CS 572 Micro Architecture

Dr. Tao Xie

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Fall, 2017

These slides are adapted from notes by Dr. Dave Patterson (UCB) and Dr. Xiao Qin (Auburn)

Grader

Chinmay Kulkarni

Email: chinmayk93@gmail.com

Office: GMCS 557

Office hours: Monday&Wednesday 4 pm to 5 pm

Outline

- Course Objectives
- Course Content & Grading
- Laboratory Assignments
- Technology Trends
- Introduction to Computer Organization and Technology

CS 572: Semester Calendar

See the class webpage for the most up to date version!

http://taoxie.sdsu.edu/cs572

tao xie sdsu

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San Diego State University

Tao Xie

Ph.D.

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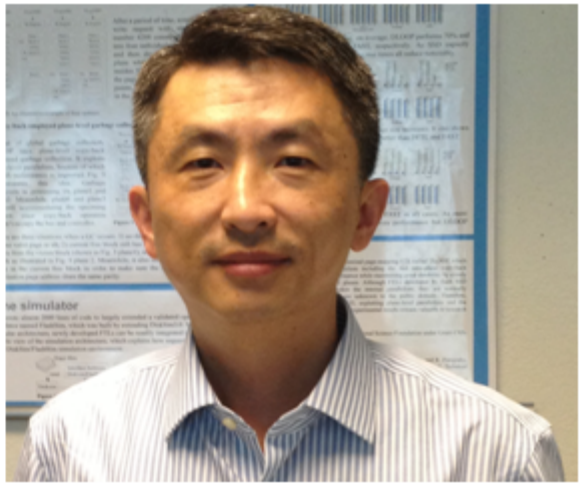
SAN DIEGO STATE UNIVERSITY

Tao Xie

Professor
Department of Computer Science
San Diego State University



About Me

I am a professor in **Computer Science** at the San Diego State University.

I received my B.S. in Electrical Engineering and M.S. in Computer Engineering both from Hefei University of Technology, Hefei, China. I received my Ph.D. in Computer Science from New Mexico Institute of Mining and Technology in May 2006.

Recent Events

- [11/29/16]: My student Deng Zhou successfully defended his Ph.D. dissertation entitled "I/O Stack Optimization for Non-Volatile Memory Based Storage Systems". Congratulations to Deng Zhou!
- [10/06/16]: My student Wen Pan presented our paper entitled "How Many MLCs Should Impersonate SLCs to Optimize SSD Performance?" at MEMSYS 2016 in Washting D.C.
- [05/16/16]: Our paper entitled "How Many MLCs Should Impersonate SLCs to Optimize SSD Performance?" is accepted by the 2nd International Symposium on Memory Systems (MEMSYS 2016). Congratulations to Wei Wang, Deng Zhou, and Wen Pan!
- [11/30/15]: The source code and the traces of our publication "I/O Characteristics of Smartphone Applications and Their Implications for eMMC Design (IISWC 2015)" are available now! The

CS 572 Micro Architecture

Fall 2017
MW 2pm - 3:15pm, ENS-106
San Deigo State University

Instructor: Dr. Tao Xie
Office: GMCS 535, Phone: 619-594-2014, Email: txie@mail.sdsu.edu
Office hours: Monday and Wednesday 11 am - noon; or by appointment
Grader: Chinmay Kulkarni, Chinmay Kulkarni, GMCS 557, lab hours: Monday&Thursday 10 am ~ 12 pm

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General Information | Announcements | Syllabus | Assignments | Lectures

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Announcements

Course Information

This course aims to introduce many issues and challenges involved in designing and implementing modern computer systems. Since applica
systems. Understanding the interdependence of architectural and implementation decisions is of help to the development of applications wi

Objectives

- To learn the principles behind the design of modern computer systems (e.g., tradeoffs: cost vs. performance, speed vs. flexibility)
- To understand the design of instruction sets

CS 572 Micro Architecture

Fall 2017
MW 14:00-15:15, ENS-106
San Diego State University

Instructor: Dr. Tao Xie
GMCS 535, 619-594-2014
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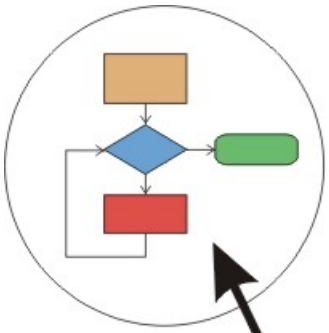
Lectures and Schedule

