Computer Systems and Networks

ECPE 170 – Vivek Pallipuram– University of the Pacific

Introduction

The slides are courtesy of Dr. Jeffrey Shafer

Dr. Venkittaraman Vivek Pallipuram Krishnamani

Evolution of Dr. Pallipuram’s Name

Originally: Vivek Raman

Father’s Name: P.K.V. Raman

School Gave the Government my name as: Vivek P.K.V. Raman

Government took my name as: Venkittaraman Vivek Pallipuram Krishnamani

Clemson University took my name as: Vivek Kris. Pallipuram

ECE Department gave me several names: Vivek, Kris., Krishna..

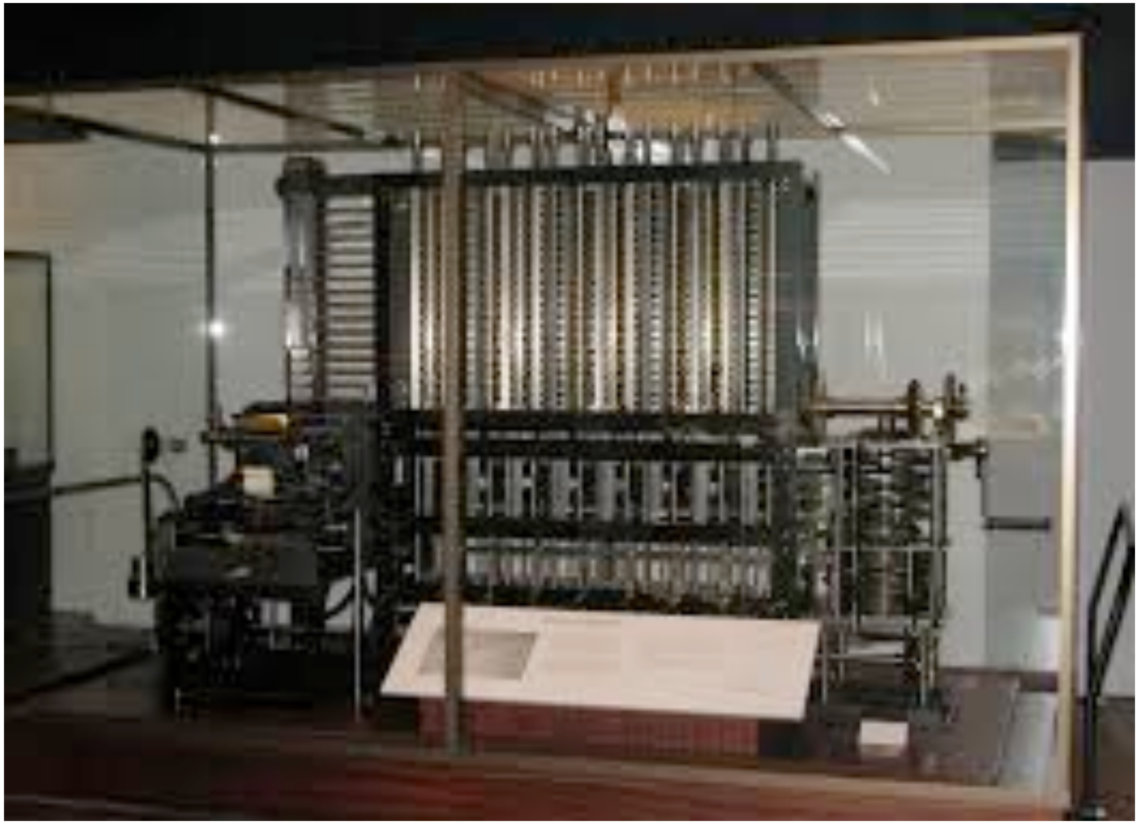
Dr. Venkittaraman Vivek Pallipuram Krishnamani

My Background

- Started as an Instrumentation and Control Engineer
- Found real interest in computing
  - Master’s degree and Doctorate in Computer Engineering
- Extensive experience in:
  - Porting scientific applications on supercomputers
  - Performance analysis (prediction of runtime without running an application) using probability theory
  - Probabilistic modeling in other fields: climate modeling

What is this machine?

Charles Babbage’s Difference Machine circa 1847

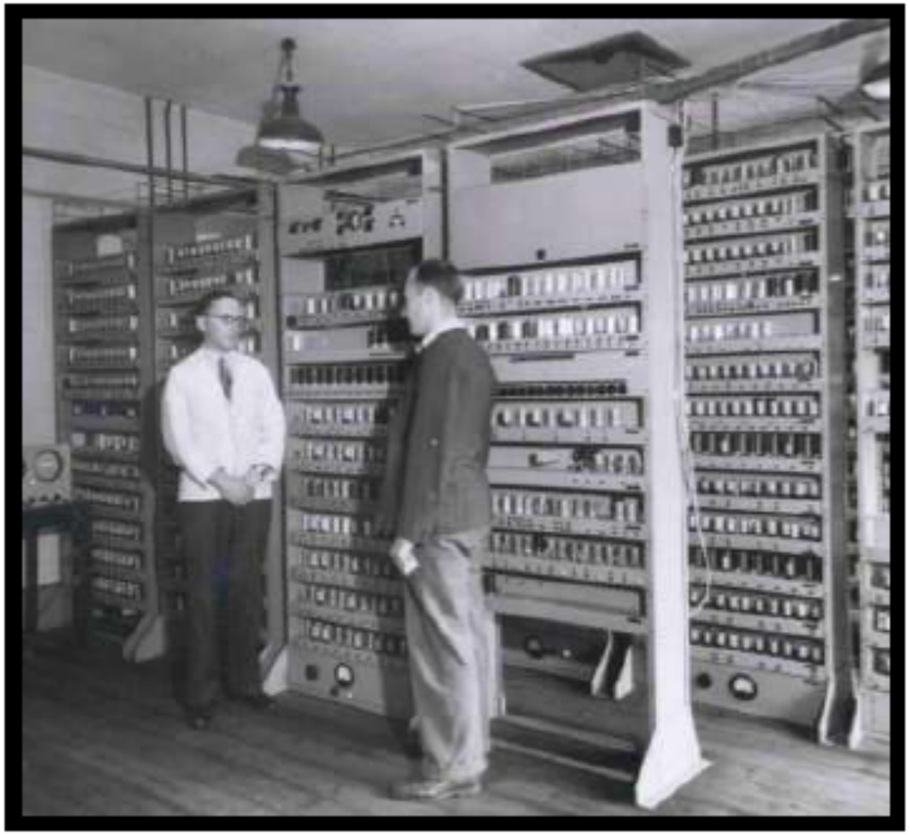


ENIAC - 1946

Eckert and Mauchly

- 1st working electronic computer (1946)
- 18,000 Vacuum tubes
- 1,800 instructions/sec
- 3,000 ft^3

EDSAC 1 - 1949



EDSAC 1 (1949)

