuqurDMtE90QEvSpAXG4QJuMjvxIGZrs

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Office hours

- Arranged by appointment via email
- in-person or remotely
- Room 106, 1st floor Building "E" (map)

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Class Material

- Released on the class website and on moodle
- Suggested books (though not mandatory!):
  - "*Operating System Concepts*" Ninth Edition – Silberschatz, Galvin, Gagne
  - "*Modern Operating Systems*" Fourth Edition – Tanenbaum, Bos
  - "*Operating Systems: Three Easy Pieces*" – Remzi and Andrea Arpaci-Dusseau [available online]
- Any additional resource available on the Web!

Moodle

- Provides native support for:
  - Sharing news and messages (forum)
  - Uploading class material (e.g., slides, exercises)
  - Exam simulations (e.g., quizzes)
  - …

Remember to enroll in the course from the moodle web page!

Exam

- Moodle Quiz:
  - 20 multiple-answer questions (max. 60 minutes)
  - Marks: +3 (correct answer), 0 (no answer), -1 (wrong answer)
    - score <= 14/30 → FAIL
    - 15/30 <= score <= 17/30 → ORAL REQUIRED
    - score >= 18/30 → PASS (oral upon request by the student)
- Oral Session:
  - Questions and exercises on the subjects covered during the whole semester

Outline of the Course

- Part I: Introduction

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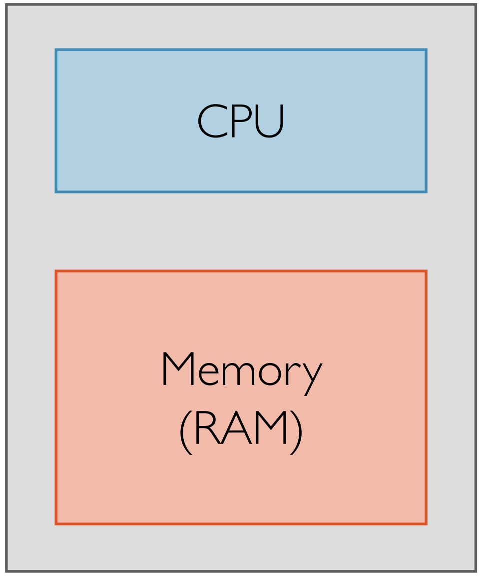
- Part VI: File System
- Part VII: Advanced Topics

Language and Naming Conventions

- OS → Operating System
- HW → Hardware
- SW → Software
- VM → Virtual Machine
- …
- Other shortcuts/acronyms may appear here and there without notice!

  Please, ask if anything is not clear!

High-Level View of a Computer System



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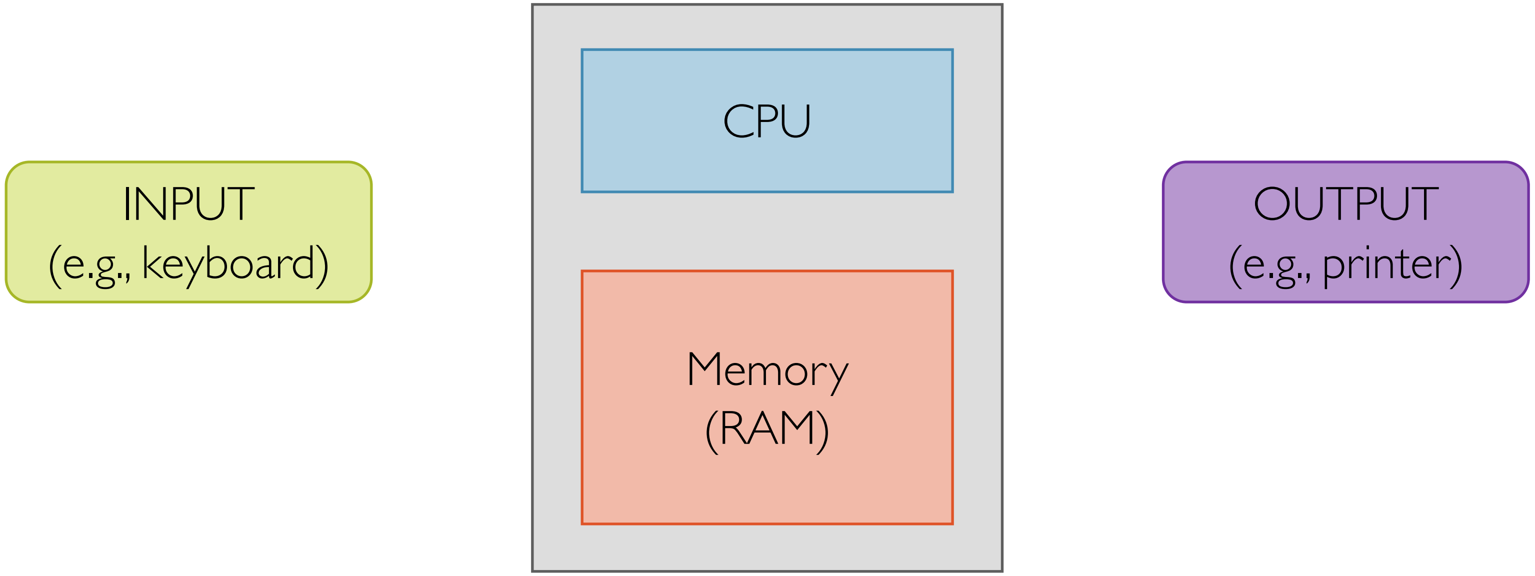