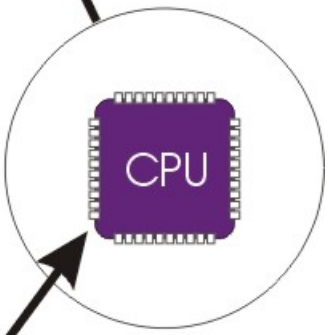
Date	Topics	Reading Assignments	Slides
8/28/17	Introduction	Ch 1.1-1.6	Lec01.pdf
8/30/17	Performance Measurement	Ch 1.8-1.9	Lec02.pdf
9/06/17	Instruction Set Architecture	B.1-B.3, B.4, B.5	Lec03.pdf
9/11/17	Instruction Set Architecture: MIPS1	B.6, B.7, B.9	Lec04.pdf
9/13/17	Instruction Set Architecture: MIPS2		Lec05.pdf
9/18/17	Single-Cycle Processor Implementation1		Lec06.pdf
9/20/17	Single-Cycle Processor Implementation2		Lec07.pdf
9/25/17	Multi-Cycle Processor Implementation 1		Lec08.pdf
9/27/17	Multi-Cycle Processor Implementation 2		Lec09.pdf
10/02/17	Pipeline: Introduction	A.1	Lec10.pdf
10/04/17	Pipeline: Structural Hazards	A.2	Lec11.pdf
10/09/17	Pipeline: Data Hazards	A.3	Lec12.pdf
10/11/17	Pipeline: Branch Prediction	A.3	Lec13.pdf
10/16/17	Exercise Class		Lec14.pdf
10/18/17	Review session for midterm exam	The Study Guide for the Midterm exam	Lec15.pdf
10/23/17	Midterm		
10/25/17	Midterm Summary Session		Lec16.pdf

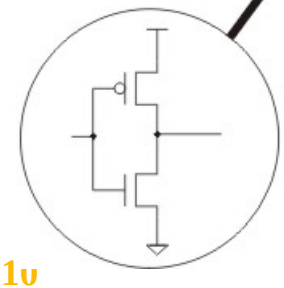
Why We Need to Learn Hardware?

- Always Important
  Every hardware system is different
  Understanding hardware → more efficient algorithms, programs
  (Microsoft developers say so!)
  Understanding hardware → more effective use of OS
  Understanding hardware → more efficient database design
- Timely
  Multicore, hyper-threading, security, . .
- Opens doors
  Yet another option!
  You won't know what you need until you need it
  (and this will probably be after you graduate)

Software and Hardware







Software

Hardware

Application

Algorithm & Data Structure

Language

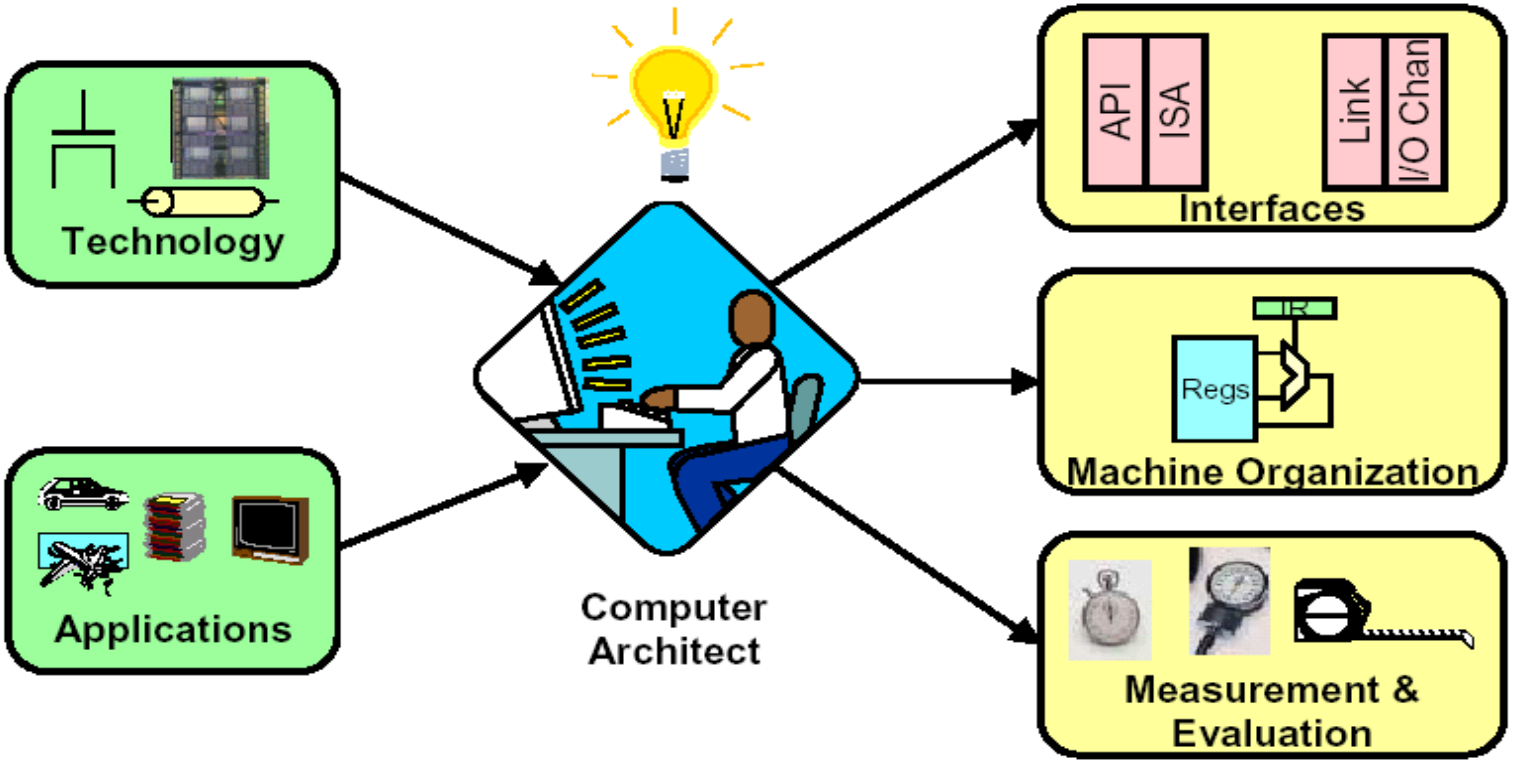
Machine Architecture, ISA (CS572)