http://www.cl.cam.ac.uk/UoCCL/misc/EDSAC99/

- Maurice Wilkes

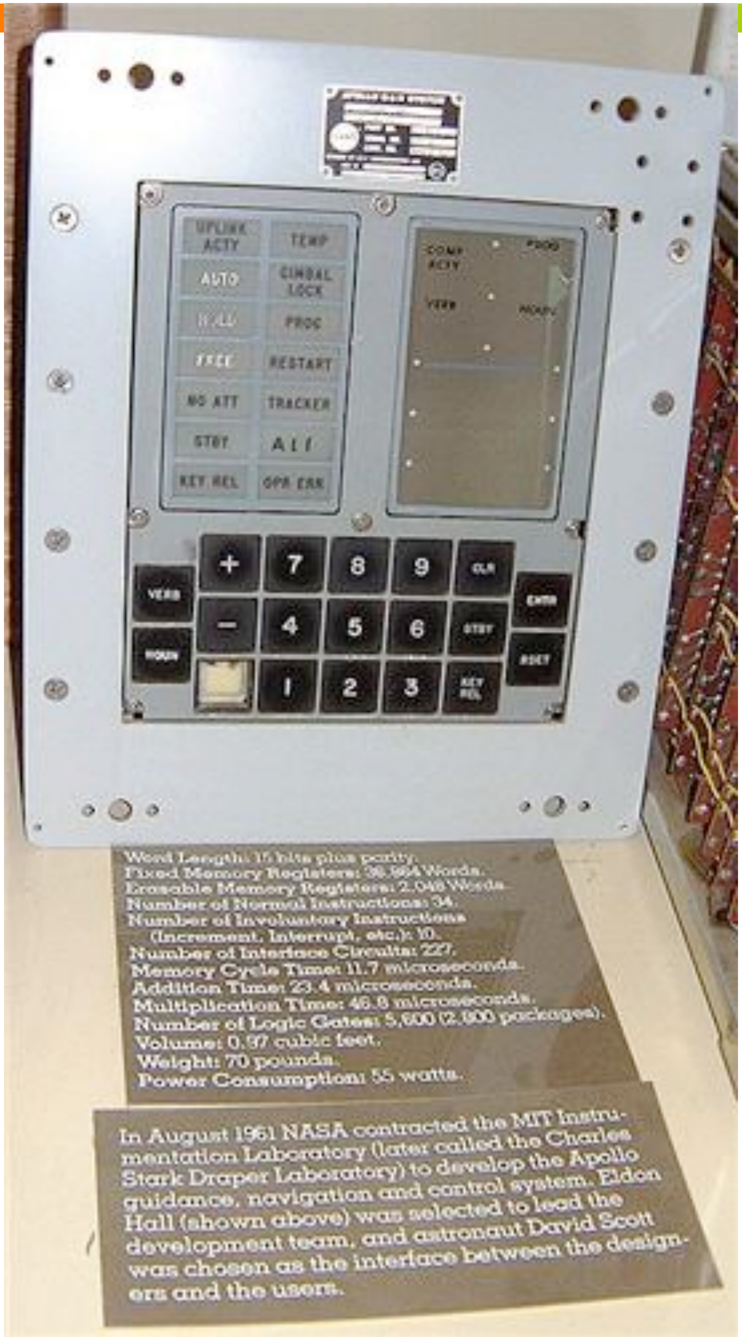
1st stored program computer

650 instructions/sec

1,400 ft^3

Apollo Guidance Computer

Used to send man on the moon



Word Length: 15 bits plus parity.
Fixed Memory Registers: 36,864 Words.
Erasable Memory Registers: 2,048 Words.
Number of Normal Instructions: 34.
Number of Involuntary Instructions (Increment, Interrupt, etc.): 10.
Number of Interface Circuits: 227.
Memory Cycle Time: 11.7 microseconds.
Addition Time: 23.4 microseconds.
Multiplication Time: 46.8 microseconds.
Number of Logic Gates: 5,600 (2,800 packages).
Volume: 0.97 cubic feet.
Weight: 70 pounds.
Power Consumption: 55 watts.

In August 1961 NASA contracted the MIT Instrumentation Laboratory (later called the Charles Stark Draper Laboratory) to develop the Apollo guidance, navigation and control system. Eldon Hall (shown above) was selected to lead the development team, and astronaut David Scott was chosen as the interface between the designers and the users.

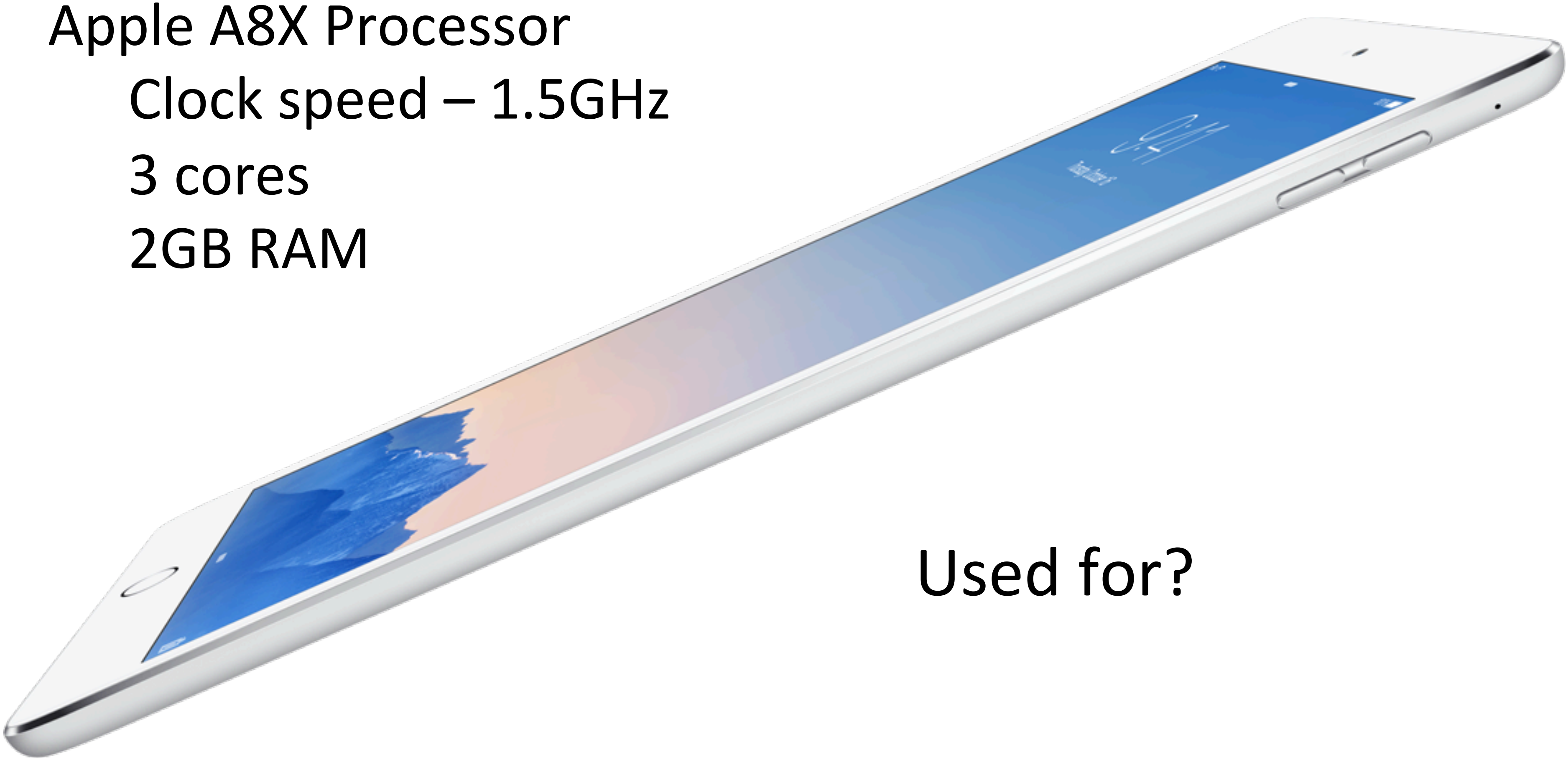
64 KB memory

Clock speed: 43 KHz

A Modern Computer – iPad Air "2"

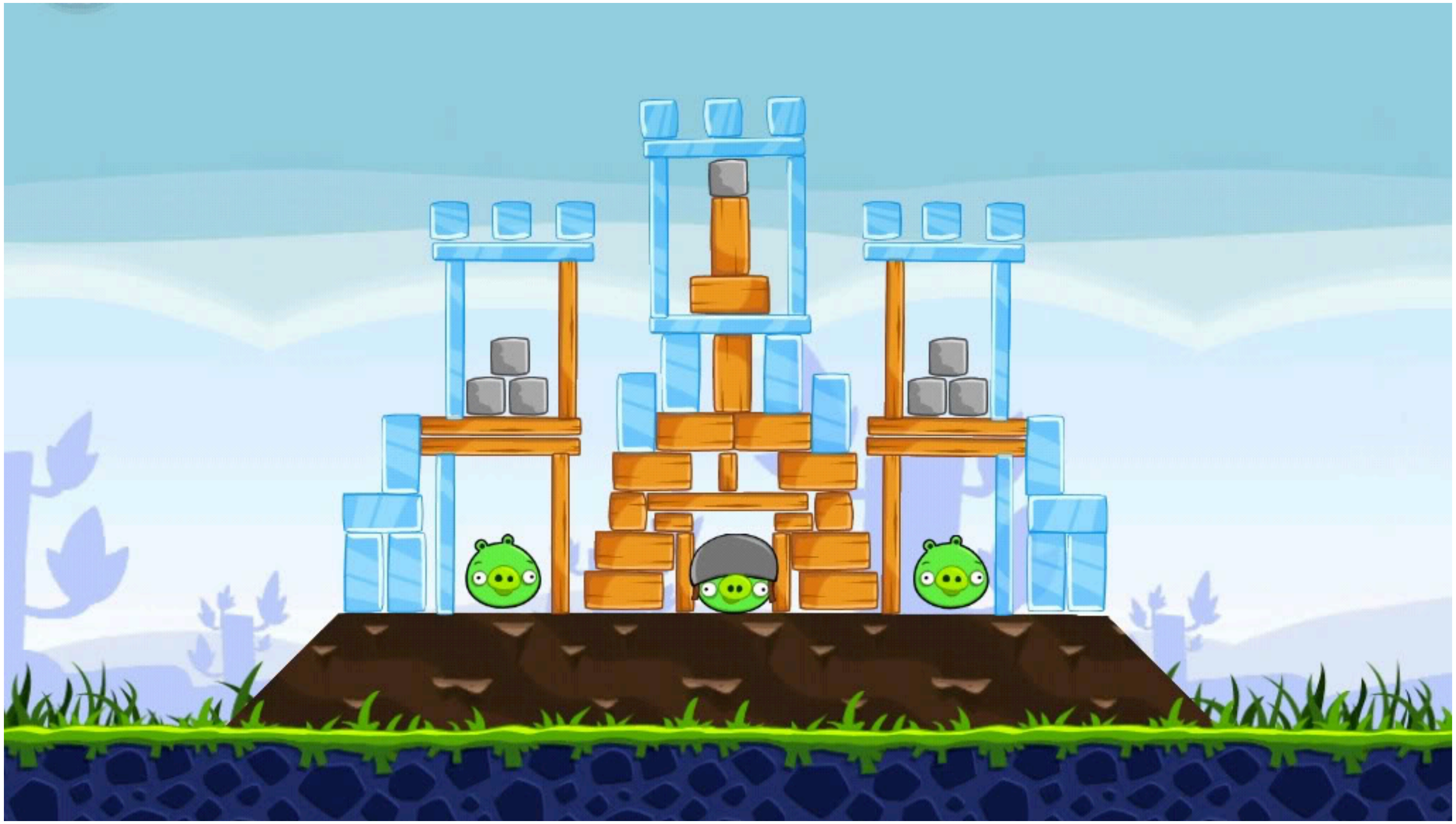
Apple A8X Processor

- Clock speed – 1.5GHz
- 3 cores
- 2GB RAM



Used for?