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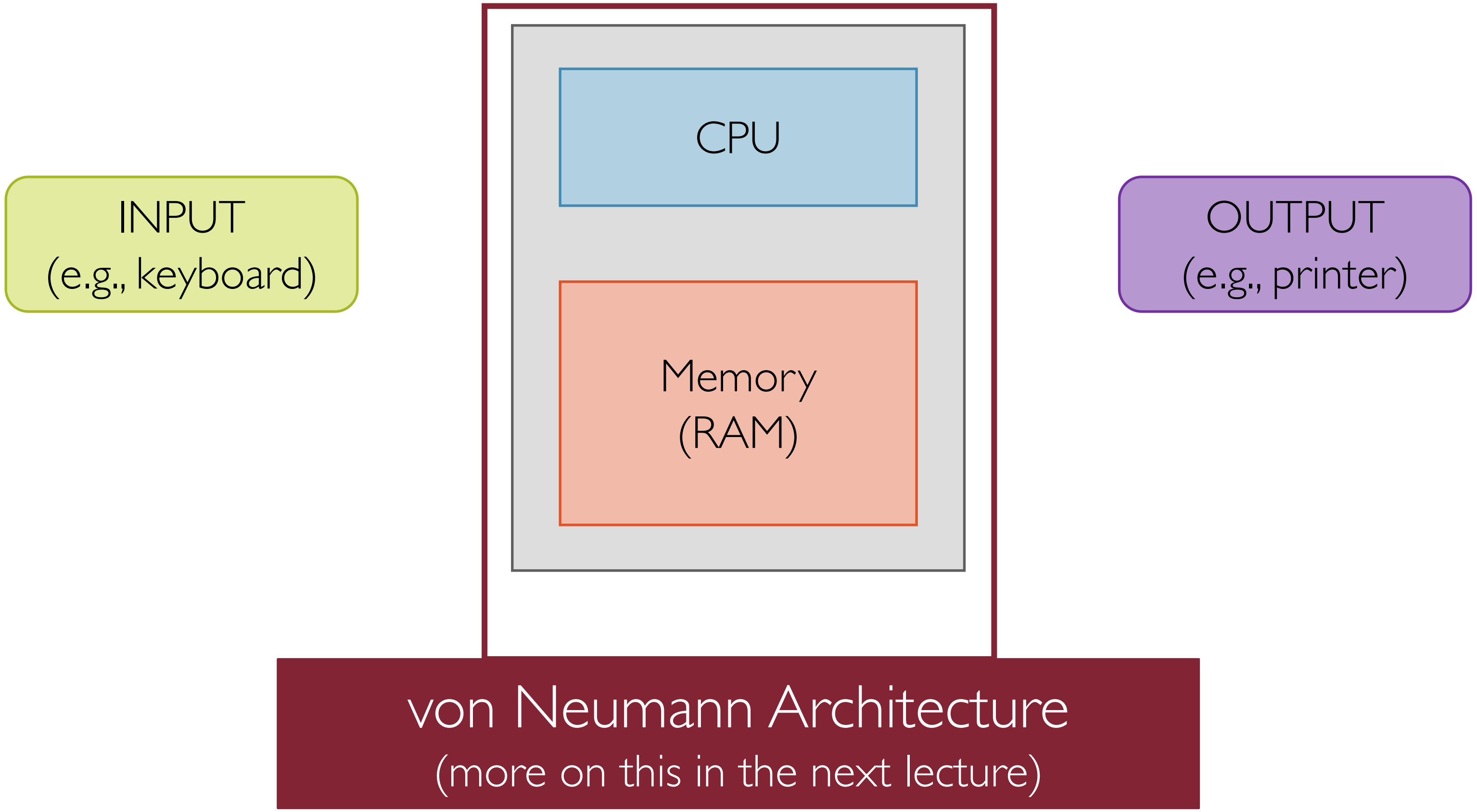

What is an Operating System?

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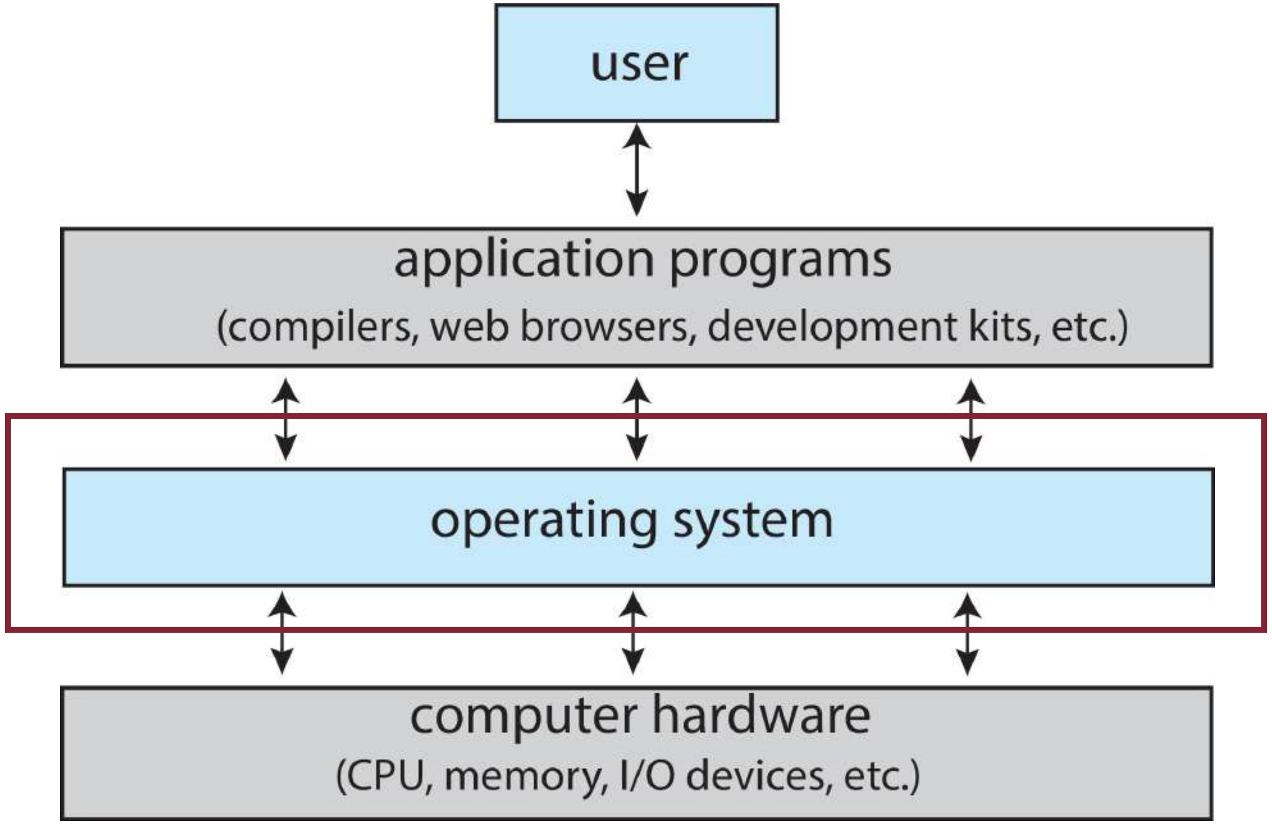
- However, the following definition is quite appropriate:

Implementation of a **virtual machine** that is (hopefully) easier to program than bare hardware

Computer System Overview



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- Different systems may have different requirements:
  - general-purpose, real-time, mobile, etc.
- Typically, we distinguish between:
  - kernel → the "core" of the OS (always up and running)
  - system programs → everything else which is still part of the OS

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  - Manages shared physical resources: CPUs, memory, I/O, etc.