Microarchiture

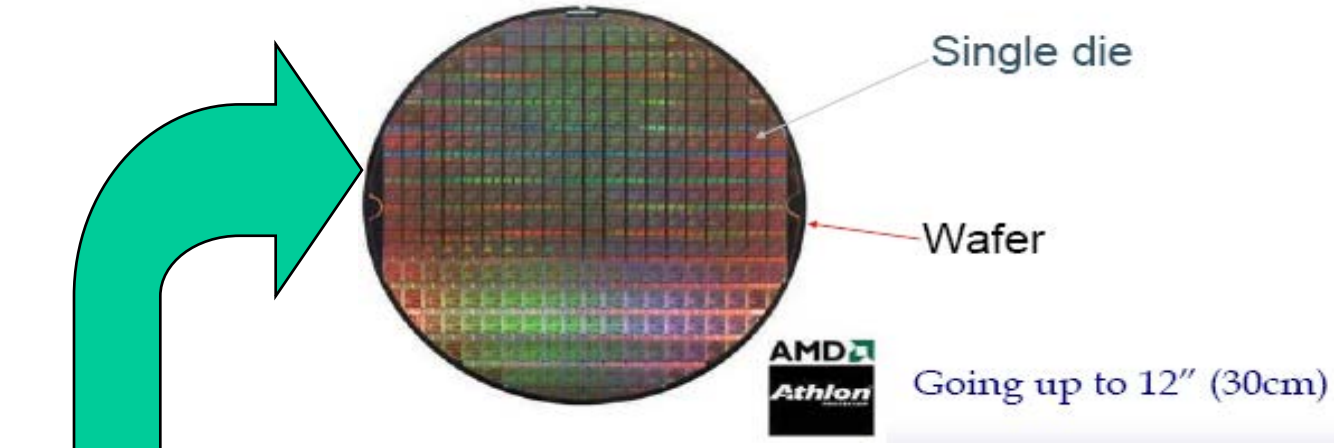
Logic and IC (CS370)

