# An Introduction to Operating Systems

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2022

# Course Information

# Course Objective

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- The course has five modules:
  - Module 1: Process management
  - Module 2: Process synchronization
  - Module 3: Memory management
  - Module 4: Storage management
  - Module 5: File systems

# Intended Learning Outcomes (ILOs)

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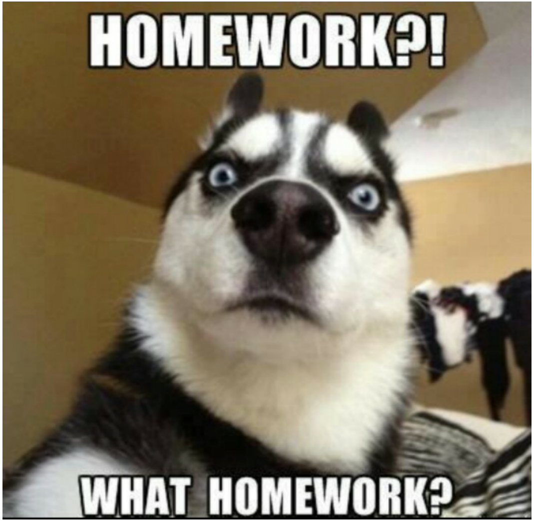
- ILO2: Apply the grabbed knowledge to implement the given tasks in different OS modules.
- ILO3: Analyze the technical merits of a specific OS module.


HOMEWORK?!
WHAT HOMEWORK?

# The Course Assessment

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- Task3: the lab assignments.
- Task4: the essay and the presentation.
- Task5: the final exam.

# How Each ILO is Assessed?

| | Task1 | Task2 | Task3 | Task4 | Task5 |
|---|---|---|---|---|---|
| **ILO1** | x | x | | | x |
| **ILO2** | | x | x | | |
| **ILO3** | | | | x | |

# Task1: The Review Questions

- One set of review questions per module.
- The review questions are graded P/F.
- They should be done individually.

# Task2: The Lecture Assignments

- One lecture assignment per lecture.
- No deadline.

# Task3: The Lab Assignments

- One lab assignment per module.
- The review questions are graded P/F.
- They should be done in group.

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- Each part is graded A-F.
- The final grade is computed as $0.5 \times E + 0.2 \times P + 0.2 \times Q + 0.1 \times A$.

# Task5: The Final Exam

- The final exam covers all the modules presented during the course
- It is graded A-F.

# The Final Grade

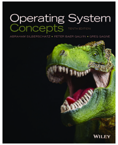
- To pass the course: you must pass Task 1 and Task 3 and get at least E in Task 4 and Task 5.
- The final grade of the course is computed as $0.5 \times Task4 + 0.5 \times Task5$.

# How to Submit the Assignments?

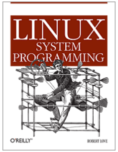
- Through Canvas.
- You will work individually on Task 1 and Task 5.
- You will work in groups of three or four on Task 3 and Task 4.

# Course Textbooks

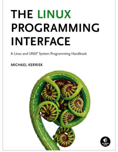
- Operating System Concepts, 10th Edition
  Avil Silberschatz et al., Wiley, 2018




- Linux System Programming, 2nd Edition
  Robert Love, O'Relly Media, 2013




- The Linux Programming Interface
  Michael Kerrisk, No Starch Press, 2010



# The Course Web Page

`https://kth-os.github.io`

## The Discussion Page

https://tinyurl.com/35avmfea

# What is an Operating System?

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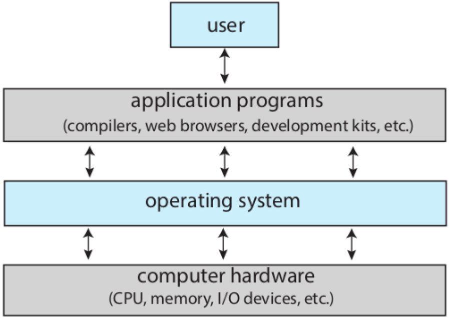
- A program that acts as an intermediary between a user of a computer and the computer hardware.