Applications



Application – Angry Birds

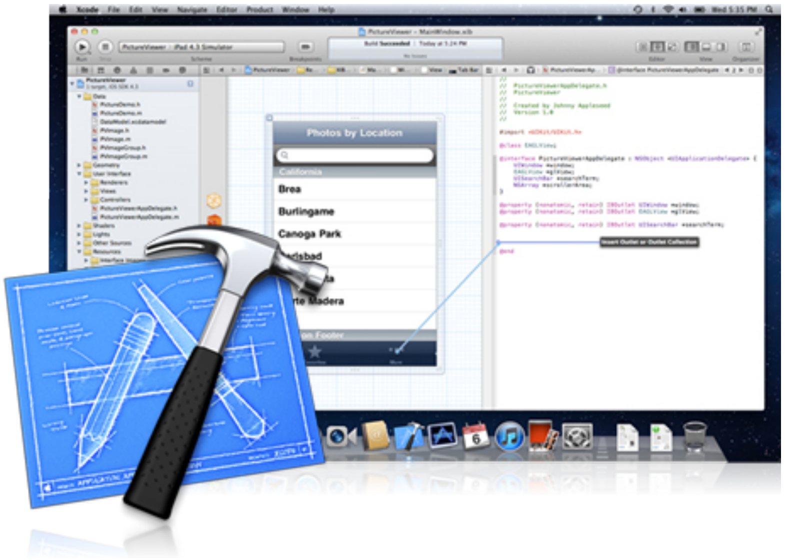
- Written in a high level language (Objective C)
- What **resources** does *Angry Birds* need to run? (i.e. what does the *Angry Birds* executable file need to execute?)
  - Hardware
    - Processor(s) – Run program, display graphics, …
    - Memory – Store programs, store data
    - I/O – Touch screen, storage, network, 3-axis gyro, …
  - Software - Operating system

Software - Operating System

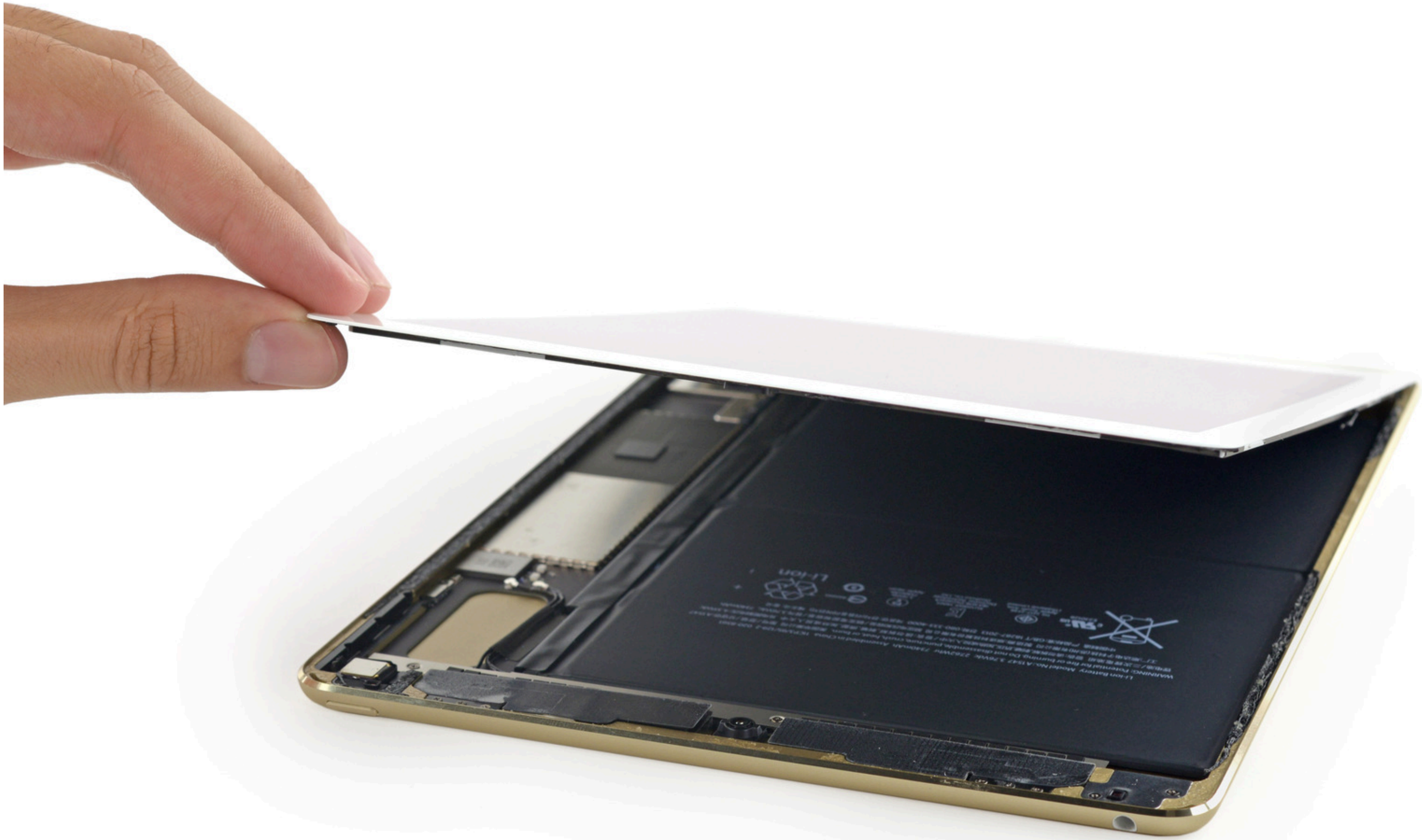
- Apple iOS – Used in iPads, iPhones, iPods, Apple TV
  - Variant of Mac OS X operating system used on traditional Macs
- **What are some jobs of this operating system?**
  - Manage hardware
  - Manage applications (multitasking)
- Written in high-level languages
  - C, C++, Objective C (varies by component)
  - **Can we run this code directly on the processor?**

Software - Compilers / Interpreters

- These are programs that **build** other programs!
- Goal: Convert high-level languages into machine code that can be directly executed by hardware
- Examples
  - Apple Xcode
  - Microsoft Visual Studio
- **What's the difference between a compiler and interpreter?**