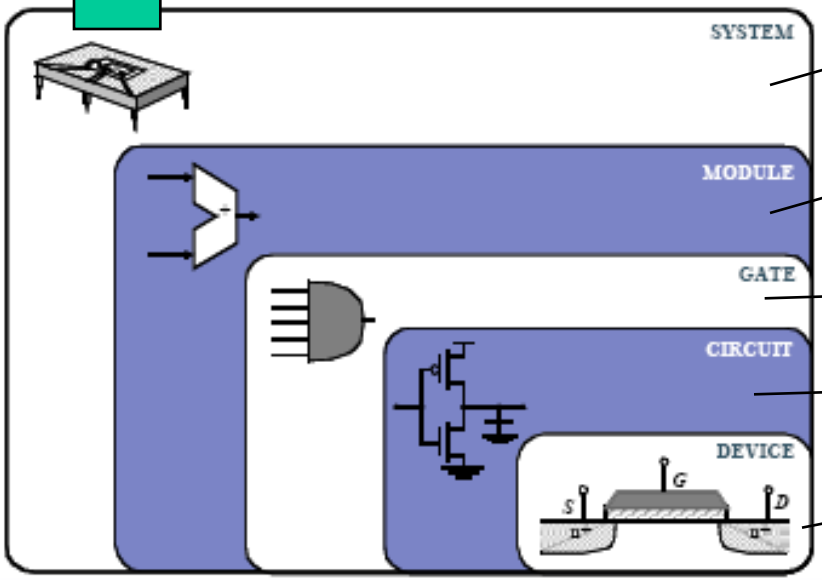
Device

Computer System Design



System, Component, Logic Circuit, IC, Transistor





CPU chip，SOC chip

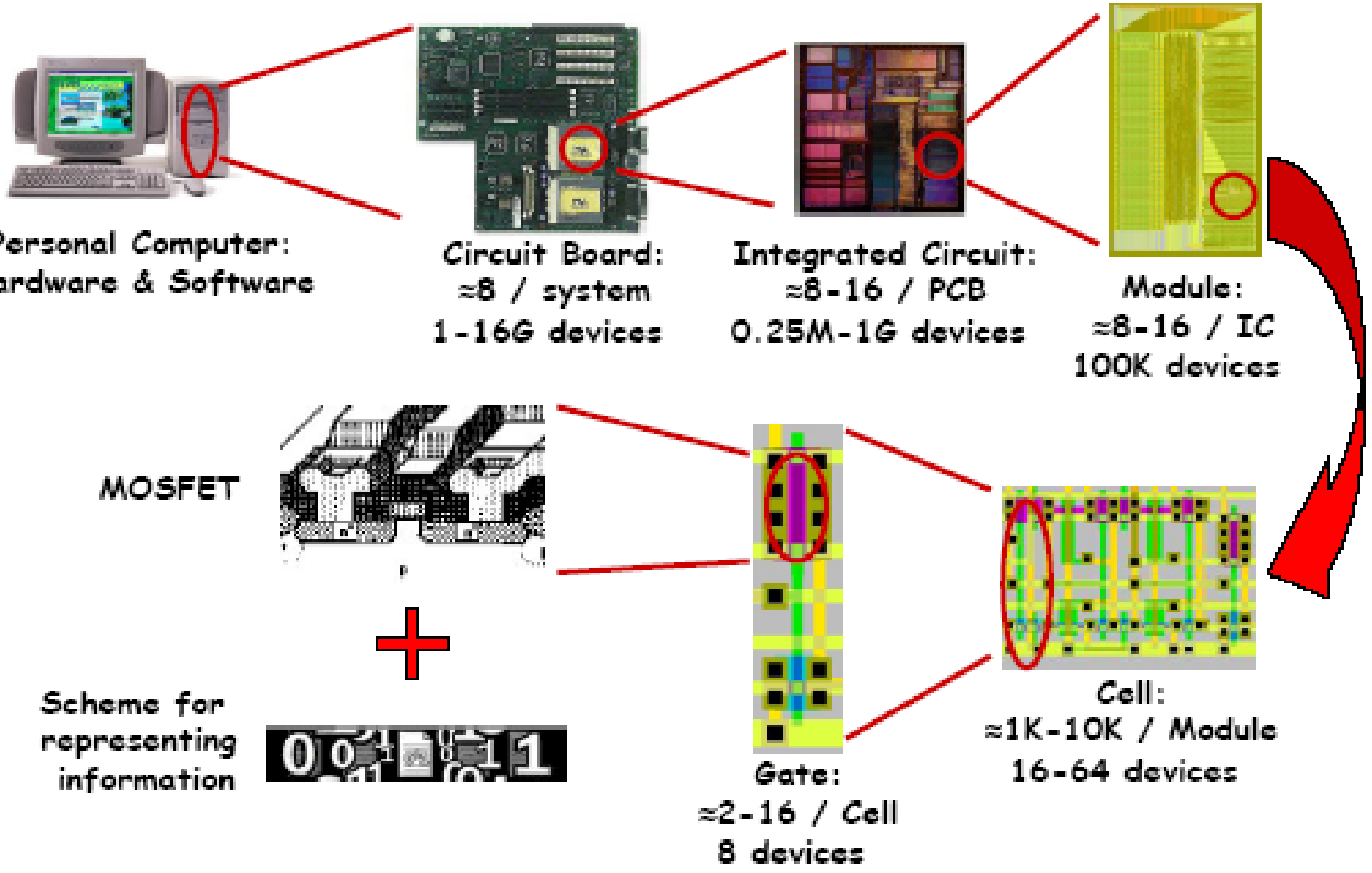
Functional Block（ALU，FPU，…）

Logic Gate（NOT/NAND/NOR。。。）

CMOS

Transistor（MOSFET：PMOS/NMOS）

The Implementation of Computer System



Course Objectives

- To learn the principles behind the design of modern computer systems (e.g., tradeoffs: cost vs. performance, speed vs. flexibility)
- To understand the design of instruction sets
- To learn pipelining techniques
- To understand issues in hierarchical memory system design
- To classify and describe parallel computer architectures
- To demonstrate the ability to program microprocessors in assembly language

