Operating Systems

CS3281 / CS5281

Spring 2025

ISIS
Tel (615) 343-7472 | Fax (615) 343-7440
1025 16th Avenue South Nashville, TN 37212
www.isis.vanderbilt.edu

VANDERBILT UNIVERSITY

Team

- Instructors
  - Dr. Sandeep Neema, Dr. Shervin Hajiamini
- Graduate TAs
  - Lantian Xia, Bo Ni, Weiheng Qiu
- Graders
  - Emre Bilge, Minseok Song, Mohammed Khan, Binh Mai, Muhammad Rahman

Top Hat

- You will receive an email for your section. Please join.

- Visit https://www.tophat.com and enter the join code:
  - Section 1: 527733
  - Section 2: 076807

Office Hours

- See on github.

Important Links

Textbook	http://pages.cs.wisc.edu/~remzi/OSTEP/
Discussion Forum & Announcements	https://piazza.com/vanderbilt/spring2025/cs32815281
Lectures	https://github.com/cs3281/lectures
Programming Assignments	https://classroom.github.com/classrooms/30844110-cs3281-classroom-spring2025
Announcements & Administration	https://vanderbilt.edu/brightspace/

Programming Assignments

- Administered through GitHub Classroom
  - Requires admission to the `cs3281` repository using your GitHub username
  - Fill the following form to share your GitHub username. Use your **Vanderbilt account** to access the form

https://forms.office.com/r/DcaxBd2iC4

Programming Assignments

- Graded using the VUIT-provided AWS Virtual Machines
  - Access your WorkSpace on a virtual machine in a browser at https://webclient.amazonworkspaces.com

    or download the AWS WorkSpaces client from: https://clients.amazonworkspaces.com/

  - Enter the following registration code: SLiad+DGTNYL

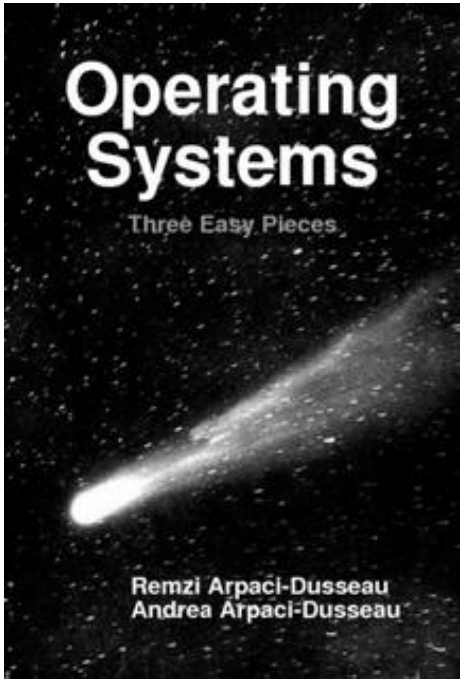
  - Log in with your VUNetID and password
  - If you have any issues with logging, send a ticket to VUIT via https://tdx.vanderbilt.edu/TDClient/33/Portal/Home/

Programming Assignments

- Automate GitHub credentials:
  - Go to https://github.com/settings/tokens
  - Click "Generate new token (classic)"
    - Note: Development
    - Expiration: No expiration
    - Select scopes: repo, user, codespace
  - Click "Generate token"
  - Copy Personal Access Token and write it down or save it somewhere
  - In a terminal, run "git clone https://github.com/cs3281/lectures.git"
    - When prompted, enter you GitHub username and enter the above-generated Personal Access Token as your password
    - You should never be prompted to do enter these credentials again
  - In a terminal, run "git config --global credential.helper store"
    - Git should save your token in ~/.git-credentials file

Textbook

- We will draw material from a variety of sources
- Primary textbook: Operating Systems: Three Easy Pieces
  - Available for free at http://pages.cs.wisc.edu/~remzi/OSTEP/
- Other possible texts:
  - The Linux Programming Interface
  - Computer Systems: A Programmer's Perspective
  - Linux Kernel Development