Hardware



https://www.ifixit.com/Teardown/iPad+Air+2+Teardown/30592

Hardware

Apple A8X 64-bit Processor

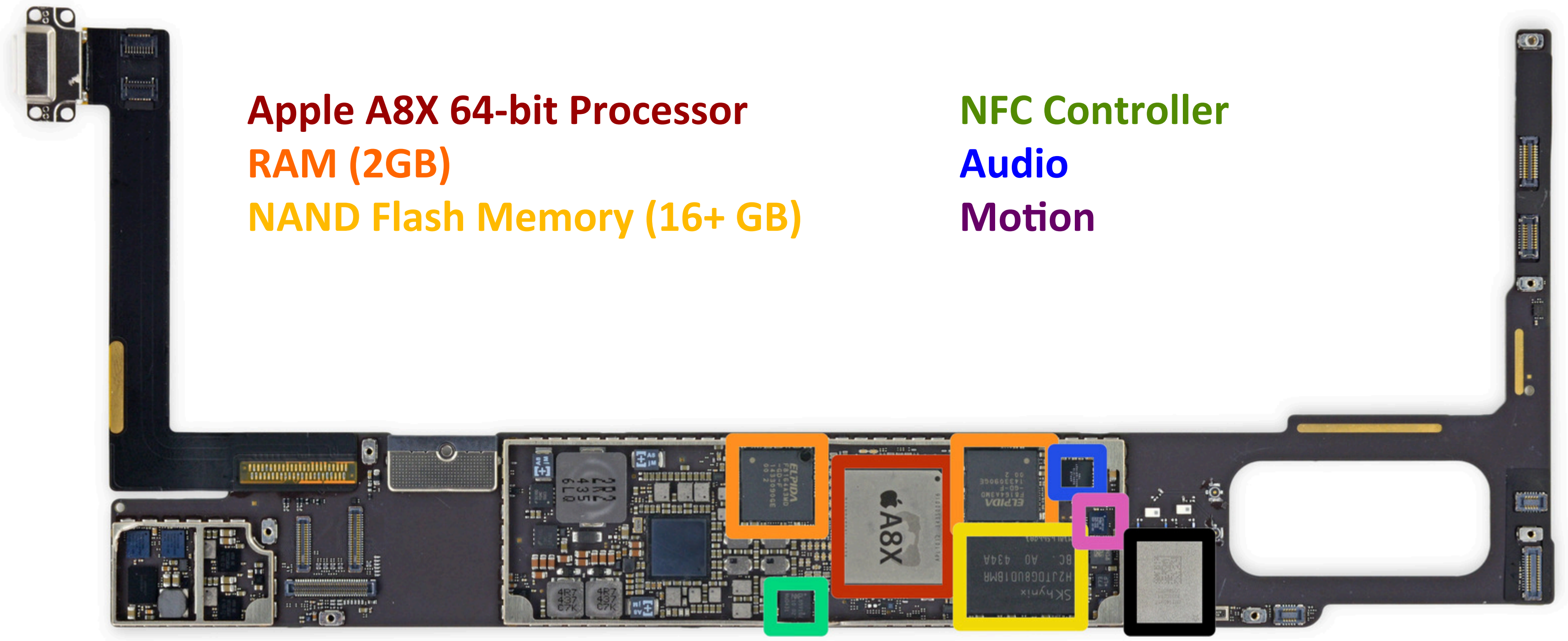
RAM (2GB)

NAND Flash Memory (16+ GB)

NFC Controller

Audio

Motion



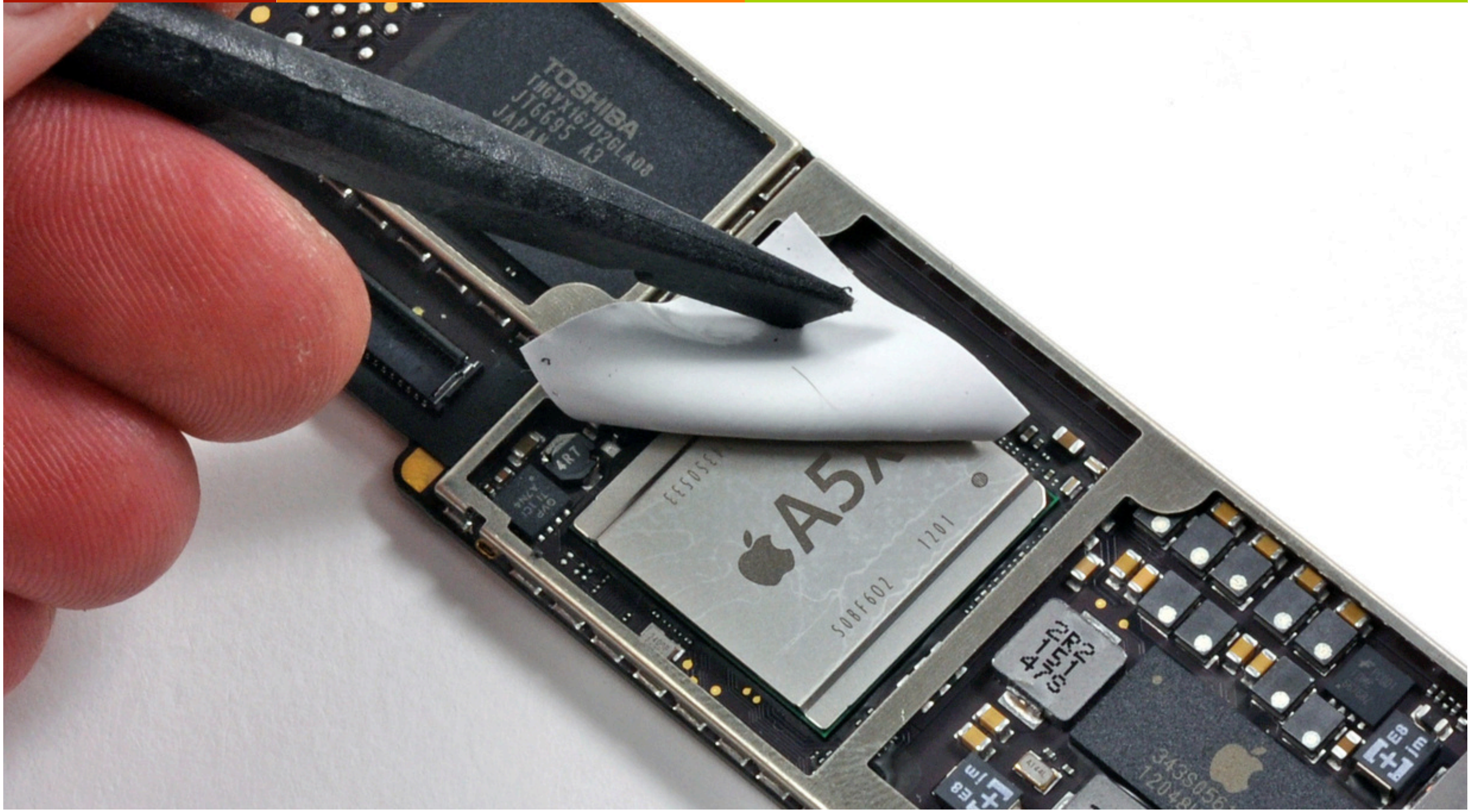
iPad Air “2” Processor

- Apple A8X Processor
  - Clock speed – 1.5GHz
  - 3 cores
  - 2GB RAM

What do these mean?

- **What does a processor do?**
  - Executes machine language instructions
    - **Machine language?**
  - **How does the processor execute the instructions?**

Microarchitecture



How Does It Work?

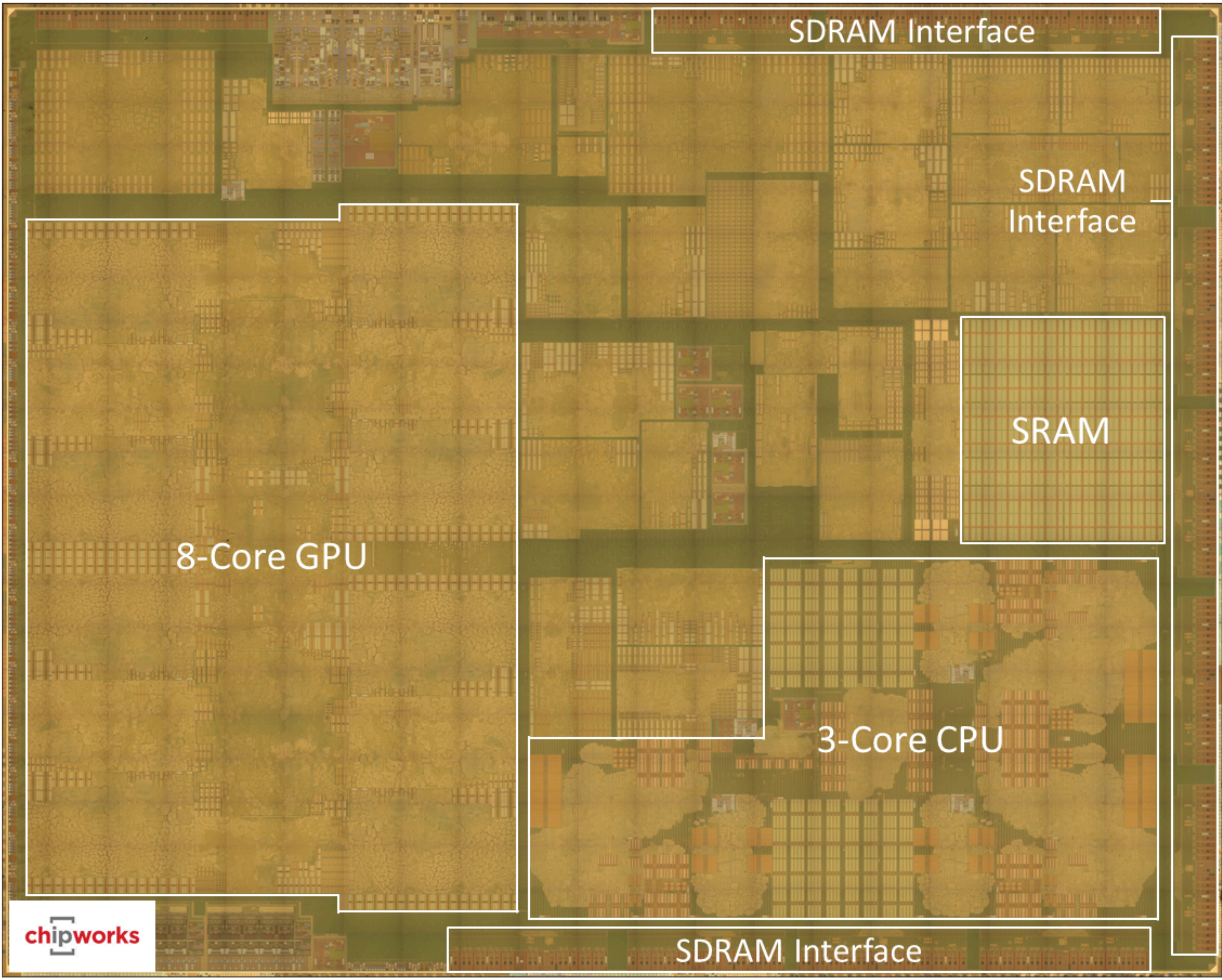
- Apple won't tell us – trade secret!
- Experts can dissolve (with acid), burn, or grind off outer protective layers of chip and then peer inside:
  - Need a *really good* microscope!
  - *Reverse Engineering in the Semiconductor Industry:* http://www.scribd.com/doc/53742174/Reverse-Engineering

