WHAT’S THIS COURSE ABOUT?

- Ostensibly, it’s about operating systems
  - architecting complex software
  - identifying needs and priorities
  - separating concerns
  - implementing artifacts with desired properties

- It’s really about software design principles
  - It just so happens that OSes illustrate organizational principles and design patterns
WHAT KIND OF A COURSE IS THIS?

- Constructive, top-down
  - We start from first principles and re-derive the design of every component of a complex system

- Deconstructive, bottom-up
  - We dissect existing systems, learn what tradeoffs they make, what patterns they use
COURSE OBJECTIVE

Establish a foundation for building complex programs

- Architect systems
- Identify desirable properties
- Build large systems
- Debug complex systems

Understand all layers of the software stack between hardware and applications
WHAT IS AN OPERATING SYSTEM?

- An operating system (OS) provides a virtual execution environment on top of hardware that is more convenient than the raw hardware interface
  - “All of the code you did not write”
- Simpler
- More reliable
- More secure
- More portable
- More efficient
WHAT DO OSES DO?

- Manage physical resources
- Provide virtual resources
- Implement mechanisms and enforce policies to arbitrate access to resources
- Mediate the interaction of mutually distrusting applications
- Provide an extensible, general-purpose platform for a variety of applications
WHAT RESOURCES DO OSES CONTROL?

- Physical Resources
  - CPU, memory, disks, networks, I/O devices, ...

- Virtual Resources
  - Files, directories, sockets, names, ...
ISSUES IN OS DESIGN

- **Structure**: how is an OS organized?
- **Concurrency**: how are parallel activities created and controlled?
- **Sharing**: how are resources shared?
- **Naming**: how are resources named by users?
- **Protection**: how are distrusting parties protected from each other?
- **Security**: how to authenticate, authorize and ensure privacy?
- **Performance**: why is it so slow?
MORE ISSUES

- **Reliability**: how do we deal with failures?
- **Extensibility**: how do we add new features?
- **Communication**: how do we exchange information?
- **Scale**: what happens as demands increase?
- **Persistence**: how do we make information outlast the processes that created it?
- **Accounting**: who pays the bills and how do we control resource usage?
WHY LEARN OPERATING SYSTEMS?

- At most 1% of software developers will work on OS code
- The material taught in this course is critical not just for building Oses, but for building correct, high-performance applications (clients of Oses), as well as building reusable platforms for others
- Course will go far beyond OS design, covering all aspects of computer organization: including concurrency, synchronization, input/output, filesystems, networking, routing, distributed systems and so forth
- Engineering pride alone requires full understanding
FACT

- There has never been as exciting a time to work on systems hardware and software as now!!!

- The world is increasingly dependent on computer systems
  - Connected, networked, interlinked

- People just do not know how to build robust systems
BSOD

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Kernel Debugger: COM2 Port 0x2f8, Baud Rate 19200

Restart and set the recovery options in the system control panel or the /CRASHDUMP system start option. If this message reappears, contact your system administrator or technical support group.
BSOD
BSOD
A problem has been detected and Windows has been shut down to prevent damage to your computer.

**UNMOUNTABLE_BOOT_VOLUME**

If this is the first time you've seen this stop error screen, restart your computer. If this screen appears again, follow these steps:

Check to make sure any new hardware or software is properly installed. If this is a new installation, ask the hardware or software manufacturer for any Windows updates you might need.

If problems continue, disable or remove any newly installed hardware or software. Disable BIOS memory options such as caching or shadowing. If you need to use Safe Mode to remove or disable components, restart your computer, press F8 to select Advanced Startup Options, and then select Safe Mode.

**Technical Information:**

*** STOP: 0x000000ED (0x82F5D030, 0xC000006, 0x00000000, 0x00000000)***
A problem has been detected and Windows has been shut down to prevent damage to your computer.

MACHINE_CHECK_EXCEPTION

If this is the first time you’ve seen this stop error screen, restart your computer. If this screen appears again, follow these steps:

- Check to make sure any new hardware or software is properly installed.
- If this is a new installation, ask your hardware or software manufacturer for any Windows updates you might need.
- If problems continue, disable or remove any newly installed hardware or software. Disable BIOS memory options such as caching or shadowing. If you need to use Safe Mode to remove or disable components, restart your computer and press F8 when the Windows logo appears. Use the arrow keys to select Safe Mode, and press Enter.

If you see a message that the file is corrupted, or if you see a message that a required device driver is missing or corrupted, use the system restore feature to return your computer to a previous point in time when the problem did not occur.