Course Assessment

- Programming assignments: 50%
- Take-home quizzes: 8%
- Exam 1: 20%
- Exam 2: 20%
- Attendance: 2%

Quizzes

- There will be biweekly quizzes throughout the semester
- You will do the quizzes outside class
- Each quiz covers topics covered after the previous quiz
- Expected to be conducted on Brightspace

Late days

- You have a total of 4 late days that you can use across programming assignments as you wish
  - A maximum of two late days can be used on a given programing assignment
  - Example: assignment is due by 11:59pm Monday; you can use two late days to submit that assignment by 11:59pm Wednesday with no penalty
- To use late days: push a file named late_days.md to the top-level directory of your assignment repo with a line stating whether you're using one or two late days
- Assignments submitted more than two days late will not be accepted
- **No collaborations unless explicitly permitted**

Late days

- Assignments submitted on or after 12:00am the next day are required to use late days or take the late-day penalty, 20% per day
- Do not wait until 11:59pm to make your first push!
- You may commit and push incremental results and are suggested to do so early and often
- The last push before the deadline will be graded unless specified with late_days.md

Regrade Requests

- Grading errors can and do happen
  - Not malicious!
- You can “challenge” if you believe an error was made
- If you are wrong, you may lose a late day

ChatGPT and AI assistants

- We have entered a new era with AI assistants
- Our goal is to use them to enhance the learning experience
- You can use ChatGPT and other AI tools however you want!
- ChatGPT can be a helpful aid, but it can't totally do your homework for you! Sometimes, it can lead you off track, so think critically about its outputs

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Course expectations

- You are expected to attend class and participate in class discussions

- All assignments are released in GitHub Classroom. You will access the assignments via Brightspace

Course expectations: Office Hours

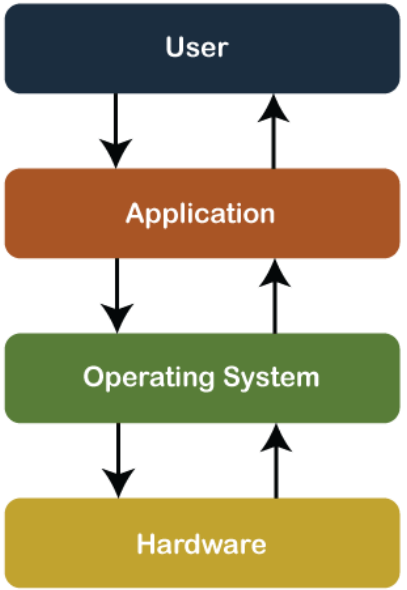
- We will use an office-hour policy similar to the one listed here: https://www2.seas.gwu.edu/~gparmer/resources/2021-09-20-Office-Hours-HOWTO.html
  - Please read this policy carefully and adhere to its guidelines
  - It will help you and us

Development Environment

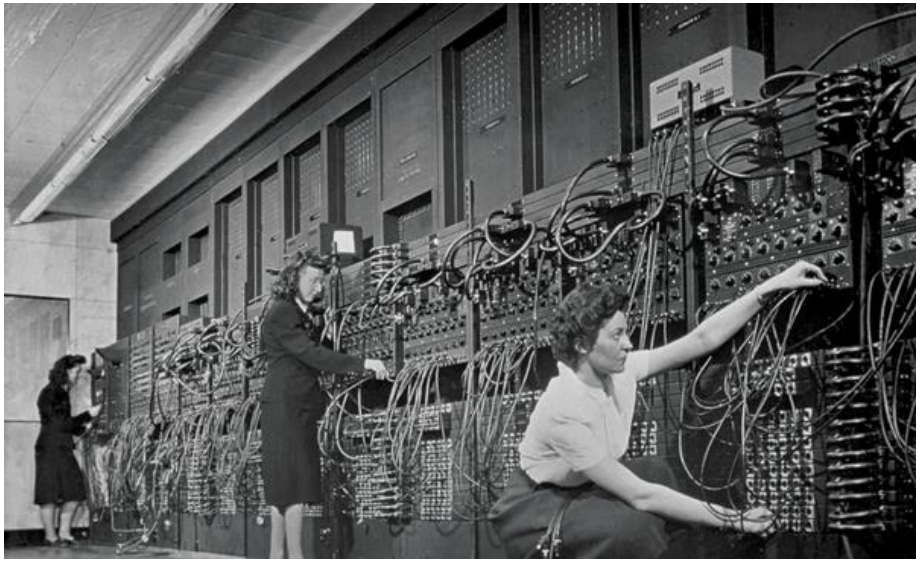
- This course will use C
  - This is an OS course, not a course on C
  - While some C material will be discussed, it is up to you to learn and build your proficiency in C if you aren't proficient already
    - Remember, you can ask ChatGPT for help!
- We will use Ubuntu (a Linux distribution) as the development environment
  - VMs provided through VUIT
  - You're free to choose your development environment, but your work will be tested and evaluated on the Ubuntu VM environment
  - We do not support alternative environments
- We will use GitHub and git for content and assignment management