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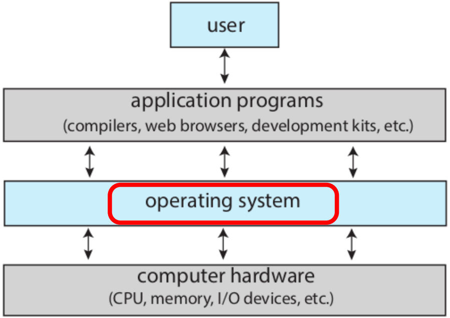

# Operating System Goals

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- Use the computer hardware in an efficient manner.

# What Operating Systems Do?

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  - Manages all resources.
  - Decides between conflicting requests for efficient and fair resource use.
- OS is a control program
  - Controls execution of programs to prevent errors and improper use of the computer.

# Operating Systems Definition

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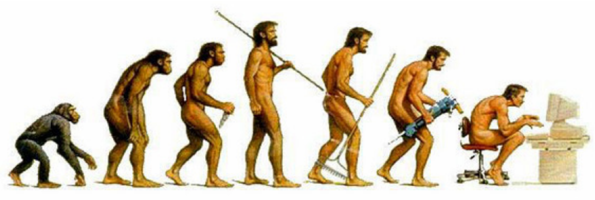
- Everything else is either a system program or an application program.

# A Brief History of Operating Systems



# First Generation: 1945-1955 (1/2)

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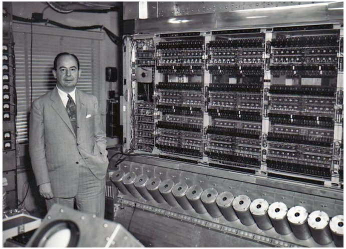

[http://ysfine.com/wigner/neumann.html]

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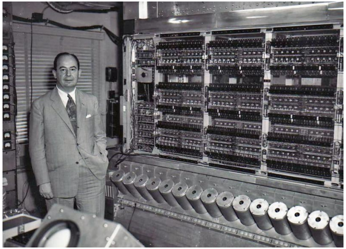

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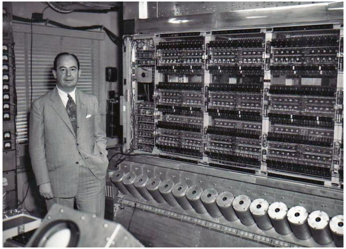

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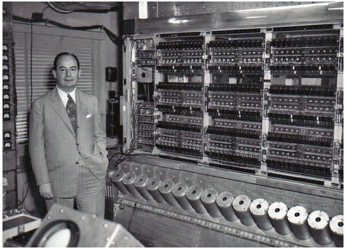

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# First Generation: 1945-1955 (2/2)

- Problems:
  - Serial processing: users had access to the computer one by one in series.
  - Users had to write again and again the same routines.

# Second Generation: 1955-1965 (1/5)

- Mainframes

IBM 7094 at Columbia University
[http://www.columbia.edu/cu/computinghistory/1965.html]

# Second Generation: 1955-1965 (2/5)

- Separation between operators and programmers.
  - The programmer: prepares her/his job off-line.
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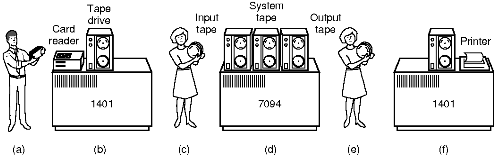
- Job
  - A program or set of programs.
  - A programmer would punch it on cards.
  - Programs are in FORTRAN or in assembly language.

# Second Generation: 1955-1965 (3/5)

- Batch the jobs together.