If you see a message that the system is not found or that a required memory module is missing, check that the memory module is correctly installed and check that the memory settings in the BIOS match the type and size of memory installed in your computer.
THERAC-25

- A safety-critical system with software interlocks
- Beam controlled entirely through a custom OS
THERAC-25

- Old system used a hardware interlock
  - A lever that could either be in the “zap” or “x-ray” position

- New system was computer controlled

- A synchronization failure was triggered when competent nurses used the back arrow to change the data on the screen “too quickly”
THERAC-25 OUTCOME

- Beam killed one person directly, burned others, and may have given inadequate treatment to cancer patients

- Problem was very difficult to diagnose; initial fix involved removal of the back arrow key from the keyboard

- People died because a programmer could not write correct code for a concurrent system
DENVER AIRPORT

- The most modern, most expensive airport in recent history
  - Cost overrun in excess of $2B

- Highly automated luggage handling system was supposed to deliver your luggage to you at arrival

- Lack of persistence caused luggage carts to “forget” their contents, sprinkling the luggage on the runway
BITCOIN BANKS

- There is a new crop of systems for holding data known as NoSQL databases

- We cautioned about the errors people were committing with NoSQL systems

- The simplest attack against banks, of simultaneous withdrawals, actually works! Attackers stole millions of dollars from Bitcoin banks
  - One bank lost a million and folded
  - Another lost $500K, took losses
OTHER SYSTEMS

- FAA air traffic control system
- IRS data management system
- IBM “Microkernel”
- Pentagon data security
- Many others, too numerous to list
SUMMARY

- We do not have the necessary technologies and know-how to build robust computer systems

- There is huge demand for people who deeply understand and can build robust systems
PHILOSOPHY

- Not your grandparents’ OS course

- We believe that the following topics are critical for every software engineer
  - Building concurrent systems
  - Architecting networked components
  - Building transactional systems

- Not widely shared, the course is unique
LOGISTICS

- Lectures
  - Tuesday, Thursday 2:55-4:10pm, Uris G01

- Instructors:
  - Prof. Sirer & Prof. Bracy
  - cs4410-prof@cornell.edu: *goes to both of us*
  - Office Hours
    - Prof. Sirer: Tuesday 4:10-5:10pm
    - Prof. Bracy: Mondays 10:30-11:30am, Tuesdays 1:15-2:15 pm

- TAs
COMMUNICATION

- Course Web Page
  - Office hours, assignments, lectures, and other supplemental materials will be on the web site

- Piazza:
  - For 99% of the communication
    - Private posts should be visible to all course staff
    - Please do not contact course staff by other means (facebook, texts, email, etc.)
Course has three components
- Lectures and Readings
- Exams
- Assignments

Textbook
- Anderson and Dahlin

You are expected to keep up with all three
GRADING

- **CS4410 Breakdown**
  - ~45% Assignments
  - ~50% Exams (best 2 of 3)
  - ~5% Flexgrade (participation, attitude, effort)

- **CS4411 Breakdown**
  - ~90% Projects
  - ~10% Flexgrade

- Grading will not be done on a curve
  - It is our goal to be able to give everyone an A+
  - Help us achieve this
ASSIGNMENTS IN 4410

- 4 assignments
  - *Note:* if you are taking CS 4410 and 4411 this semester, you are exempt from the 4th 4410 assignment
- To be done individually
- Start early, time management is key
PROJECTS IN CS4411

- Projects will be done in two-person teams
  - You may indicate a desired partner
  - If they also indicate you, we will pair you up
  - If you don’t have a preferred partner, we’ll pair you up with someone suitable

- Working in groups
  - Start early, time management is key
  - Manage the team effort
  - Part of what you are supposed to learn is how to manage to get work done in a small team
ACADEMIC INTEGRITY AND HONOR CODE

- All submitted work must be your own
  - All homeworks must be your own independent work
  - OK to study together
  - Cannot share solutions, ever

- Project groups submit joint work
  - All group assignments must represent solely the work of the two people in that group
  - Cannot be in possession of someone else’s solution

- Violations will be prosecuted to the fullest extent

- Closed-book exams, no calculators
OUR EXPECTATIONS

- Code of Silence
  - Absolute quiet during lectures
  - If you have a question, please speak up
    - Chances are 100% that someone else has the same question

- No electronics, Luddite zone
  - Scientific studies show that such classrooms are far more effective
PREREQUISITE

- CS3410 or equivalent required. Or permission of instructor.

- Required means required.

- If you did not take CS3410 or equivalent, you must contact course staff, explain your situation and request permission.
DRAFT SYLLABUS

- Introduction
- Architectural Support for Operating Systems
- Processes and Threads
- Scheduling
- Synchronization, Mutual Exclusion, Spin Locks, Semaphores, Condition Variables
- Deadlocks, Detection and Avoidance
- Memory Management
- Networking, LANs, WANs, Ethernet, ARP, IP, UDP, TCP
- Disks and RAID
- Filesystems, UFS, LFS
- Security
PROJECT PLAN FOR CS4411

- Threads and Concurrency
- Scheduling
- Basic Datagram Networking
- Reliable Streaming Protocols
- Filesystems
ABOUT PROF. SIRER

- **Interests:** OSes, distributed systems, self-organizing and peer-to-peer systems
- Bitcoin, flaws within, fixes to
- Sailing, wind, sea, woodworking (aka body modification)
ABOUT PROF. BRACY

- **Interests:** computer architecture, microarchitecture, processor performance

- Swimming, hiking, wrangling small children
QUESTIONS?

- And demographics...
The slides for this semester are the product of many rounds of teaching CS 4410 by Professors Agarwal, Alvisi, Anderson, Bershad, Bracy, George, Levy, Sirer, and Van Renesse.