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  - Provides a set of common services (APIs) to separate HW from SW
  - To allow applications/users to interact with the system without talking directly to the HW

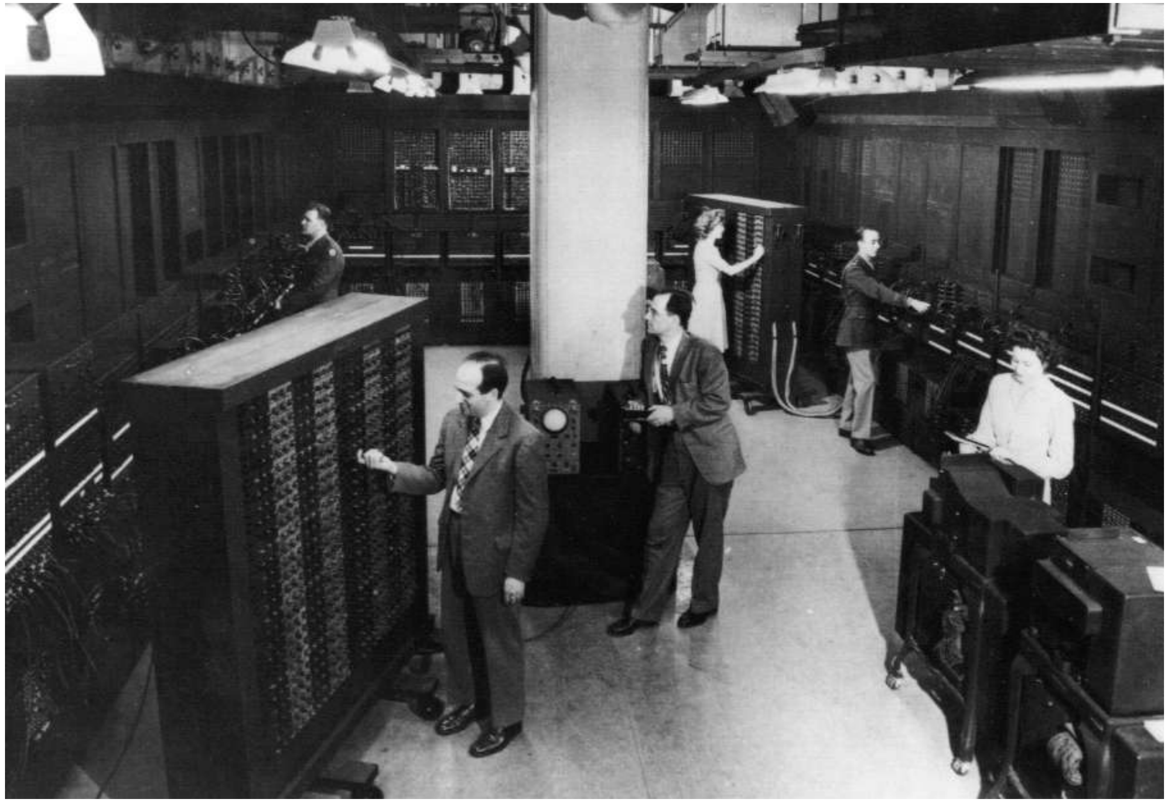
History of Operating Systems

Phase 1: Expensive HW, Cheap Humans

- 1 machine : M users
- Hand-programmed systems
- Single-user console systems (mainframes)
- Batch systems
- Multi-programming systems

1945-55: Vacuum Tubes and Plugboards

- Used by a restricted and skilled group of people
- All programming was done in machine language directly
- Basically, no OS whatsoever!
- Problem: ?



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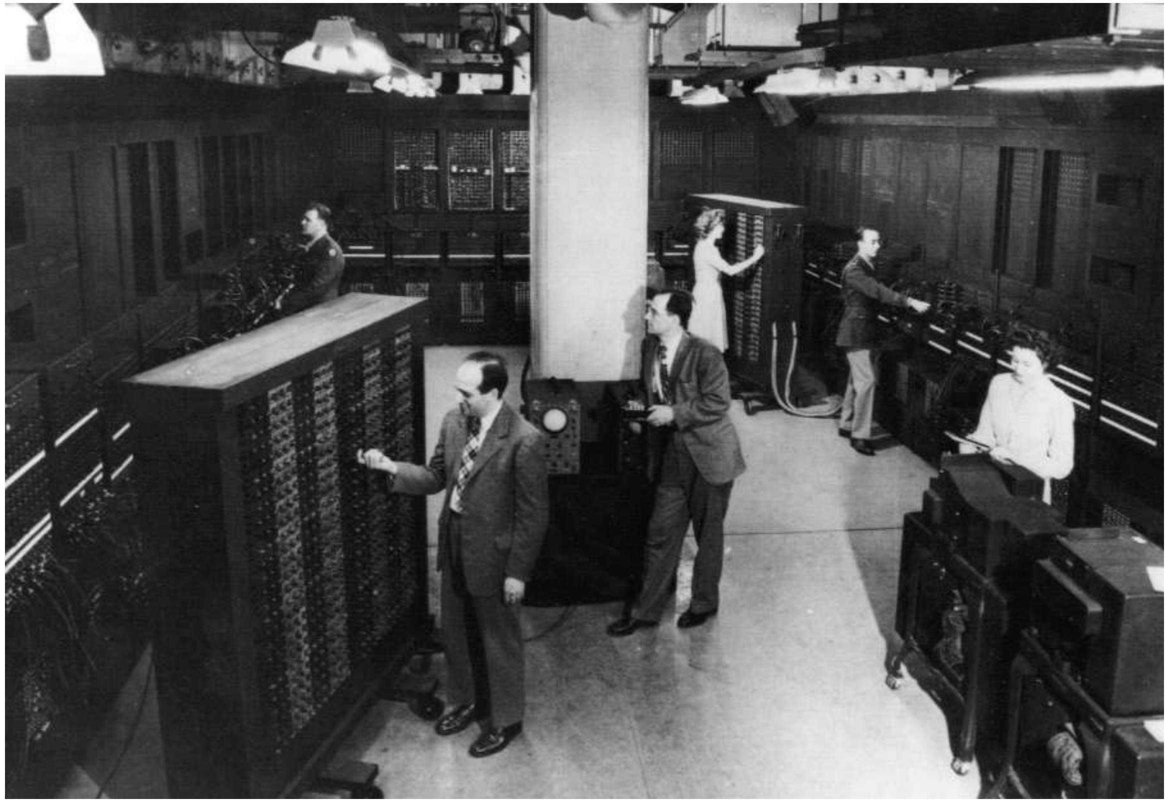

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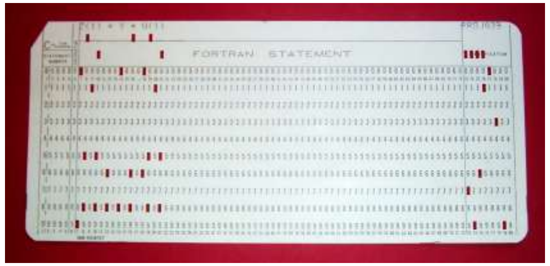

- One user at a time interacting with the machine as program runs
- Programs are written on punched cards
- Executes one thing at a time: no overlap between computation and I/O
- Primitive OS: program loader
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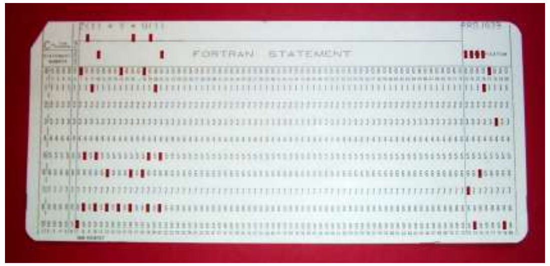