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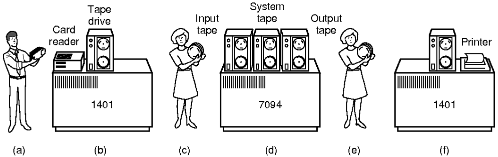


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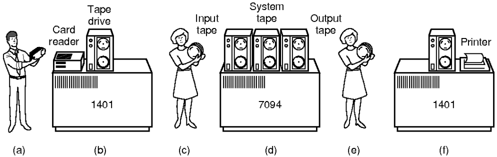


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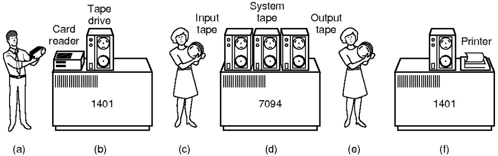


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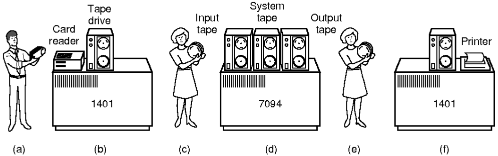
- The operator brings the full output tape for offline printing.

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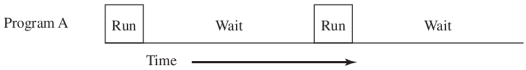
# Second Generation: 1955-1965 (4/5)

- Problems:
  - A lot of CPU time is still wasted waiting for I/O instructions to complete.
  - I/O devices much slower than processor (especially tapes!)

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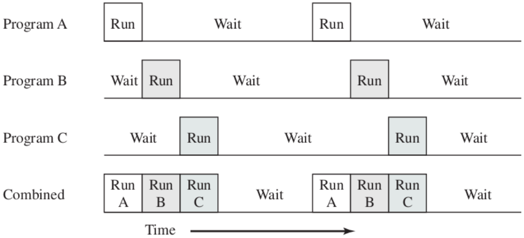
  - Operating mainframes was viewed as a low-level and low-value work.
  - Racist and sexist job: operators were often women.


[https://www.nytimes.com/2019/02/13/magazine/women-coding-computer-programming.html]

# Third Generation: 1965-1980 (1/3)

- Multiprogrammed batch systems.

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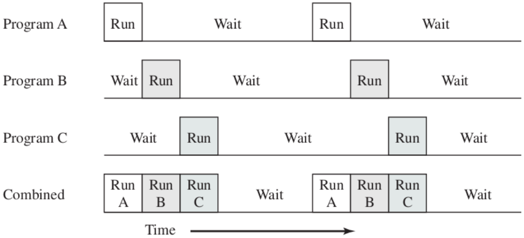
# Third Generation: 1965-1980 (1/3)

- Multiprogrammed batch systems.
- Jobs are kept in main memory at the same time and the CPU is multiplexed among them or multiprogrammed.

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- Tasks kept running until they performed an operation that required waiting for an external event such as I/O.
- But, in a multiple-user system, users want to see their program running as if it was the only program in the computer.
- Solution? time-sharing or preemptive multitasking systems.

# Third Generation: 1965-1980 (3/3)

- Time-sharing
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  - Hardware timer interrupt: switching jobs.

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  - Hardware timer interrupt: switching jobs.
- Birth of UNIX!

**UNIX®**

# Fourth Generation: 1980-Present (1/3)

- Personal Computers (PCs)
- Transition from human operators to software (Operating Systems)

[https://metagamer.nl/tips/is-ips-monitor-goed-voor-gaming]

# Fourth Generation: 1980-Present (2/3)

- From multiple users back to a single user.
- Multitasking a central feature of modern PC operating systems.
- PC systems emphasize user convenience.

# Fourth Generation: 1980-Present (3/3)

- GNU (GNU's Not Unix!): 1983
- Mac OS: 1984
- Microsoft Windows: 1985
- Linux: 1991

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- Solves many techincal problems, but ...

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- Hollywood reinforced stereotypes of PCs as a boys' toy (War Games).
- The result: parents were twice as likely to buy computers for their boys than their girls.
- University CS departments were often elitist, sexist, racist, ableist, and dominated by men.


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- These business trends mainly followed free-market policies (neoliberalism).