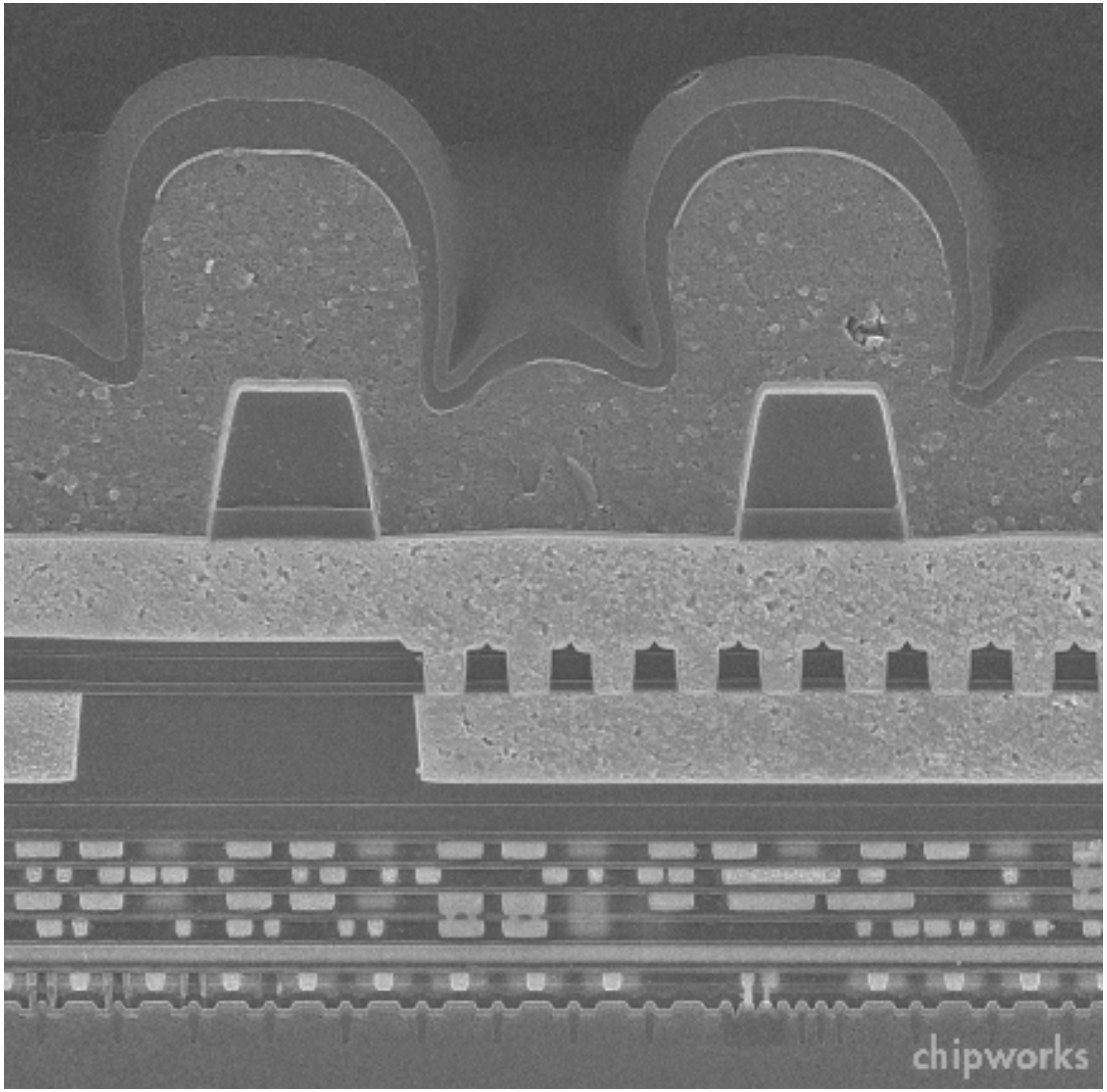
JEOL 7500F-1
scanning electron microcsope

Can see this level of detail with your own eyes…

Divided into logic blocks with different functions:

- Processor
- Cache memory
- Memory Controller
- Video (GPU)