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- Technician still schedules jobs
- OS loads and run jobs
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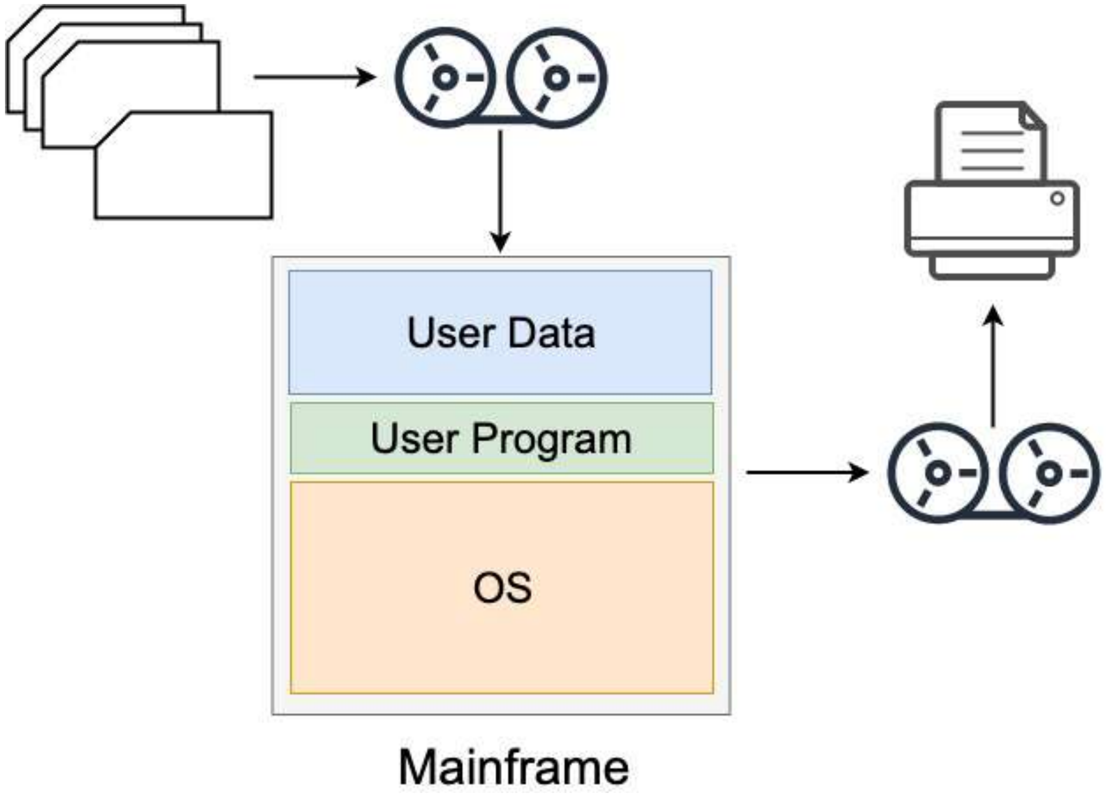

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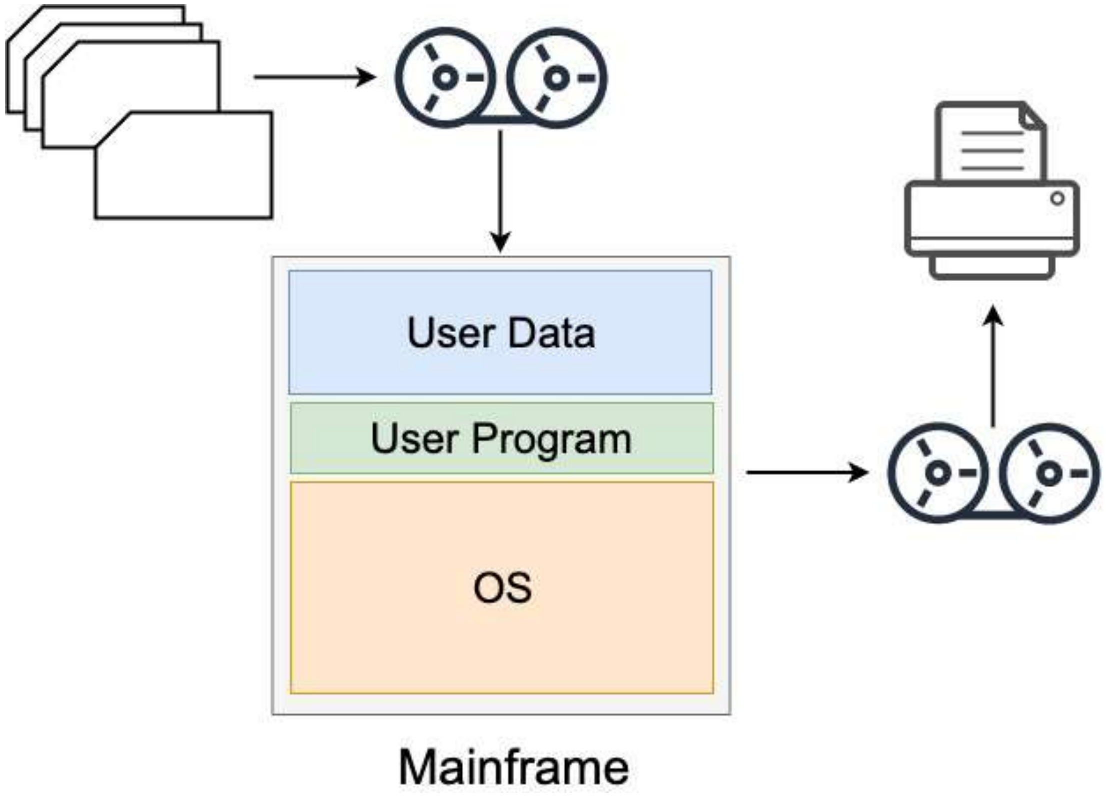