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- In 1985, in response, Stallman, founded the Free Software Foundation (FSF) and published the GNU manifesto.

FREE SOFTWARE FOUNDATION

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- Now the only thing that GNU lacked was a completely free OS kernel: GNU Hurd kernel
- In 1985, Andy Tanenbaum wrote a Unix like OS from scratch, called Minix.


[https://commons.wikimedia.org/wiki/File:Andrew_S._Tanenbaum.jpg]

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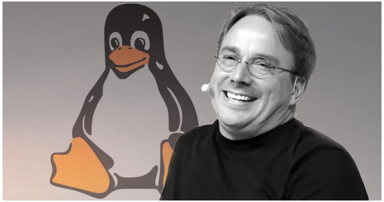

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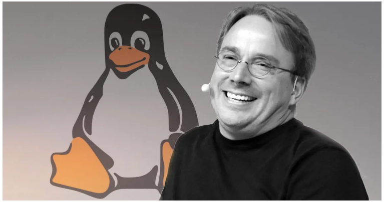

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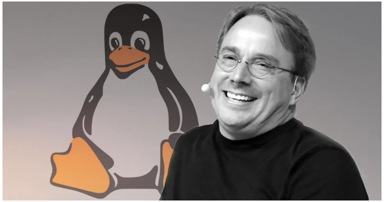

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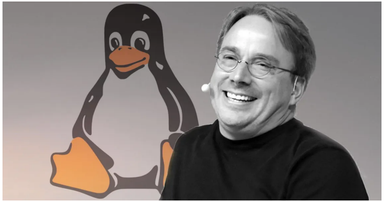
- Linux, is then, used as the kernel of the GNU in many distributions.



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# Computer System Operation

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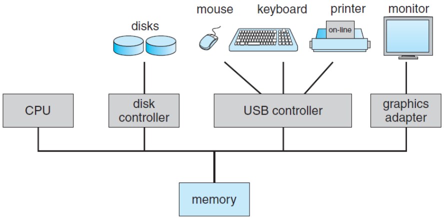

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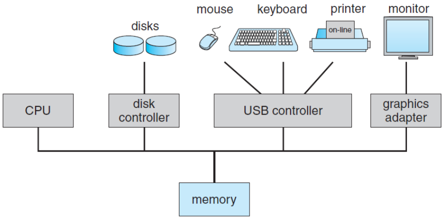

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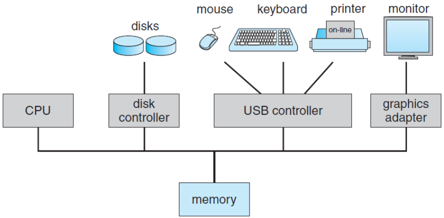
- Device controllers inform CPU that it is finished with the operation by causing an interrupt.



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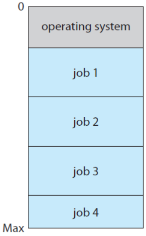
- The CPU resumes the interrupted computation, when the interrupt service routine completes.

# Multiprogramming

- Multiprogramming (batch system): needed for efficiency.



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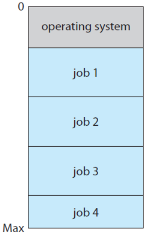

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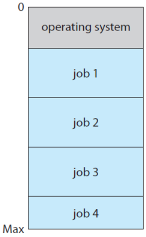

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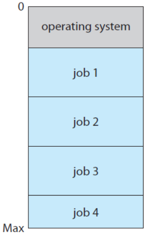

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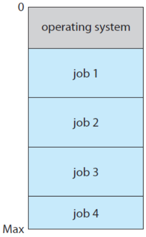
- When it has to wait (for I/O for example),
  OS switches to another job.



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    - If processes don't fit in memory, swapping moves them in and out to run.