Topic Coverage

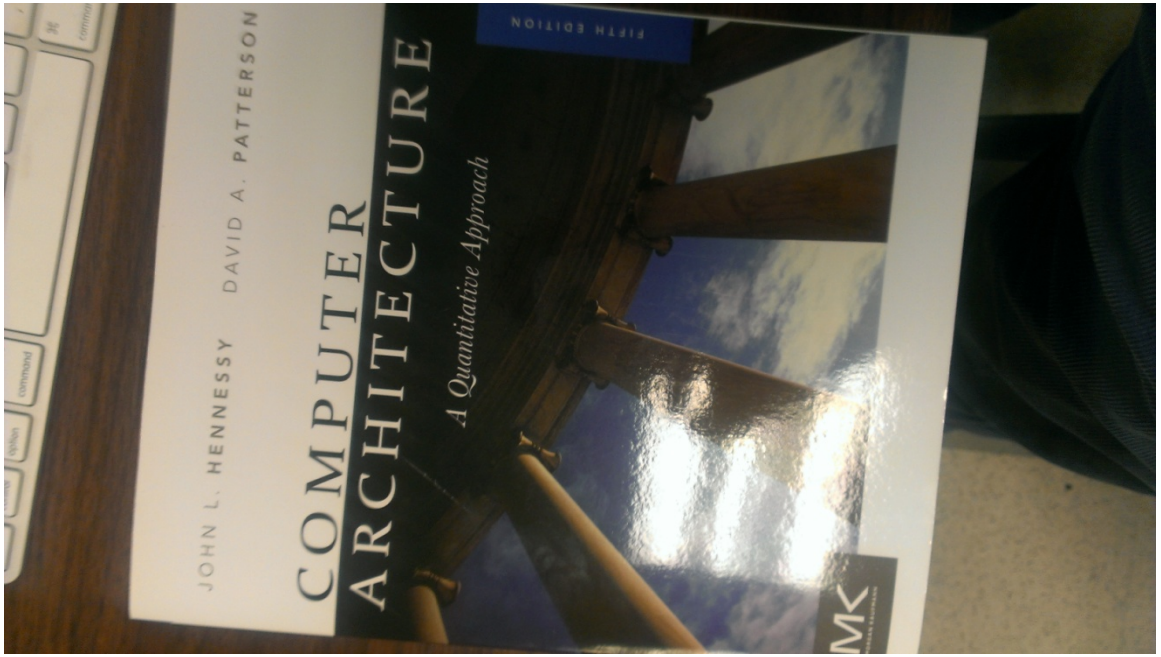
- Textbook: Patterson and Hennessy, Computer Architecture: A Quantitative Approach, 5th Ed., 2012.
- Covers (These topics may change)
  - Basics of machine organization
  - Principles of instruction set design
  - Instruction set principles and examples
  - Pipelining
  - Memory hierarchy design

Course Syllabus

- Prerequisite: CS 370 Computer Architecture
- 3 homework assignments and 3 lab assignments.
  - Homework is due at the **start** of class.
  - Late assignments will **NOT** be accepted without prior arrangement.
- 1 midterm exam and 1 final exam
- Grading
  - Class Participation 5%
  - Quizzes 10%
  - Midterm 20%
  - Final Exam 20%
  - Homework 15%
  - Lab Assignment 30%

Textbook

John Hennessy and David Patterson, "Computer Architecture: A Quantitative Approach" fifth edition, by Morgan Kaufmann, 2012, ISBN: 978-0-12-383872-8



Course Syllabus (cont.)

- **Scale**
  - Letter grades will be awarded based on the following scale.
  - A >= 90 A- >= 86 B+ >= 82 B >= 78 B- >= 74 C+ >= 70 C >= 66 C- >= 62 D+ >= 58 D >= 54 D- >= 50 F < 50
- **Cheating**
  - All assignments have to be done individually.
  - Students may discuss with their friends.
  - Assignments submitted must be yours.
  - Please do not attempt to recycle answers from the Internet (plagiarism).

Office Hours

Office hours: MW 11 am – 12 pm or by appointment at GMCS 535

Grader Office Hours: MW 4 pm – 5 pm at GMCS 557

Laboratory Assignments

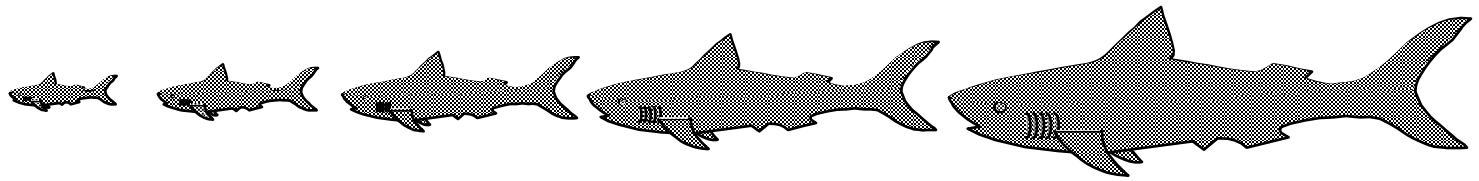
- Three lab assignments (30% of final score)
- Programming languages (C, Java)
- Simulating simple machines
  1. Implement instruction set architectures
  2. Develop single and multi-cycle machines
  3. Design and implement pipelined datapath with interlocks and forwarding

Questions

Please ask at any time!