Course Goals

- Understand operating systems by learning their architecture and services
- Experience with low-level systems development



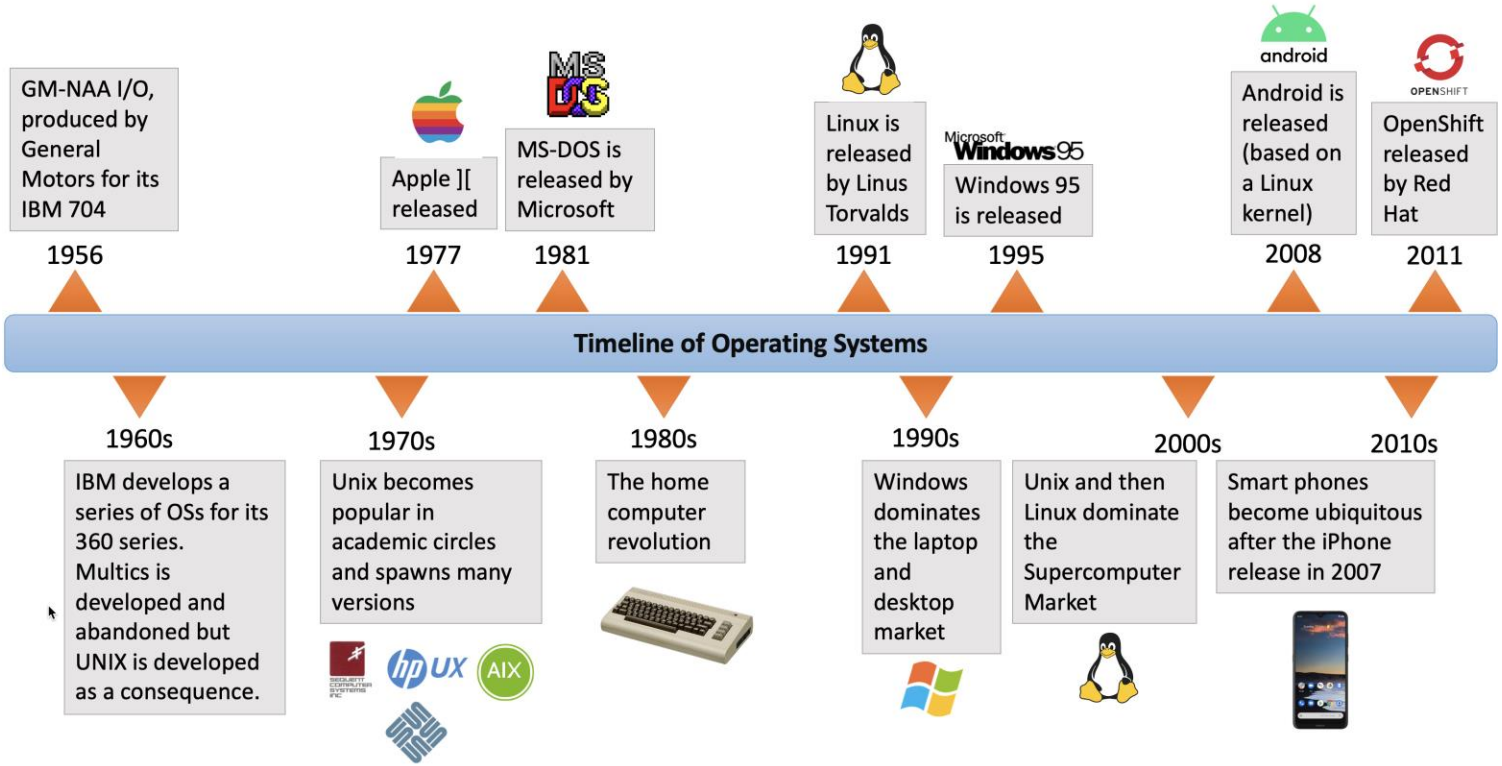
Historical Perspective



Eniac – World's first programmable general-purpose computer

Early computers did not have an operating system. People manually performed functions that are now controlled in software systems that operate the machine

History of Operating Systems – a brief timeline



https://medium.com/@tanalpha-aditya/introduction-to-operating-systems-and-networks-dfa3611befcc

Why is this important?

- Operating system is responsible for
  - Abstracting the hardware details for convenience and portability

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- Operating system is responsible for