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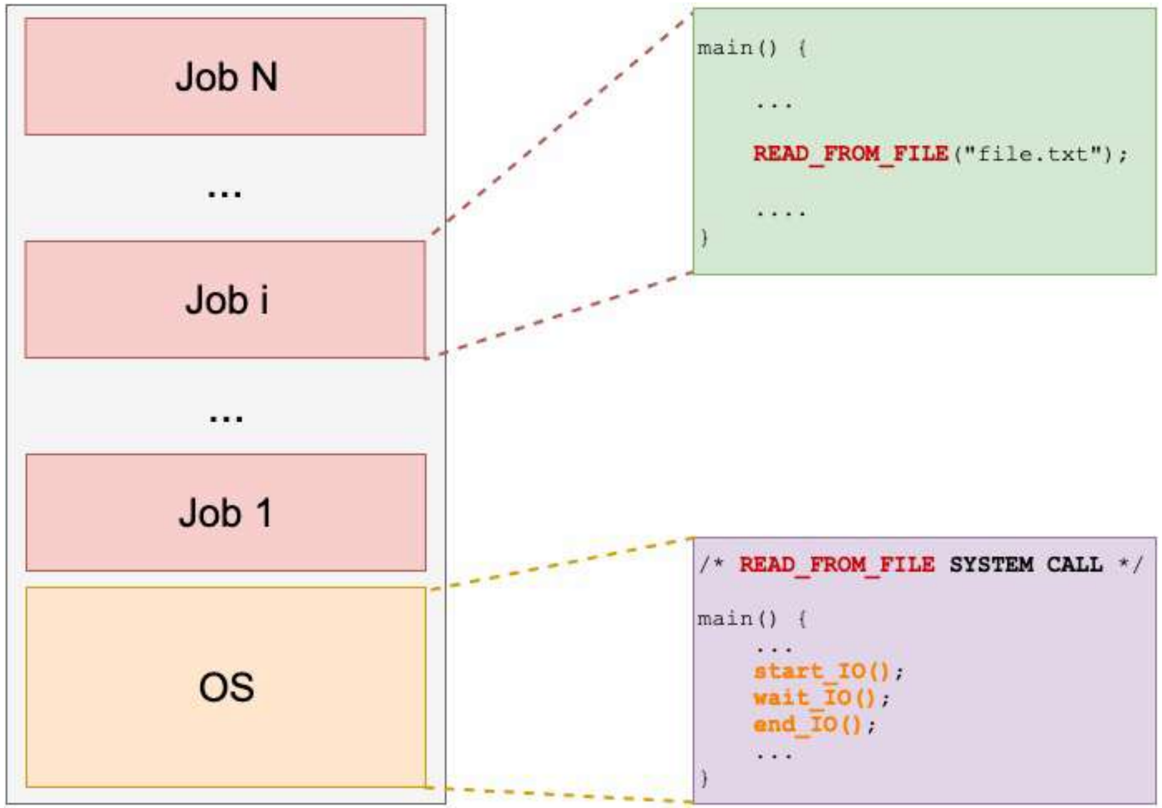