# Operating System Structure

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- We need to make sure that an error in a user program could cause problems only for the one program running.
  - E.g., stucking in a finite loop

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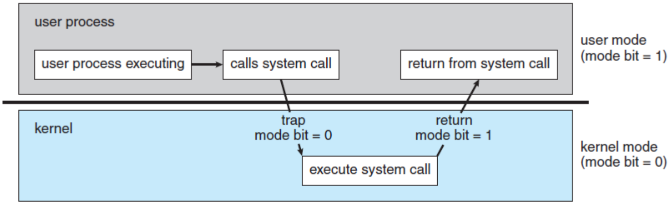


[Transition from user to kernel mode]

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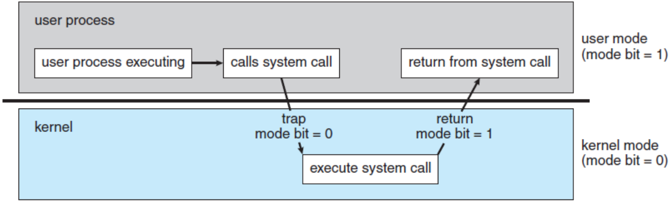
  - User mode and kernel mode.
  - System call changes mode to kernel, return from call resets it to user.

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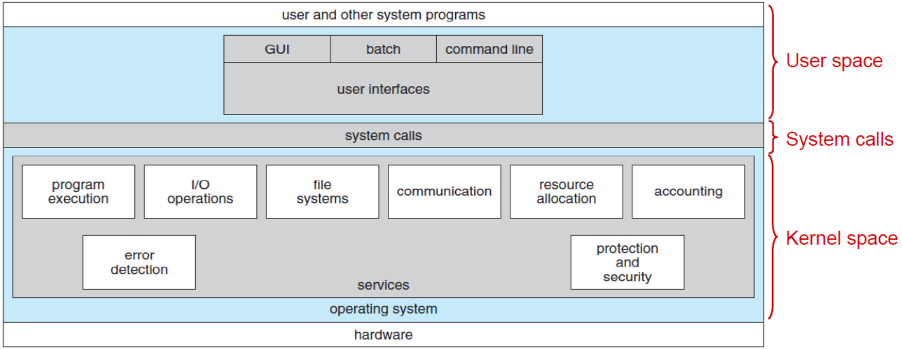

# User Space

# Programs

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- Everything else is either:
  - a system program
  - an application program

# System Programs

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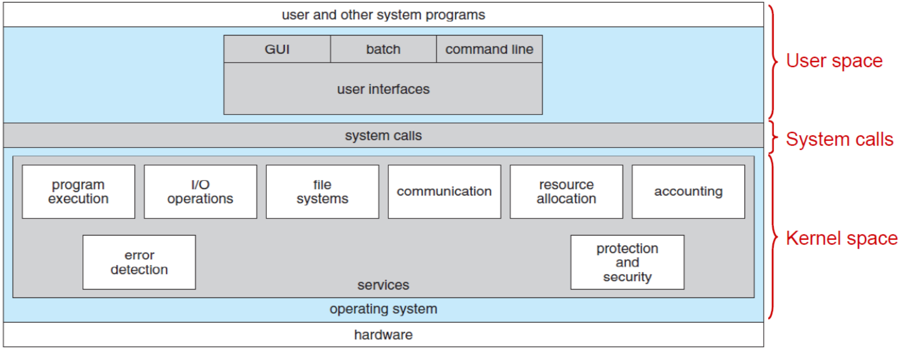
  - Background services, e.g., services and daemons

# Application Programs

- Don't pertain to system.
- Run by users.
- Not typically considered part of OS.
- Launched by command line, mouse click, finger poke.
- Web browsers, word processors, database systems, compilers, games, ...

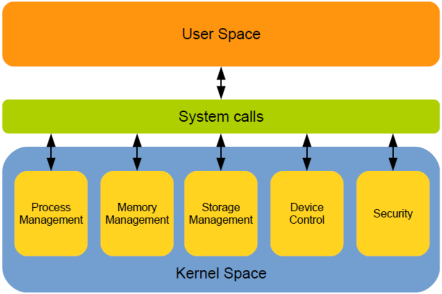
# Kernel Space

# Operating System Structure



# Splitting the Kernel

- The kernel's role can be split into the following parts
  - Process management
  - Memory management
  - Storage management and File system
  - Device control and I/O subsystem
  - Protection and security



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- Process termination requires reclaim of any reusable resources.