  - Abstracting the hardware details for convenience and portability
  - Share hardware among multiple applications
  - Isolating applications to contain bugs

Example: USB device insertion

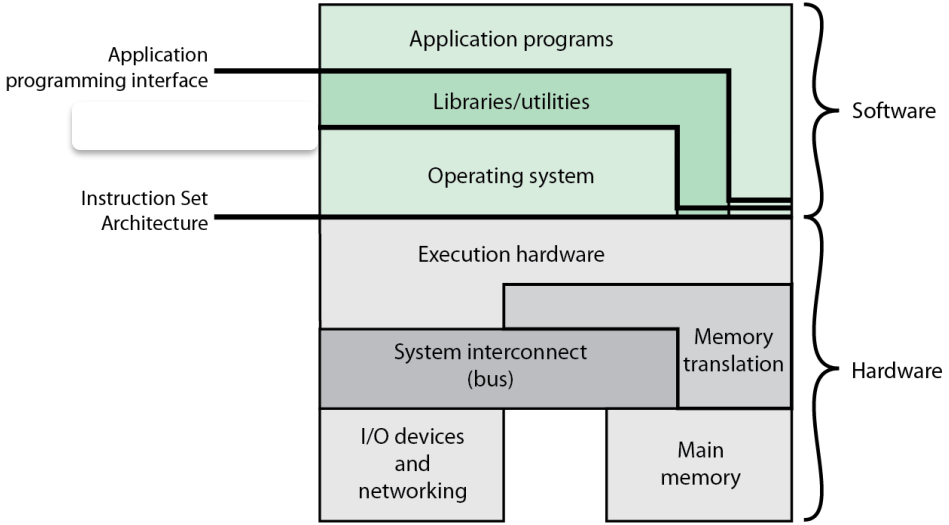
- Consider what happens when you plug-in a USB device to your laptop
  - USB controller informs its driver
    - The driver is part of the kernel
  - The driver asks the device to identify itself
    - Device sends back an ID
  - Controller uses ID to match a driver to the new device

A typical USB connector, called an "A" connection

Inside a USB cable: There are two wires for power -- +5 volts (red) and ground (brown) -- and a twisted pair (yellow and blue) of wires to carry the data. The cable is also shielded.