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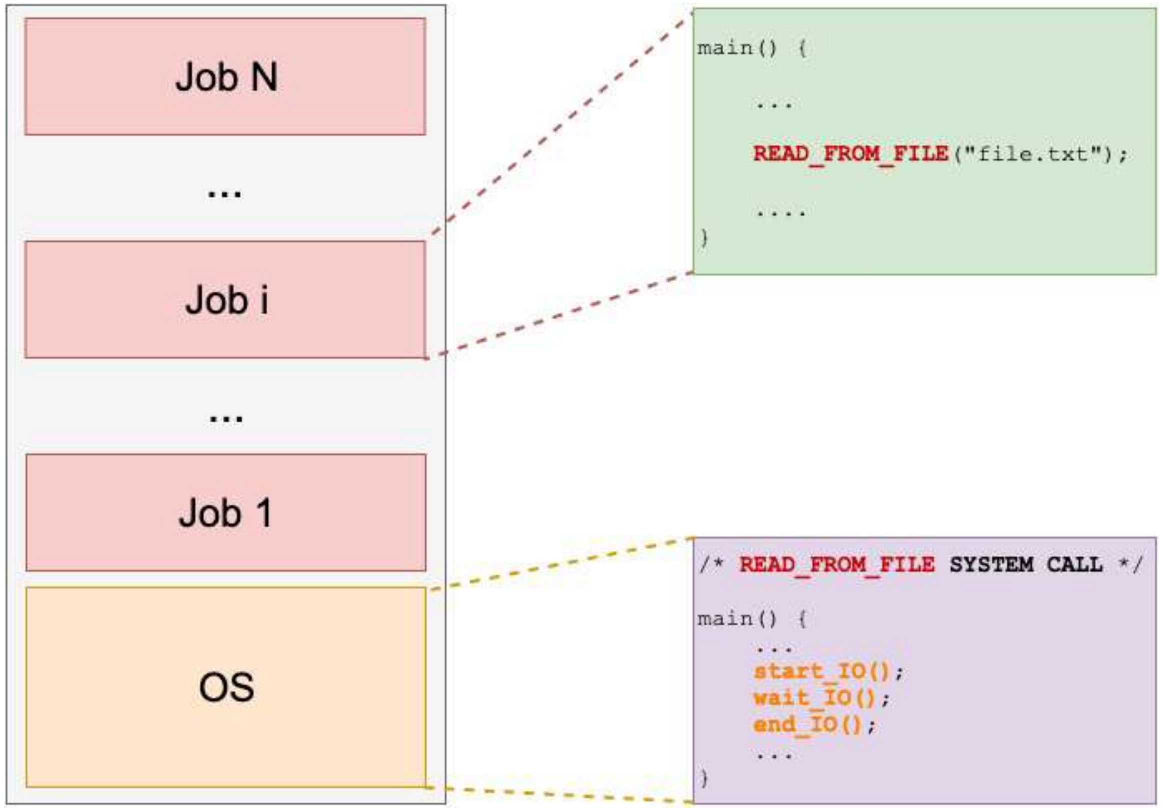
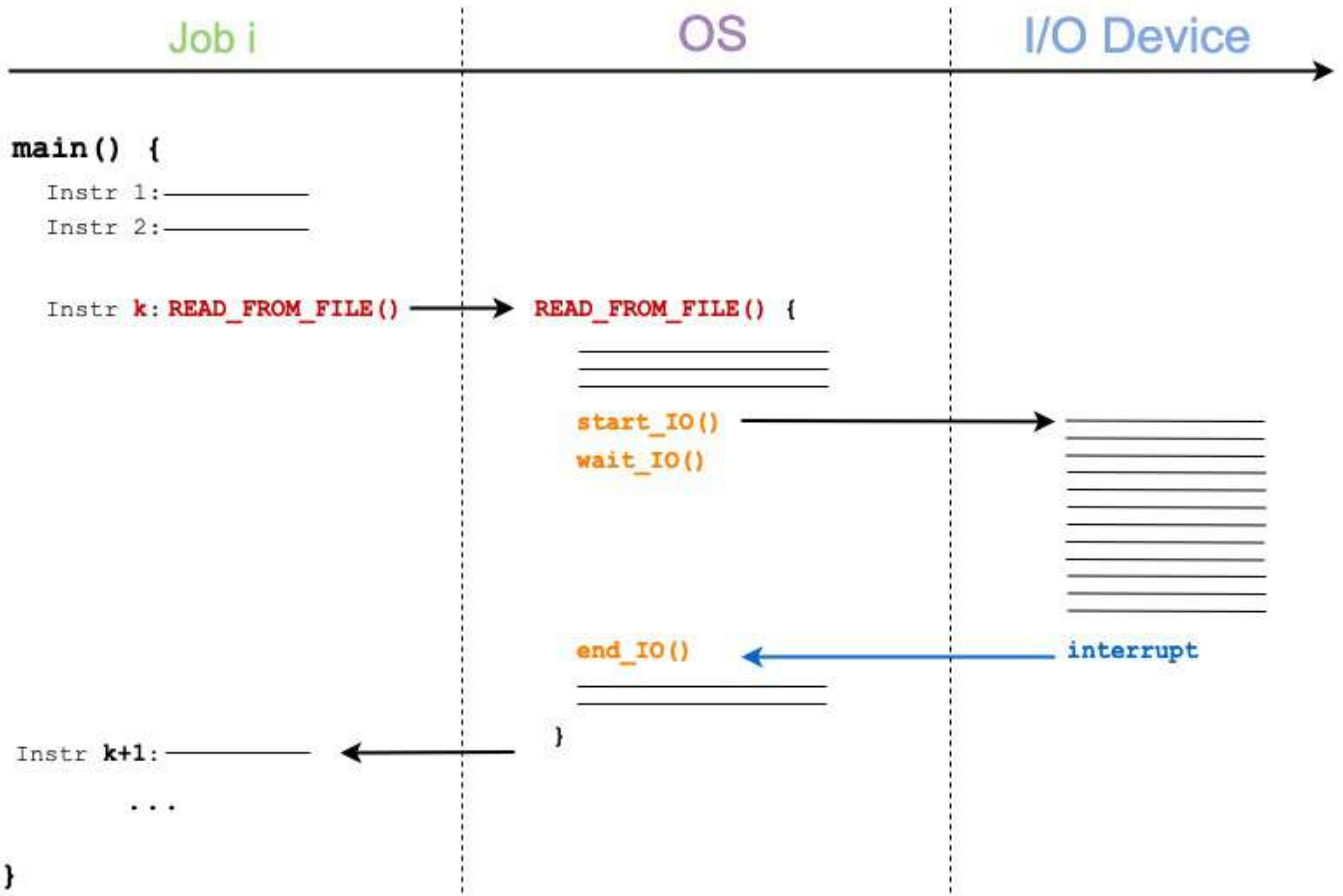
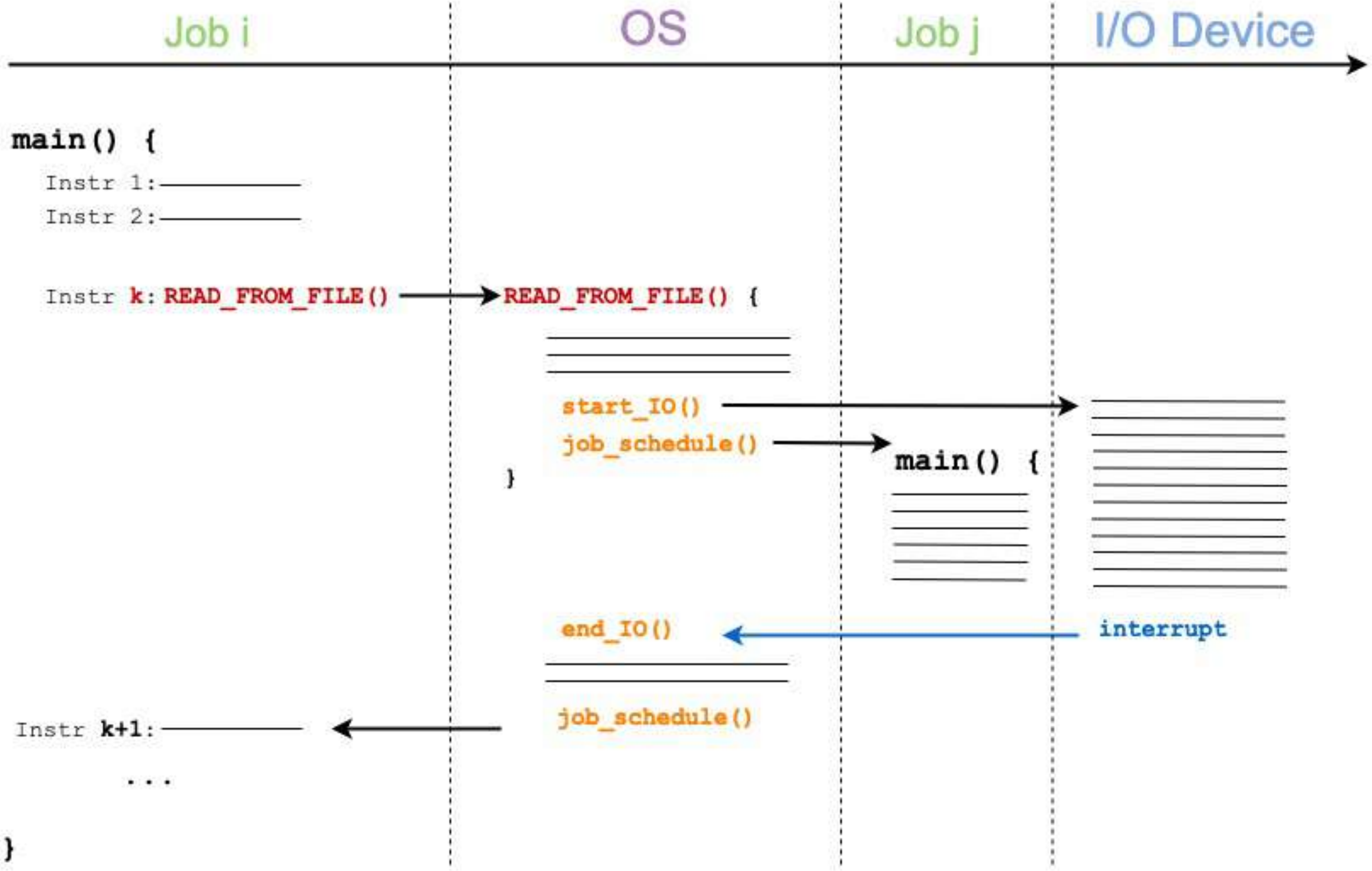