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- To execute a program all (or part) of the instructions must be in memory.
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- Memory management determines what is in memory and when.
  - Optimizing CPU utilization and computer response to users.

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  - Allocating and deallocating memory space as needed.

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- Disk management activities:
  - Free-space management
  - Storage allocation
  - Disk scheduling

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- OS maps files onto physical media and accesses these files via the storage devices, e.g., disk drive, tape drive.

# Storage Management (3/3)

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  - Backup files onto stable (non-volatile) storage media.

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  - Memory management of I/O.

# Protection and Security

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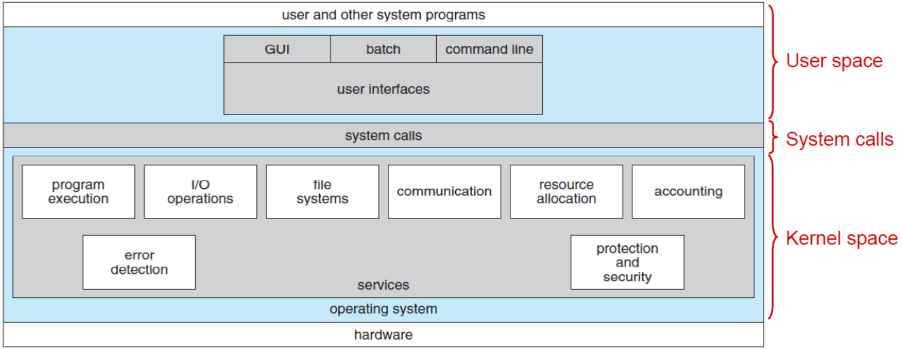
- Protection: any mechanism for controlling access of processes or users to resources defined by the OS.
- Security: defense of the system against internal and external attacks.
    - E.g., denial-of-service, worms, viruses, identity theft, theft of service, ...

# System Calls

# Operating System Structure



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- Typically written in a high-level language (C or C++).
- Mostly accessed by programs via a high-level Application Programming Interface (API) rather than direct system call use.

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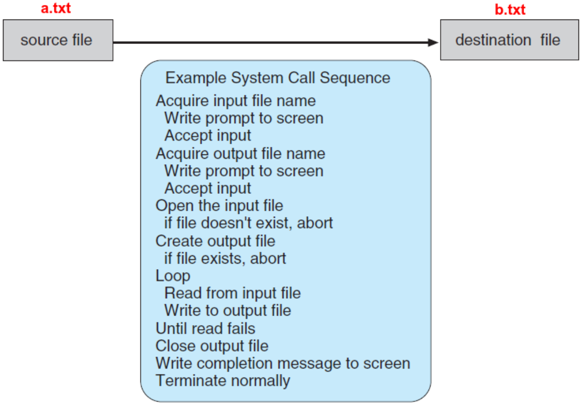
- Three most common APIs:
  - POSIX API for POSIX-based systems (including virtually all versions of UNIX, Linux, and Mac OS X)
  - Windows API for Windows
  - Java API for the Java virtual machine (JVM)

# API and System Calls (1/4)

- Why would an application programmer prefer programming according to an API rather than invoking actual system calls?