Layers of a modern computing system

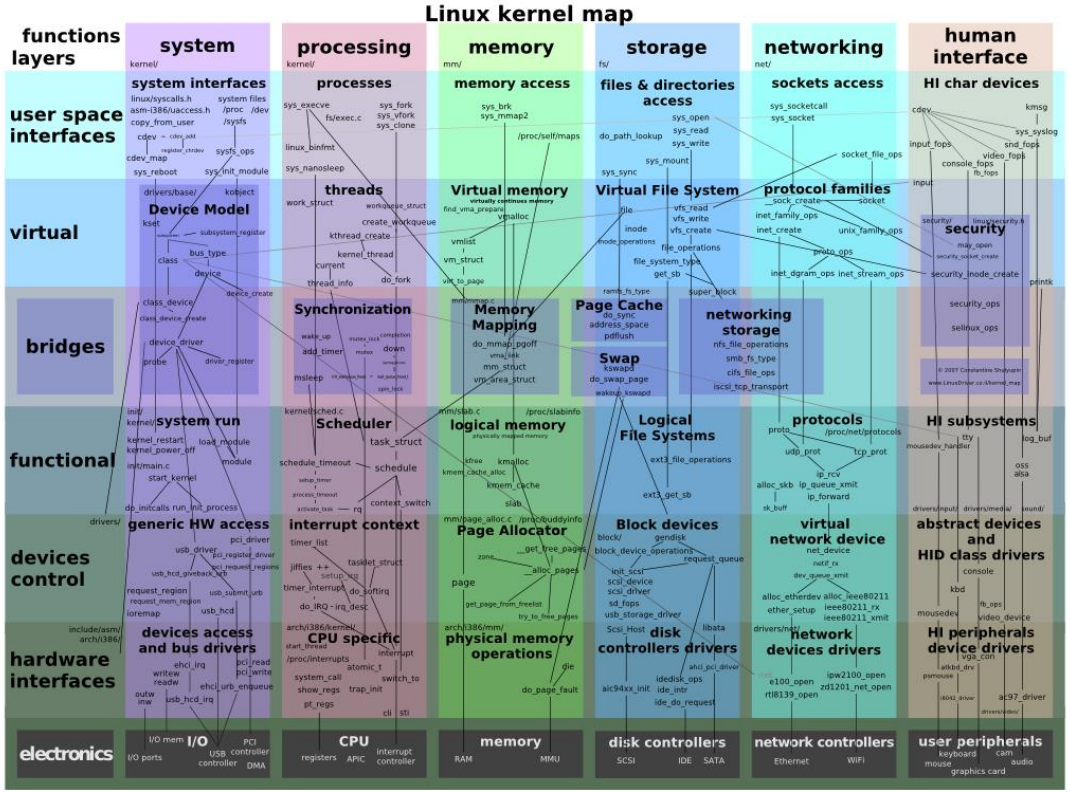
- Application – the user program.
- System Libraries – the core services of OS are encapsulated by these libraries, e.g. libc
- The operating system has full access to hardware