Blocking System I/O



Non-Blocking System I/O



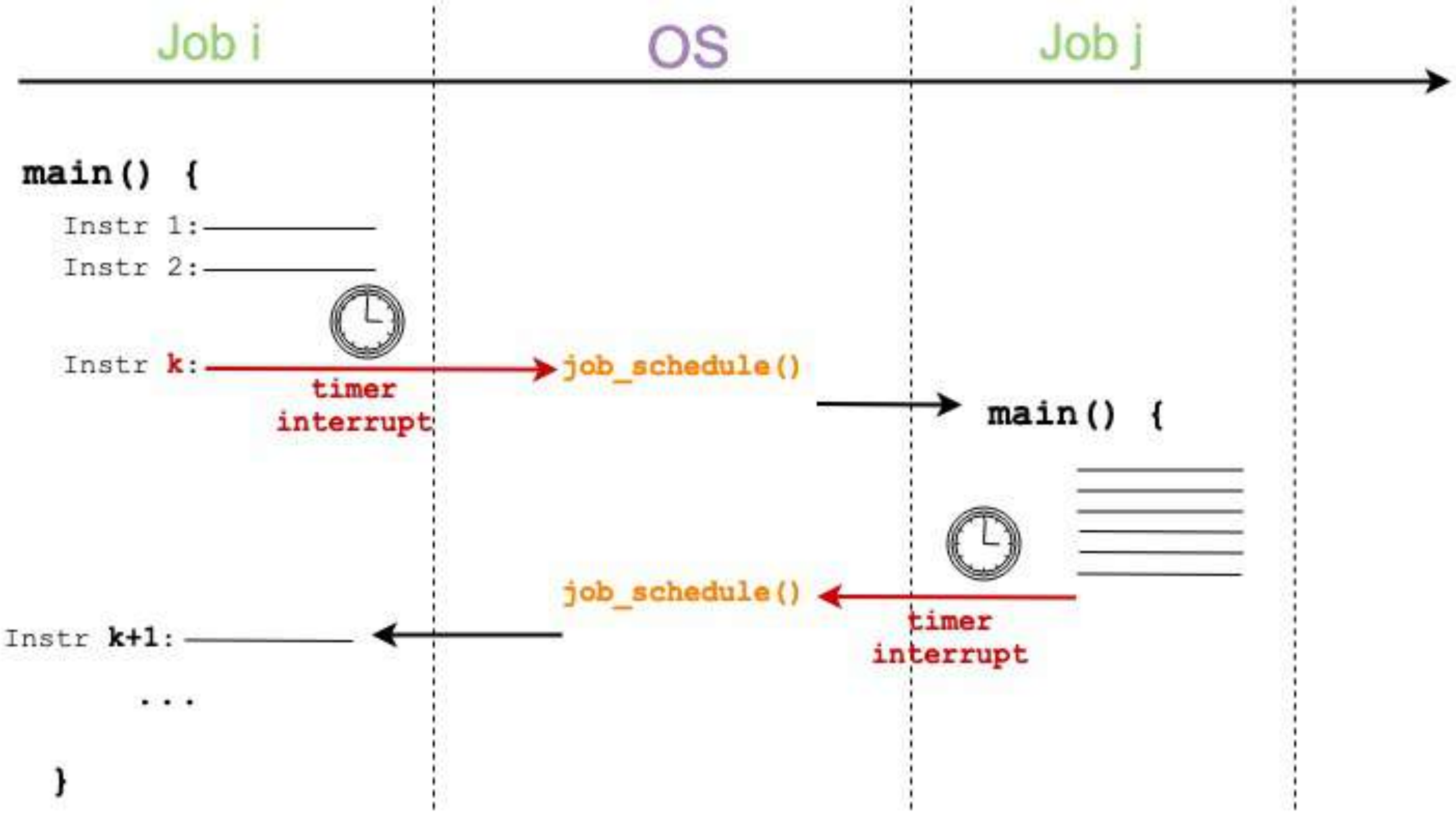
Phase 2: Cheap HW, Expensive Humans

- 1 machine : M users (still)
- Time-sharing systems

1970-: Time-sharing

- Many users connected to the same CPU via cheap consoles
- Timer interrupt used to multiplex CPU between jobs
- Illusion of parallelism (pseudo-parallelism)
- Ken Thompson and Dennis Ritchie → UNIX OS

Pseudo-parallelism



Phase 3: Very Cheap HW, Very Expensive Humans

- Personal Computing → 1 machine : 1 user

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- Personal Computing → 1 machine : 1 user
- Distributed/Ubiquitous Computing → M machines : 1 user

1980's: Personal Computers

- Initially, simple OSs:
  - No multiprogramming, concurrency, memory protection, etc.
- Later on:
  - Networking, file sharing, Graphical User Interfaces (GUIs)
- IBM PCs (1981) and Apple Macintosh (1984)

1990's-: Personal Computers (and more)

- PCs are now equipped with a fully fledged OS:
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  - Home appliances: smart TVs
- Plus, the Web has made everything distributed!

New Trends in OS Design

- Active field of research
  - OS demand is growing (many computing devices are available)
  - New application settings (Web, Cloud, mobile, cars, etc.)
  - Hardware is rapidly changing (new CPUs coming out)

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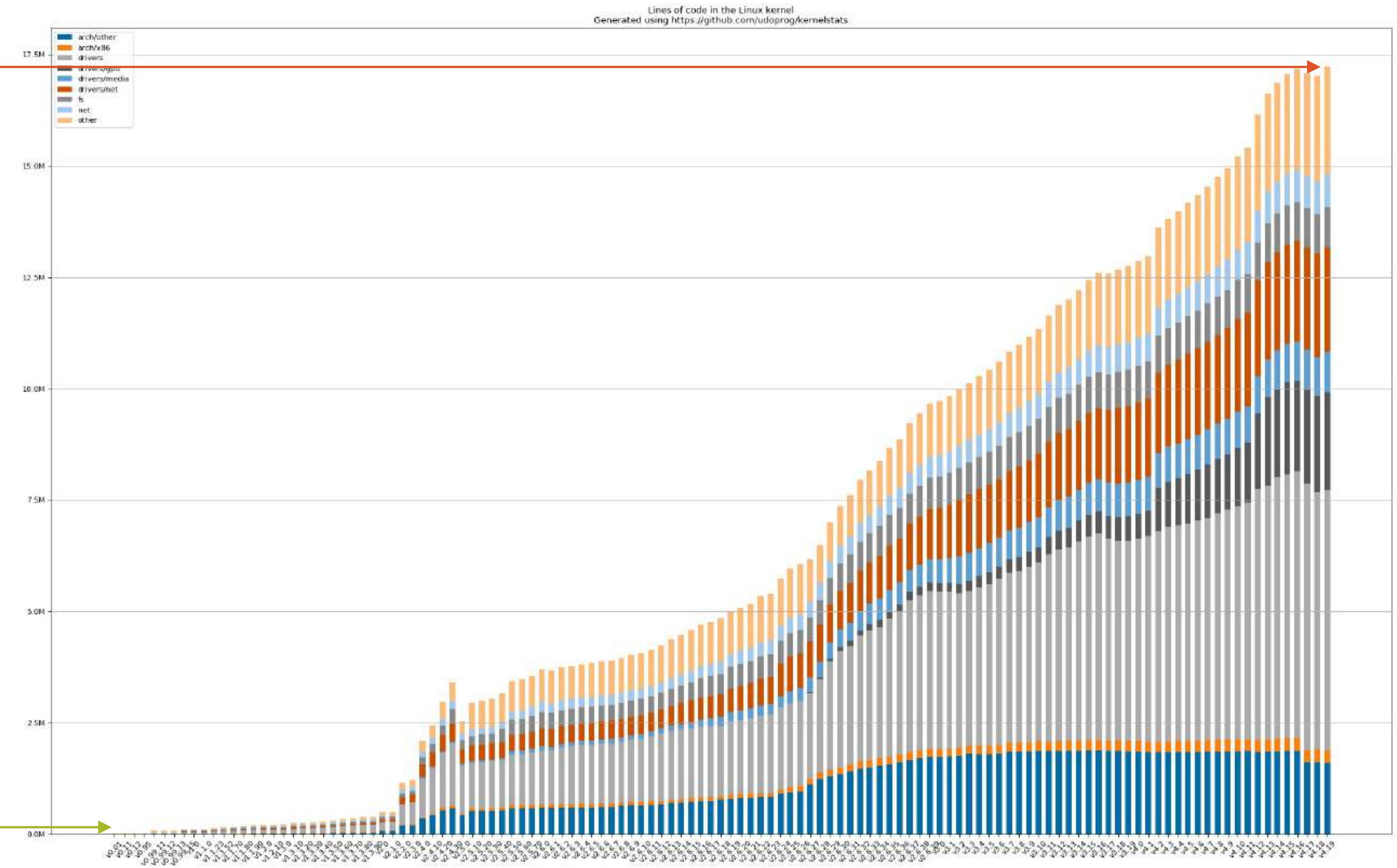
  - Hardware is rapidly changing (new CPUs coming out)
- Open-source OS (Linux)
  - Allows developers to contribute to OS development
  - Excellent research platform to experiment with

Linux Kernel Size (Lines of Code)

~17.5M



~200k

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- To learn important concepts of computer science
  - Abstraction
    - Virtualize any physical resource (CPUs, memory, I/O, etc.)