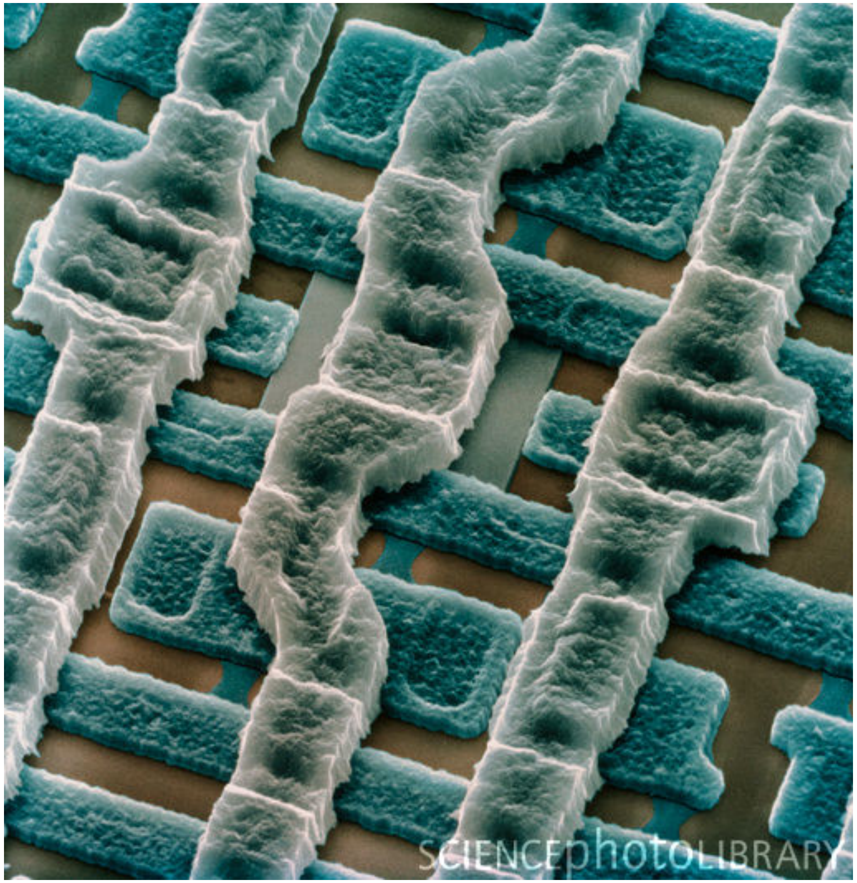




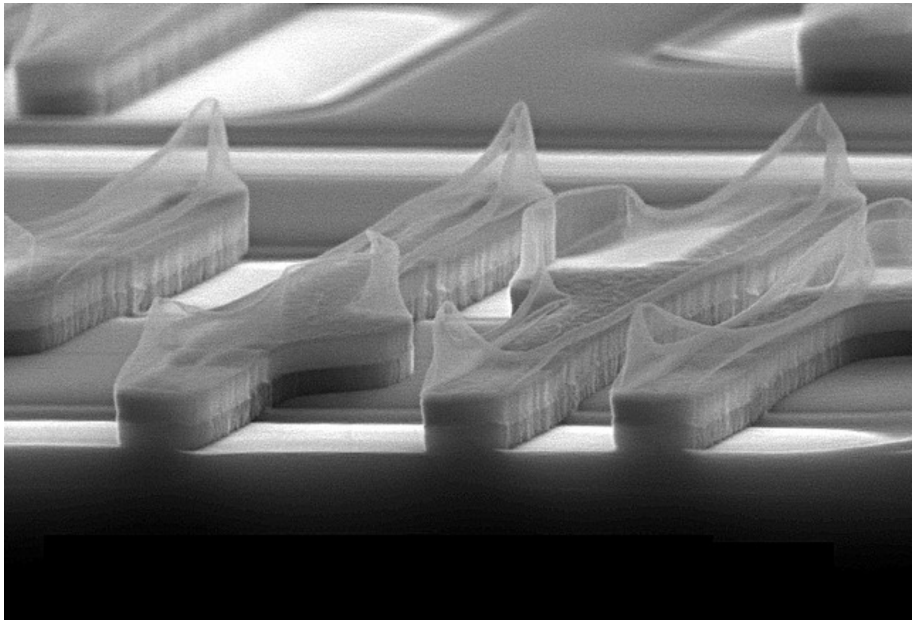
SEM Cross-Section of (older) Apple A5

Digital Logic

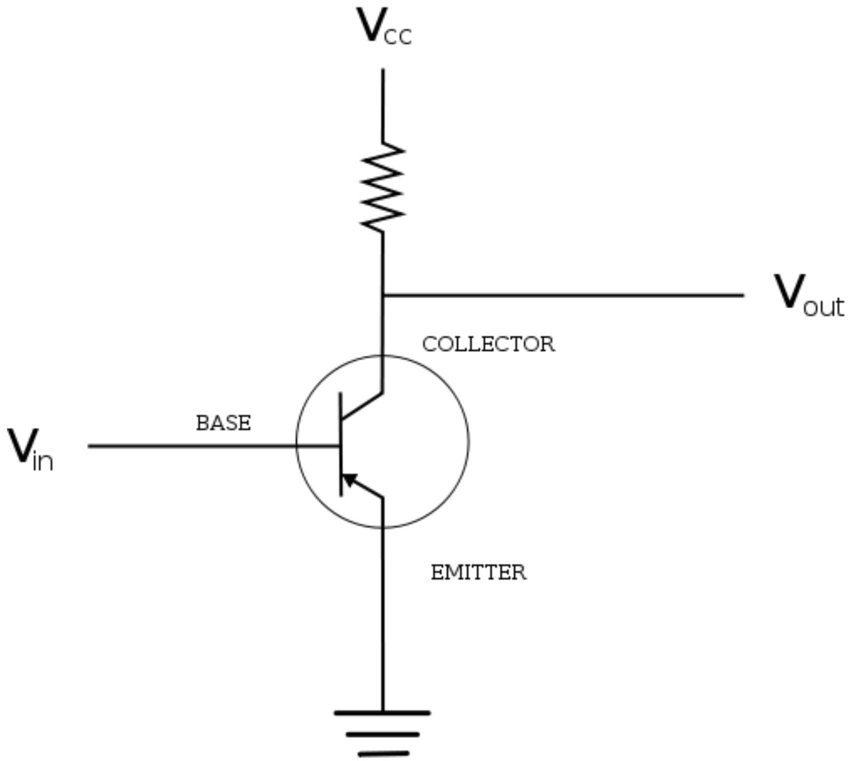
Memory cell



Transistor

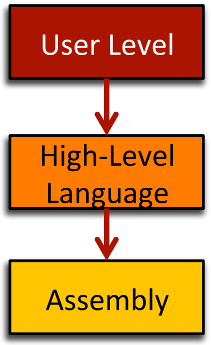


Transistors



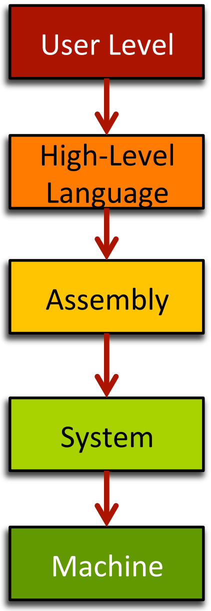
- You can still make assumptions at this level that the transistor is either "on" (1) or "off" (0)
- But below this are **analog circuits**

The Computer Level Hierarchy



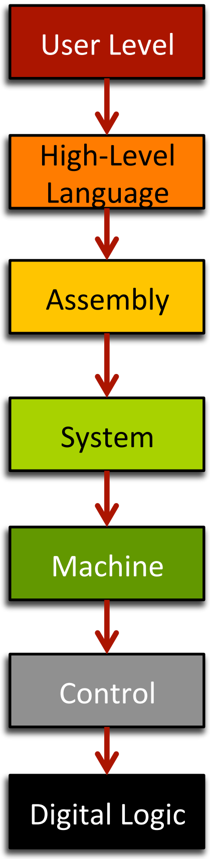
- Level 6: The **User Level** – "Angry Birds"
  - Program execution and **user interface** level
- Level 5: **High-Level Language Level** – "Objective C"
  - Programming languages like C++, Java, Python, …
- Level 4: **Assembly Language Level** – "ARM Assembly"
  - Program directly at this level, or …
  - **Use a compiler/interpreter** to process/convert high-level code

The Computer Level Hierarchy



- Level 3: **System Software Level** - “iOS”
  - Controls active programs and manages system resources
  - Assembly language instructions often pass through Level 3 without modification
- Level 2: **Machine Level**
  - Instruction Set Architecture (ISA) Level
  - Instructions are particular to the architecture of the specific machine (i.e. Intel processors, ARM processors, IBM processors…)

The Computer Level Hierarchy



These levels are too hardware-oriented for ECPE 170…

- Level 1: **Control Level**
  - Decodes and executes instructions and moves data through the system
  - **ECPE 173 – Computer Organization & Architecture**
- Level 0: **Digital Logic Level**
  - Digital circuits, gates and wires implement the mathematical logic of all other levels
  - **ECPE 71 – Digital Design**
    ECPE 174 – Advanced Digital Design

Course Overview

Motivating Question

- **What do you, as a programmer, need to know about the underlying system (software *and* hardware) to write more efficient code?**
  - Role of the tools
    - Compiler, assembler, linker, profiler
  - Role of the operating system and its efficient usage
  - Assembly programming (using the CPU efficiently)
  - Memory hierarchy and its impact on performance

General Theme: Professor Pallipuram will be the General Manager
YOU are the software engineer

Course Goals

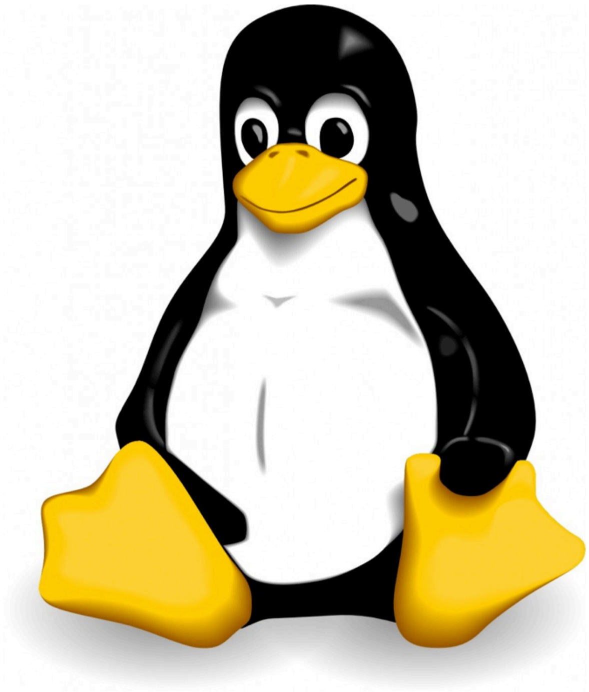
- Present a complete view of how computer systems are constructed
  - From the CPU assembly programming level to the user application level
- Understand the relationship between computer software and hardware
- Lay the foundation for future courses
  - Advanced Digital design / VLSI
  - Operating systems
  - Computer networking
  - Application development

C Programming Language

C

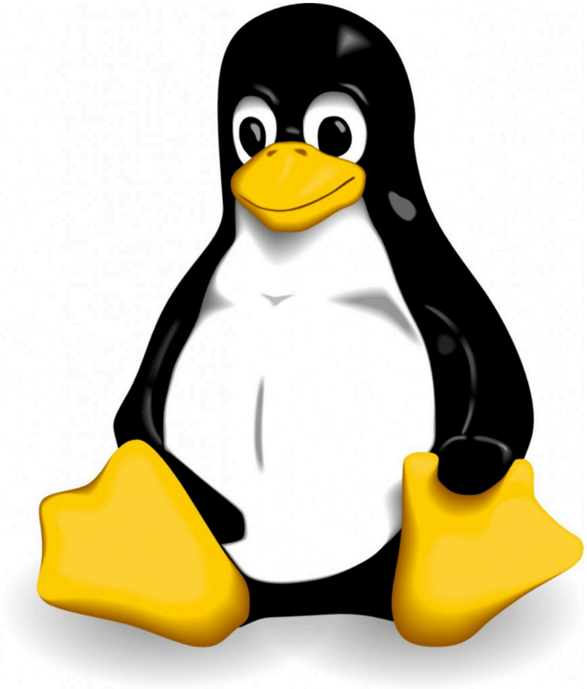
- **Why not Python, Java, Ruby, Perl, PHP, …?**
- High-level languages (especially interpreted, managed code…) try to *hide* the underlying machine from you
- ECPE 170 wants to *reveal* the underlying machine to you!