# API and System Calls (2/4)

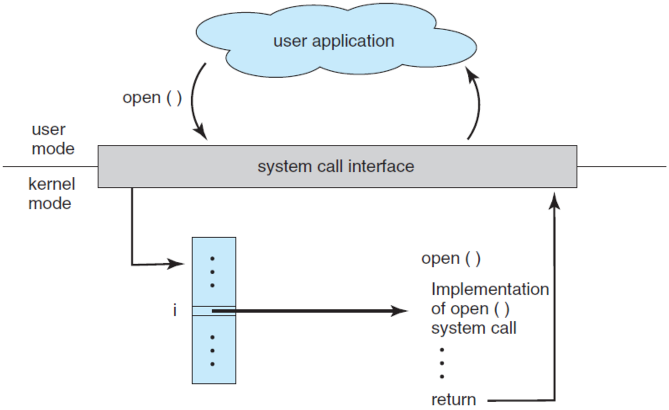
```
> cp a.txt b.txt
```



# API and System Calls (3/4)

```
> strace cp a.txt b.txt
execve("/bin/cp", ["cp", "a.txt", "b.txt"], [/* 49 vars */]) = 0
brk(0)                                  = 0x8a2d000
access("/etc/ld.so.nohwcap", F_OK)      = -1 ENOENT (No such file or directory)
mmap2(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xb76ff000
access("/etc/ld.so.preload", R_OK)      = -1 ENOENT (No such file or directory)
open("/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat64(3, {st_mode=S_IFREG|0644, st_size=108563, ...}) = 0
mmap2(NULL, 108563, PROT_READ, MAP_PRIVATE, 3, 0) = 0xb76e4000
close(3)                                = 0
access("/etc/ld.so.nohwcap", F_OK)      = -1 ENOENT (No such file or directory)
open("/lib/i386-linux-gnu/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\1\1\1\0\0\0\0\0\0\0\0\0\3\0\3\0\1\0\0\0@A\0\0004\0\0\0"..., 512) = 512
fstat64(3, {st_mode=S_IFREG|0644, st_size=120748, ...}) = 0
mmap2(NULL, 125852, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0xb76c5000
mmap2(0xb76e2000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1c) = 0xb76e2000
close(3)                                = 0
access("/etc/ld.so.nohwcap", F_OK)      = -1 ENOENT (No such file or directory)
open("/lib/i386-linux-gnu/librt.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\1\1\1\0\0\0\0\0\0\0\0\0\3\0\3\0\1\0\0\0\320\30\0\0004\0\0\0"..., 512) = 512
fstat64(3, {st_mode=S_IFREG|0644, st_size=30684, ...}) = 0
mmap2(NULL, 33360, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0xb76bc000
mmap2(0xb76c3000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x6) = 0xb76c3000
close(3)                                = 0
...
```

# API and System Calls (4/4)



# Types of System Calls (1/2)

- System calls can be grouped roughly into six major categories:

1. Process control
2. File manipulation
3. Device manipulation
4. Information maintenance
5. Communications
6. Protection

# Types of System Calls (2/2)

*EXAMPLES OF WINDOWS AND UNIX SYSTEM CALLS*

| | Windows | Unix |
|---|---|---|
| **Process Control** | CreateProcess()<br>ExitProcess()<br>WaitForSingleObject() | fork()<br>exit()<br>wait() |
| **File Manipulation** | CreateFile()<br>ReadFile()<br>WriteFile()<br>CloseHandle() | open()<br>read()<br>write()<br>close() |
| **Device Manipulation** | SetConsoleMode()<br>ReadConsole()<br>WriteConsole() | ioctl()<br>read()<br>write() |
| **Information Maintenance** | GetCurrentProcessID()<br>SetTimer()<br>Sleep() | getpid()<br>alarm()<br>sleep() |
| **Communication** | CreatePipe()<br>CreateFileMapping()<br>MapViewOfFile() | pipe()<br>shm_open()<br>mmap() |
| **Protection** | SetFileSecurity()<br>InitlializeSecurityDescriptor()<br>SetSecurityDescriptorGroup() | chmod()<br>umask()<br>chown() |

# Summary

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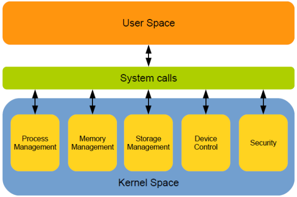
- Computer-system organization: CPU, I/O devices, interrupt
- Operating-system structure: user-space, system calls, kernel-space
- Splitting the kernel:



# Questions?