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    - HW vs. SW implementation of key features

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  - How computers work

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- The world is increasingly dependent on computer systems
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OS is a great example of a large computer system

OS as Large Computer System

- Designing large computer systems requires you to know
  - Each computer:
    - Architectural details
    - High-level programming language (mostly, C/C++)
    - Memory management
    - Concurrency and scheduling
    - File system and I/O

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  - Across clusters of computers:
    - Server architectures
    - Distributed file systems and computing frameworks

OS Design Issues (1)

- Structure → How the whole system is organized
- Concurrency → How parallel tasks are managed
- Sharing → How resources are shared
- Naming → How resources are identified by users
- Protection → How critical tasks are protected from each other
- Security → How to authenticate, authorize, and ensure privacy
- Performance → How to make it more efficient (quick, compact)

OS Design Issues (2)

- Reliability → How to deal with failures
- Portability → How to write once and run anywhere
- Extensibility → How to add new features/capabilities
- Communication → How to exchange information
- Scalability → How to scale up as demand increases
- Persistency → How to save task's status
- Accounting → How to claim on control resource usage

Architectural Trends: CPU

*Million Instructions Per Second

**1 MHz = 1,000,000 clock cycles per second

	1971 (Intel 4004)	Today (Intel Core i9)	Δ (orders of magnitude)
MIPS*	~0.09	~400,000+	+7
Instructions (fetch, decode, execute) per clock cycle	~0.12	~100+	+3
Clock frequency (MHz)**	0.74	~5,000	+4
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Moore's law: the number of transistors in a dense integrated circuit doubles about every two years

Architectural Trends: Main Memory

	1973 (DEC PDP-8)	Today (Samsung DDR4)	Δ (orders of magnitude)
Capacity (kB)	12	128,000,000	+7
Cost ($/MB)	~400,000	~0.005	-8

Architectural Trends: Disk

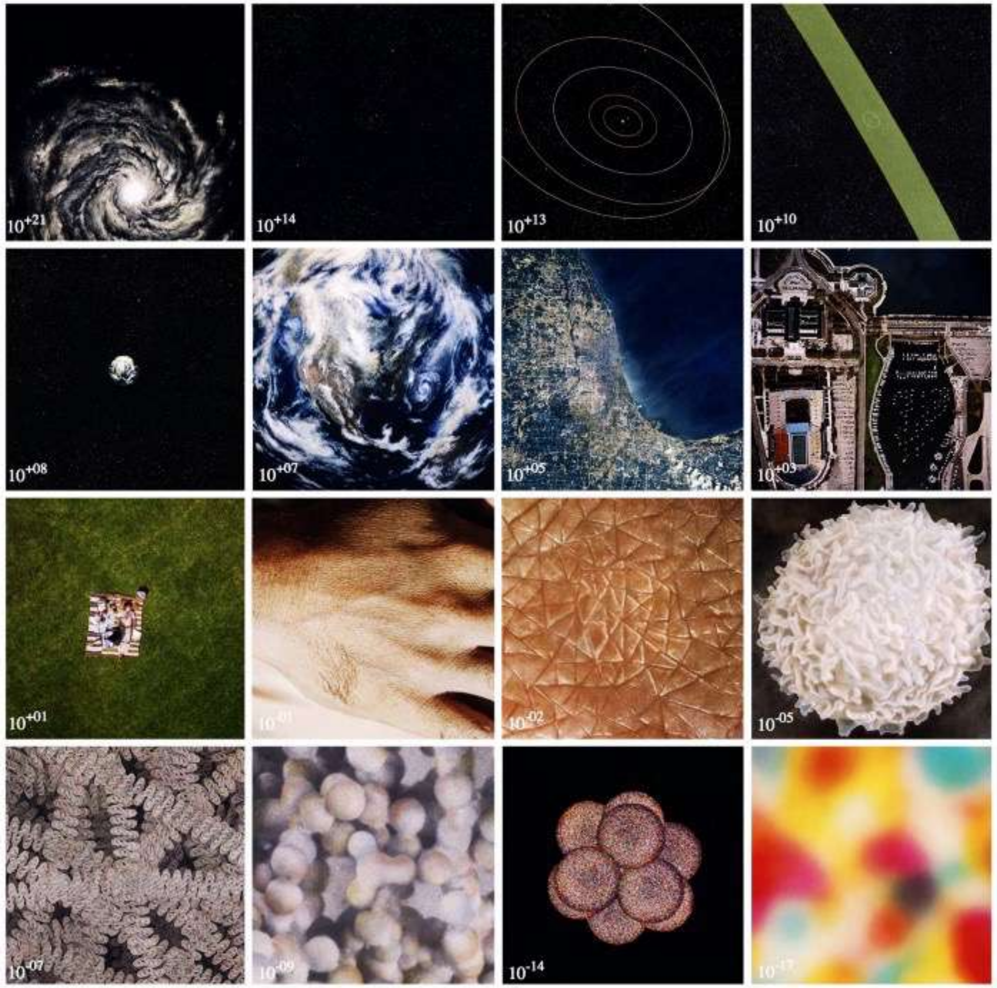
	1956 (IBM RAMAC 305)	Today (Western Digital)	Δ (orders of magnitude)
Capacity (MB)	5	15,000,000	+7
Size (inch)	24 (x50)	3.5	-3
Cost ($/MB)	640 (per month)	~0.000018	-9

Architectural Trends: Orders of Magnitude

$10^0 = 1$

source: Powers of Ten (1977)
https://www.youtube.com/watch?v=0fKBhvDjuy0

Architectural Trends: Orders of Magnitude



What's Next?

- Moore's law has hit its limit(?)
  - chip size has physical constraints
  - power vs. heat tradeoff
  - alternatives have already pushed forward the end of it:
    - multicore-manycore processors
  - other approaches are subject of research:
    - molecular/DNA transistors
    - quantum computing

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- A brief history of Operating Systems
- Operating Systems as large and complex computer systems
- New architectural trends open up novel opportunities and challenges in Operating System design