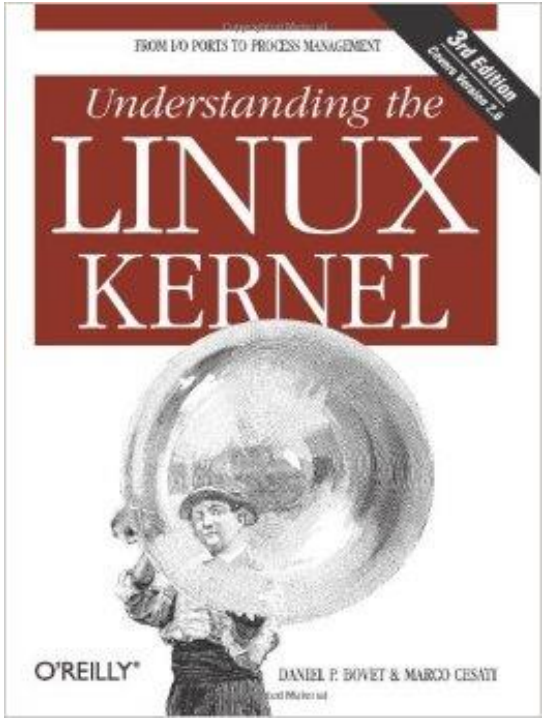


Another view of the layers

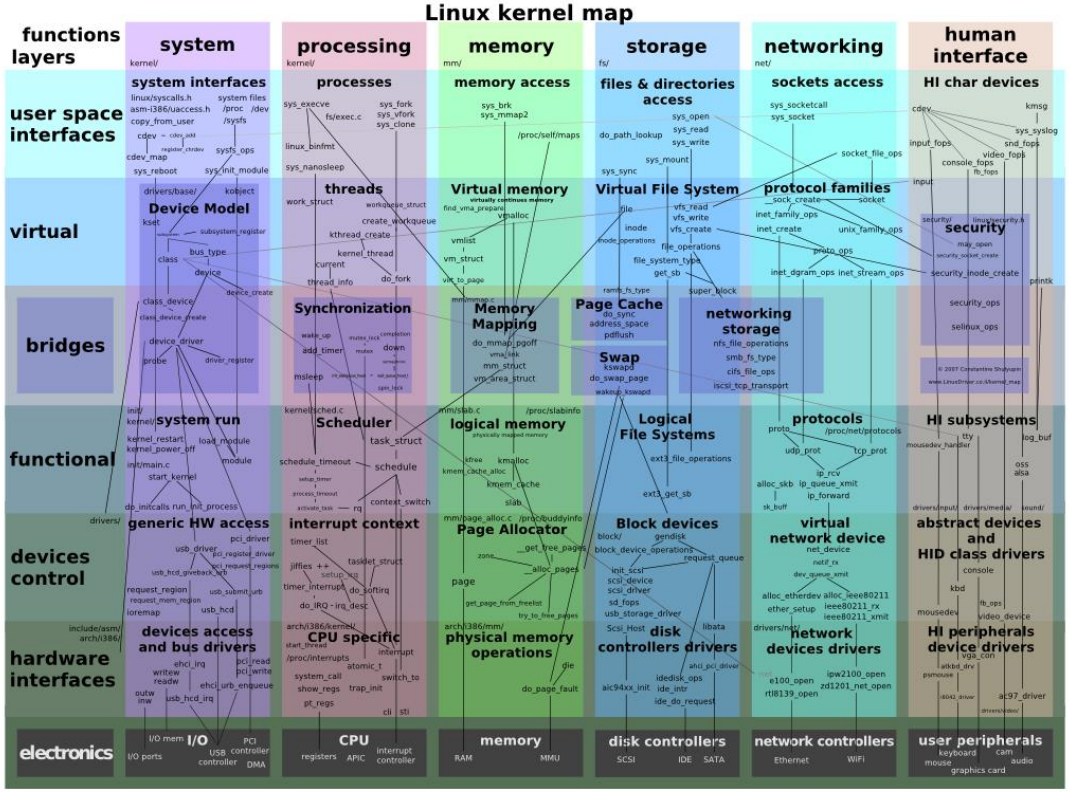
In this course we will primarily focus on The kernel and the system libraries.

The OS Kernel





The OS Kernel



- Process management
- Memory management
- File-system management
- Security
- Communication and networking
- Time Synchronization
- Many others: users, IPC, network, time, terminals

How do we interact with the kernel?

- Applications only see them via system calls (system calls are the API of the kernel)
- Examples, from UNIX / Linux:

```
pid_t pid = getpid();
printf("mypid is %d\n", pid);
```

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```
pid_t pid = getpid();
printf("mypid is %d\n", pid);
```

```
brk(0x18c9000)                  = 0x18c9000
clone(child_stack=0,
flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_
SETTID|SIGCHLD,
child_tidptr=0x7fbf4bda1a10) = 3710
getpid()                        = 3709
fstat(1, {st_mode=S_IFCHR|0620,
st_rdev=makedev(136, 6), ...}) = 0
write(1, "mypid is 3709\n", 14mypid is 3709
)       = 14
exit_group(0)
```

strace output (system calls in bold)

Why OS design is challenging

- The environment is unforgiving: weird h/w, hard to debug
- It must be efficient (thus low-level?)
  - but abstract/portable (thus high-level?)
- Powerful (thus many features?)
  - but simple (thus a few composable building blocks?)
- Resource sharing: CPU and memory
- Open problems: security

Before Next Class

- Ensure that you have full access to your VUIT Amazon AWS Virtual Machine
- Ensure that you can access the CS 3281 GitHub repo. Skim through the syllabus: https://github.com/cs3281/lectures
- Verify access to Brightspace and Piazza