Linux



- **Course will be taught 100% in Linux**
- *Did you* have *to choose Linux for ECPE 170?*
- No, not really, but…
  - Too many Pacific graduates were *escaping* without a working knowledge!
  - **Feedback from co-op employers and graduates: “More Linux/Unix skills please!”**

Linux



- **Who here has used a Linux desktop/ laptop/server before?**
- **Who here has used a Linux "device" before?**
  - *I'd be surprised if it isn't everyone…*
  - Android runs a Linux kernel
  - Amazon Kindle runs a Linux kernel
  - TiVO runs a Linux kernel

Discussion

- What is open-source?
- What is an operating system *kernel*?
  - Is the kernel everything you need from an OS?
- What is Linux?
- What is Ubuntu Linux? (RedHat? Debian? …)
  - → Show family tree of distributions ←

Virtual Machine

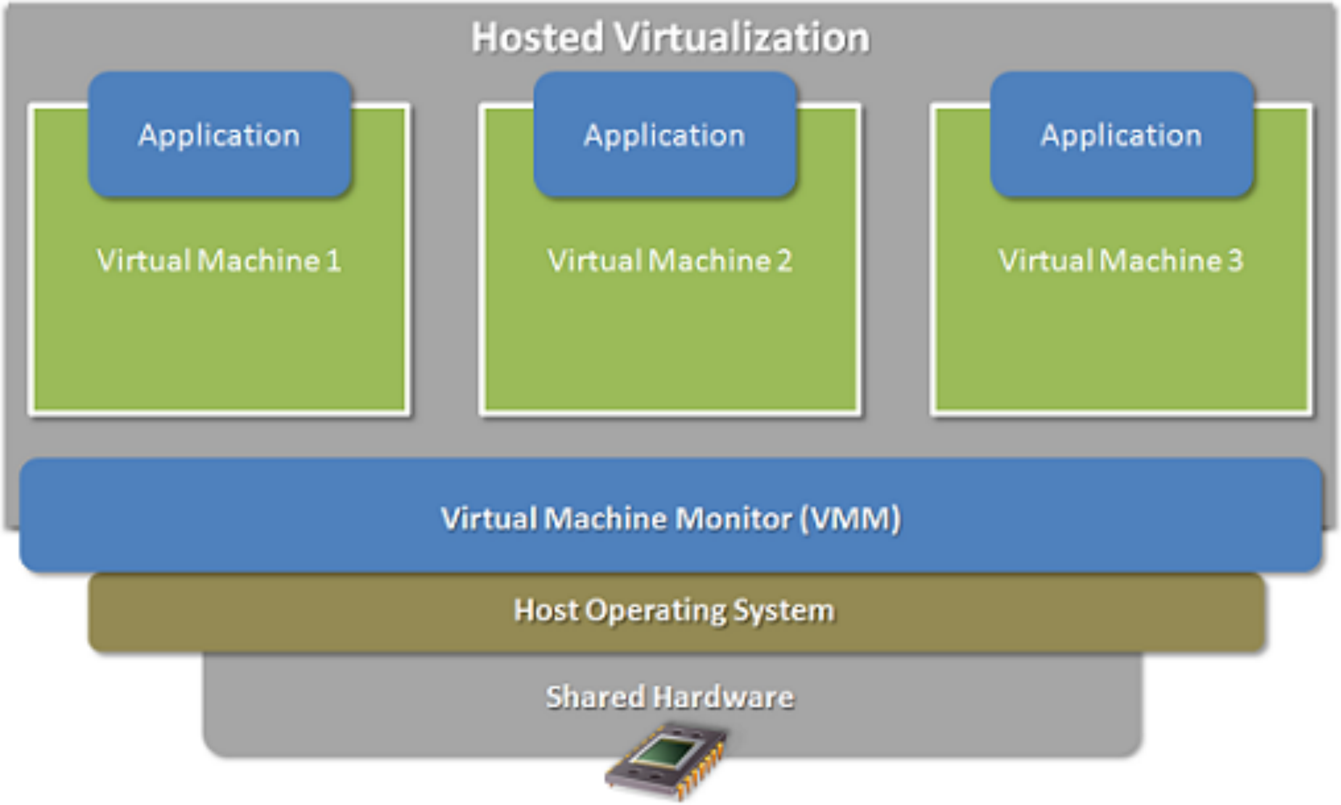
- **Course will be taught 100% from a virtual machine booting Linux that *you* install!**
- *Couldn't you just give us remote access to a server someplace that is already configured?*
- Yes, but…
  - By installing it yourself you will have the skills to use it again in the future
  - No mysterious "Professor Pallipuram/ Shafer" software configuration

Discussion

- **What is a Virtual Machine?**
  - **Is this the same thing as a *Java* virtual machine?**
- **How is it different from dual booting?**
- **Which comes first, the virtual machine, or the OS?**
  - Answer: It depends!
  - Typical desktop install: hosted virtualization
  - Typical server install: bare-metal virtualization

Recommended technique for ECPE 170

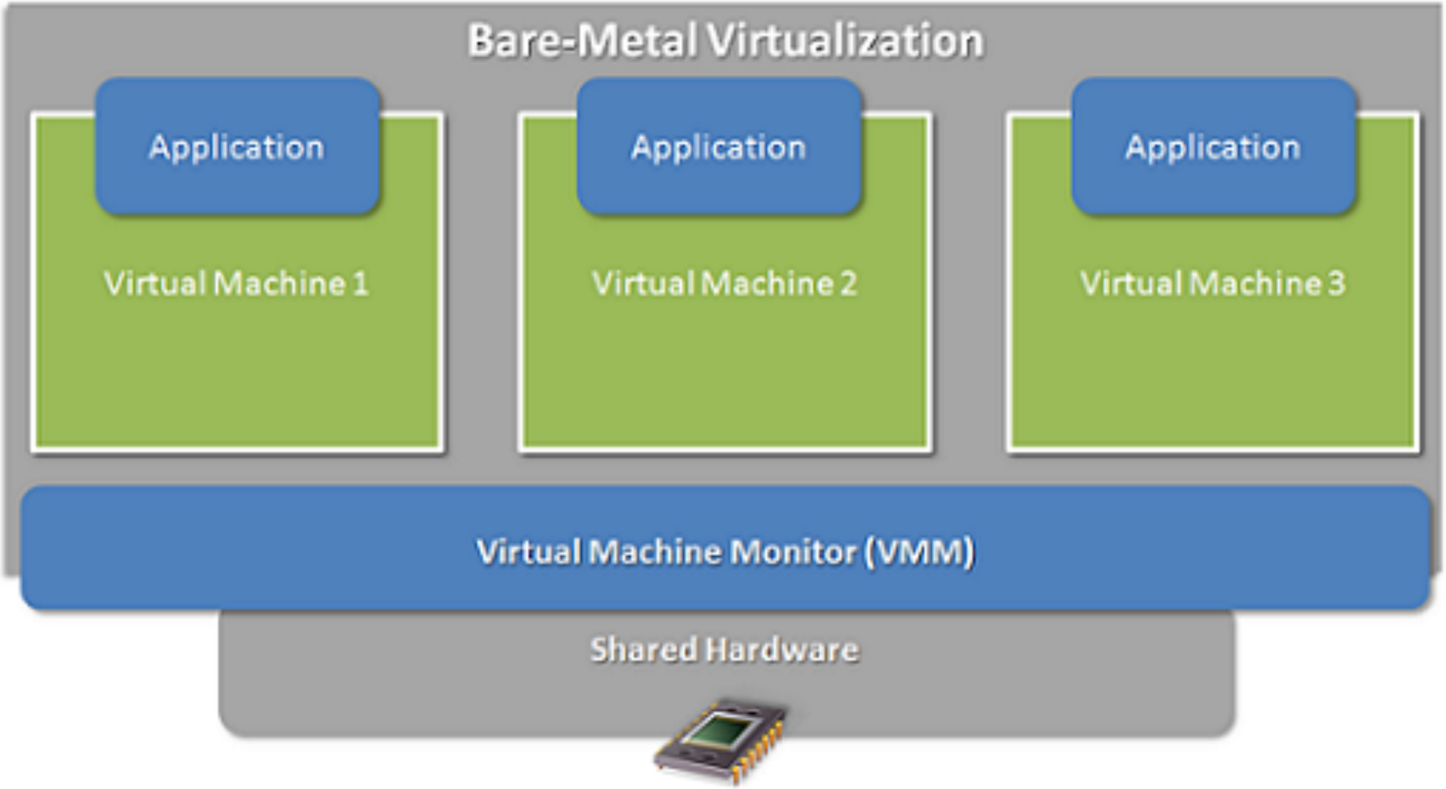
Hosted Virtualization



Bare-Metal Virtualization

More efficient, but not as easy to install.

The virtual machine monitor acts like an operating system itself!



Version Control

- **Course will use version control!**
  - Only way to get lab code or turn in assignments
- *Did you* have *to mandate VCS for ECPE 170?*
- No, not really, but…
  - Too many Pacific graduates were *avoiding* learning this on their own!
  - **Feedback from co-op employers and graduates: "Only n00bs work without version control!"**
  - Used everywhere: Source code of all kinds! (C++, Python, Matlab, VHDL/Verilog, …)

Version Control

- **Who here has used a *version control system* before?**
  - What system?
  - Where at?
  - What purpose?