Technology Trend

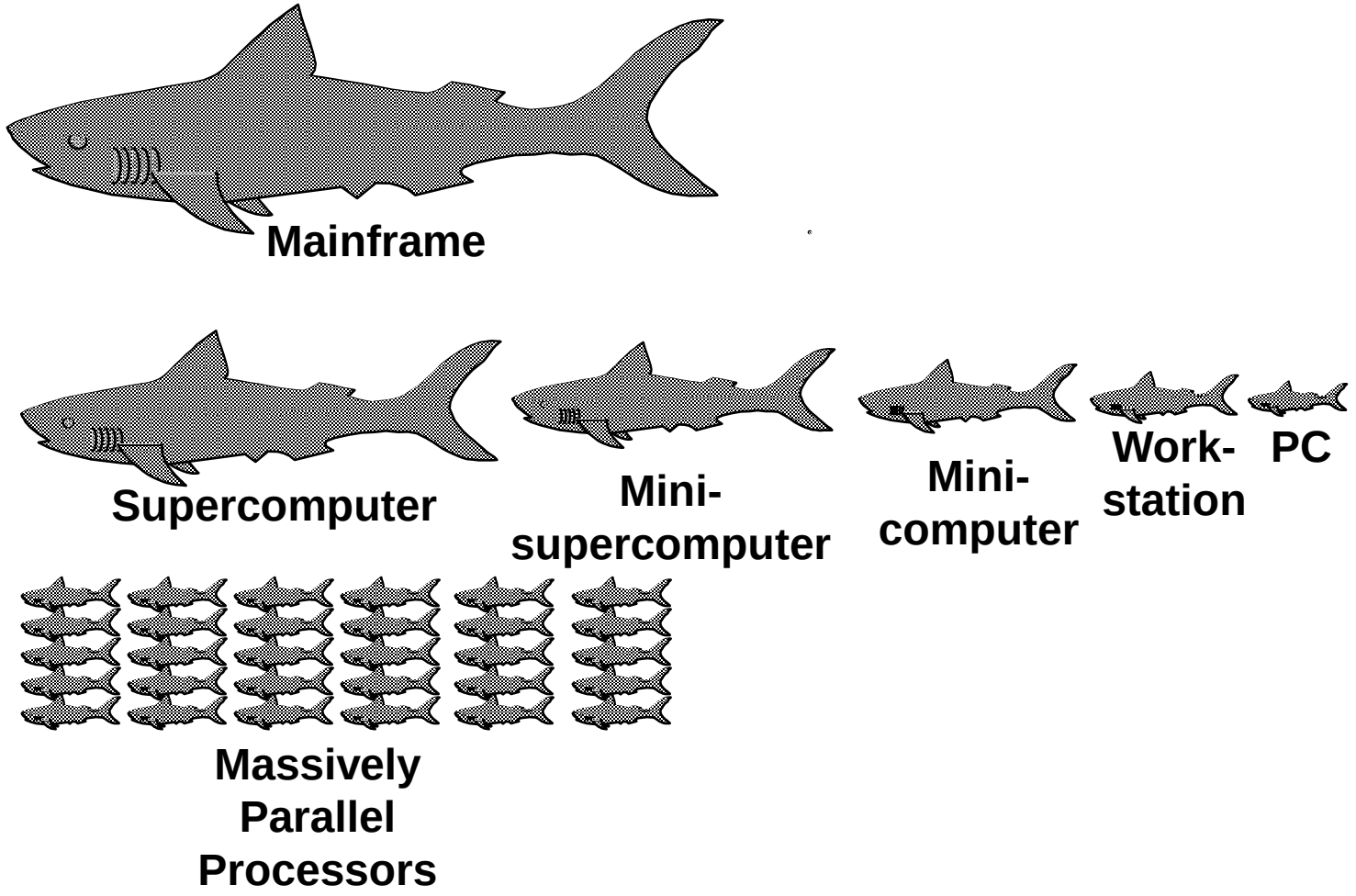
In reality:



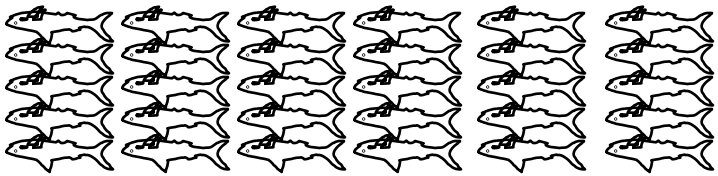
Big Fishes Eating Little Fishes

Technology Trend

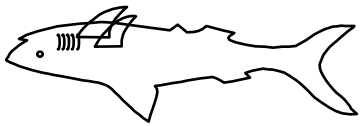
1988 Computer Food Chain



Technology Trend



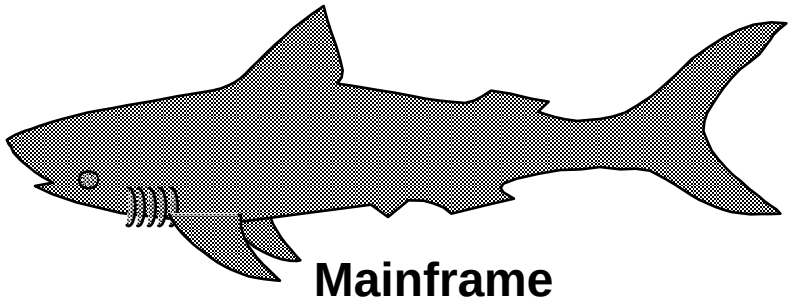
Clusters



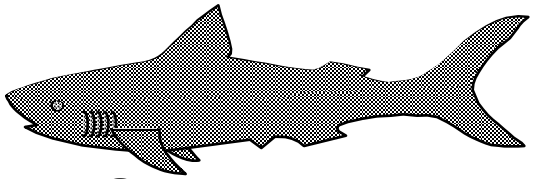
Mini-supercomputer

Mini-computer

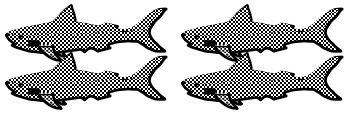
1998 Computer Food Chain



Mainframe



Supercomputer



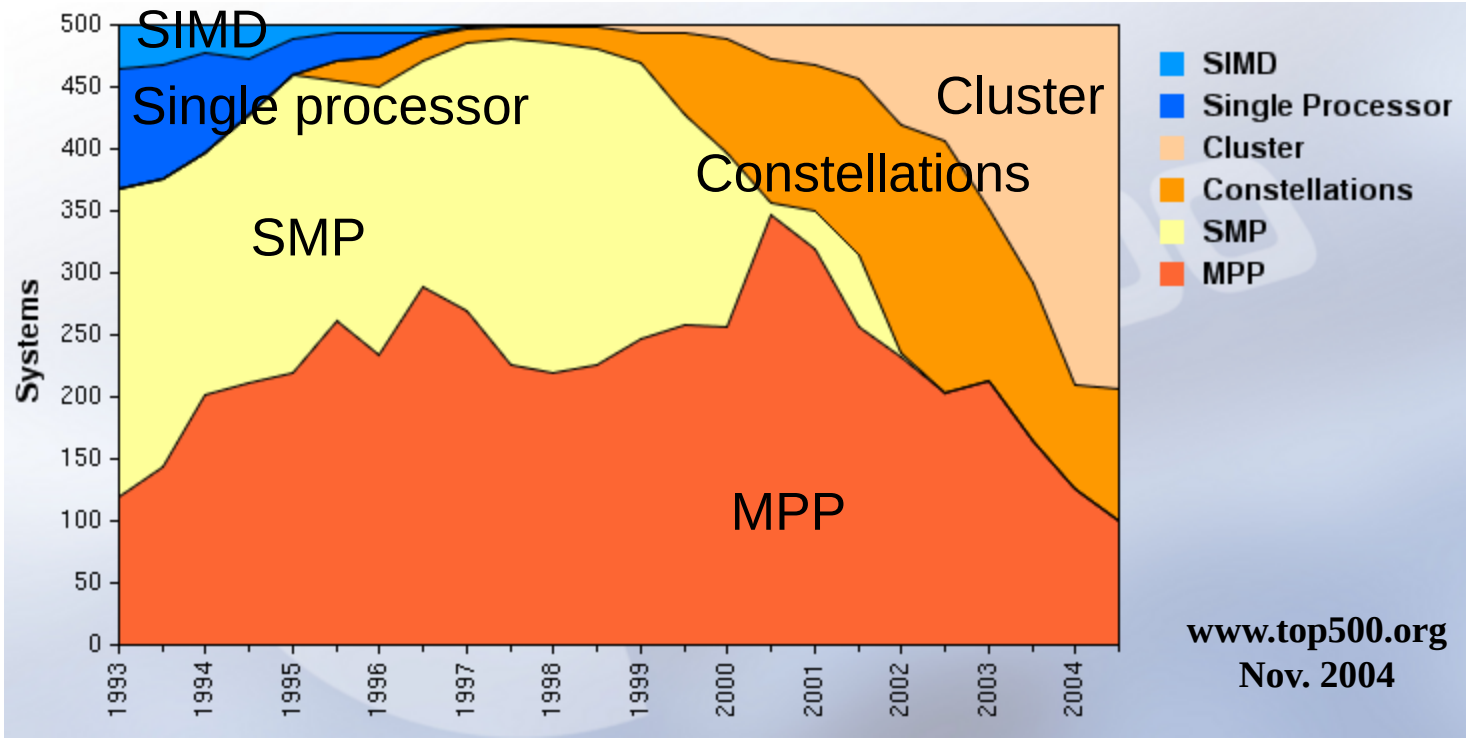
Server

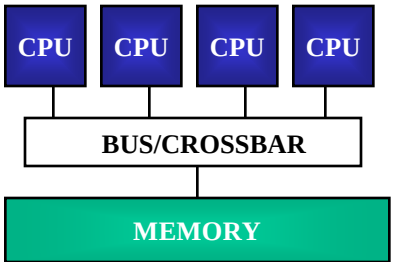
Work-station

PC

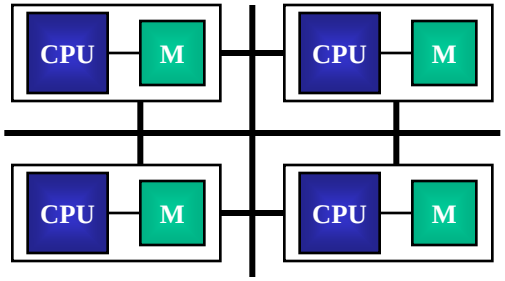
Now who is eating whom?