Questions?

- Questions?
- Concerns?

Course Mechanics

Websites

Main website (syllabus, schedule)

- http://ecs-network.serv.pacific.edu/ecpe-170

Canvas website (gradebook)

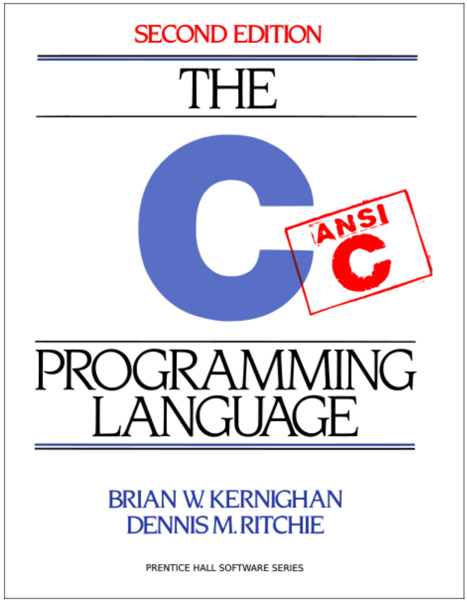
- http://canvas.pacific.edu

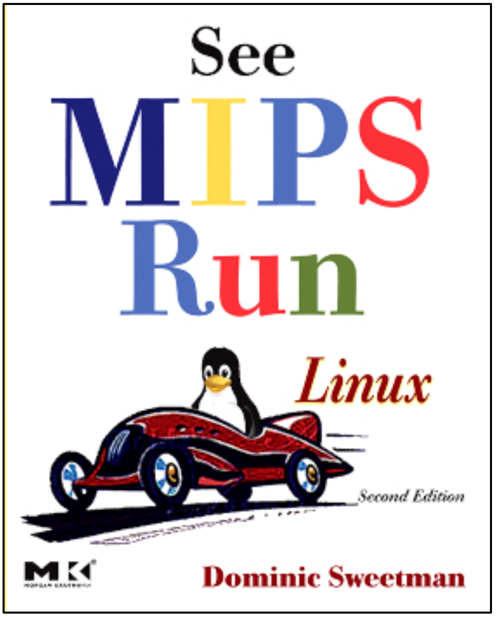
Bitbucket.org (version control)

- http://bitbucket.org

Textbook

- **No official textbook**
- Optional reference books (useful for this class and beyond)
  - The C Programming Language, 2nd Edition
  - See MIPS Run, 2nd Edition
- **Please suggest useful online or print references throughout the semester**





Grading

- **30% - Exams**
  - 15% - Mid-term exam
  - 15% - Final exam
- **70% - Labs**
  - Points assigned to each lab will vary based on complexity
  - Each lab *begins* as an in-class activity
    - Unfinished work becomes homework/project
    - **Labs are large – assume “the usual” amount of homework/projects for a 4-credit class**
  - **Tip: The best students last semester *started* the labs outside of class, and finished them as an in-class activity**

Honor Code

- **All assignments are submitted individually**
- **Encouraged Activities**
  - Collaborating with your classmates (asking questions, solving problems together)
  - Searching for solutions online
    - Provided code copied does not exceed 25% of total assignment length
    - Provided you clearly **document this copy** in your source code and lab report
      - What did you copy? Where did it come from?

Honor Code

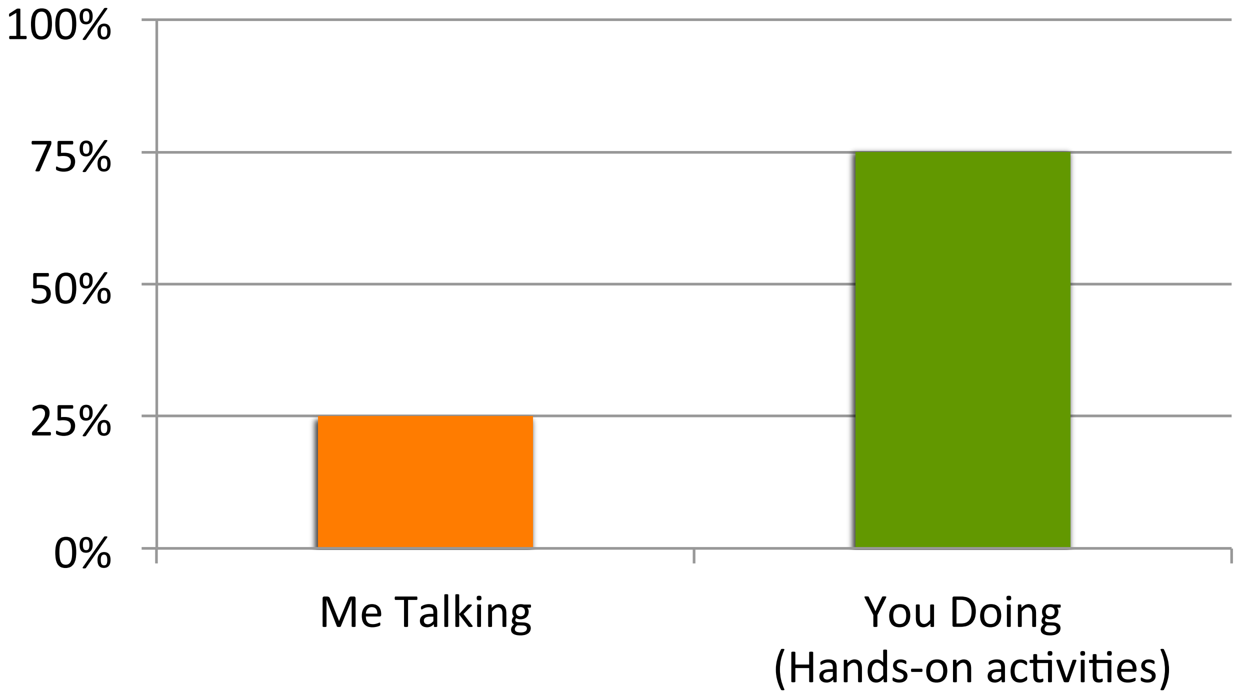
- **Risky Activities**
  - Having your classmates type on your computer or assignment file
- **Forbidden Activities**
  - Copying someone's work verbatim (classmate or otherwise)
  - Copying someone's work and obfuscating its source

Lab Topics

1. Linux
2. Version Control
3. C Programming
4. C Programming Project
5. Performance Measurement
6. Performance Optimization (compiler and programmer techniques)
7. Performance Optimization (Memory systems)
8. Network Programming 1 (Python)
9. Network Programming 2
10. Assembly Programming 1 (MIPS)
11. Assembly Programming 2
12. Assembly Programming 3

Class Time

- The goal* in designing this course:



* Actual time in any specific class may vary

Lab 1 - Linux

Homework

- **Before the next class**
  1. **Skim "Virtual Machine Setup" tutorial instructions on website**
     - http://ecs-network.serv.pacific.edu/ecpe-170/tutorials/vm_setup
  2. **Decide on what computer system you want to use for this class**
  3. **Download all software**
     - Virtual machine installer (VMWare Player)
     - Linux .iso image (installer) – 64-bit version

Next Class - Linux Installfest

- Tutorial Day
- Objectives
  - Follow the “Virtual Machine Setup” tutorial from website to install Linux
  - Debug individual problems if needed
  - Verify OS works
  - **Email me screenshot as proof of success**

Next Class - Linux Installfest

- **I want you to be comfortable <u>as professionals</u> working independently to solve problems**

- If you complete the "Virtual Machine Setup" tutorial independently (**<u>and email me a screenshot by Thursday morning</u>**), you don't need to attend Thursday's class. Sleep in! *(Or come help out)*

- I will still be here to answer all questions and solve problems

Next Class - Linux Installfest

- **Warning: Don’t skip class Thursday, and then tell me next Tuesday at Lab #1 that your OS doesn’t work!**

Lab 1 - Linux

- **The first lab is next Tuesday**
  - Topic: Linux
  - Crash course in command-line usage
- **Lab 1: Pre-Lab**
  - Show me the working command prompt in your Linux install. Hopefully you will have this done by end-of-class Thursday
  - **Pre-Labs are always due at the start of the lab**

Bring Laptop!

Every class – bring your laptop

Bring Laptop!

Every class – bring your laptop!

Bring Laptop!

Every class – bring your laptop!!

(*) Maybe not this one, but you get the idea…

Bring Laptop!

Every class – bring your laptop!!

Just assume we'll do at least *some* lab activity in class unless it's been made crystal clear in advance that a day will be all lecture/discussion instead…

Bring Laptop!

- *No laptop? Let's try installing Linux to a USB stick and dual boot the classroom computers.*
- ***See me after class*** *to sign-out hardware…*

Questions?

- Questions?
- Concerns?