Supercomputer Trends in Top 500

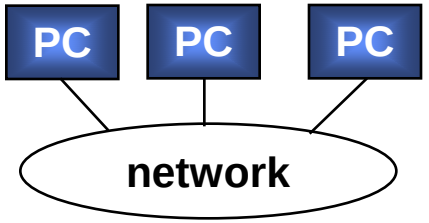




Symmetric Multiprocessing (SMP)



Massively Parallel Processor (MPP)

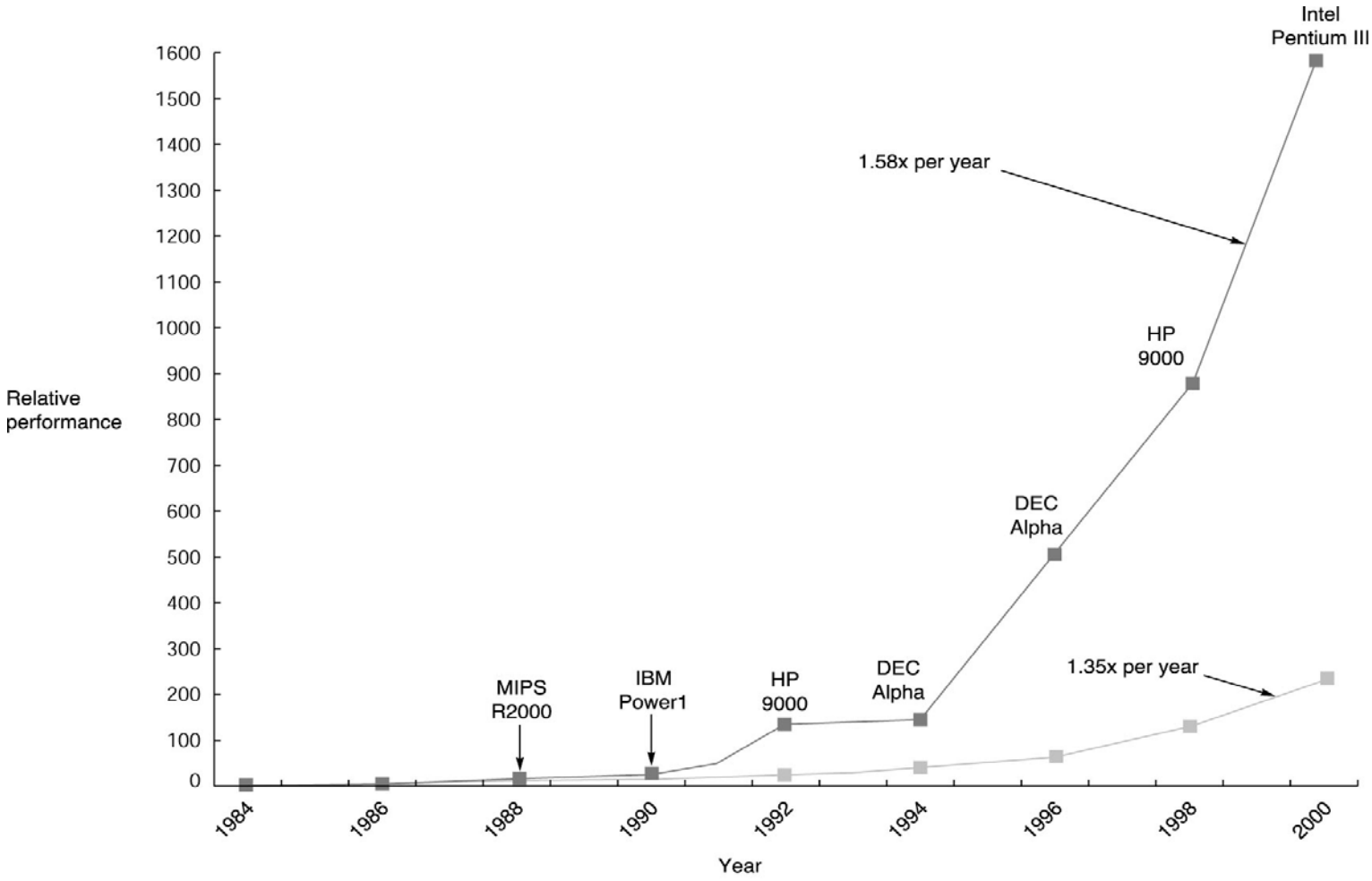


cluster

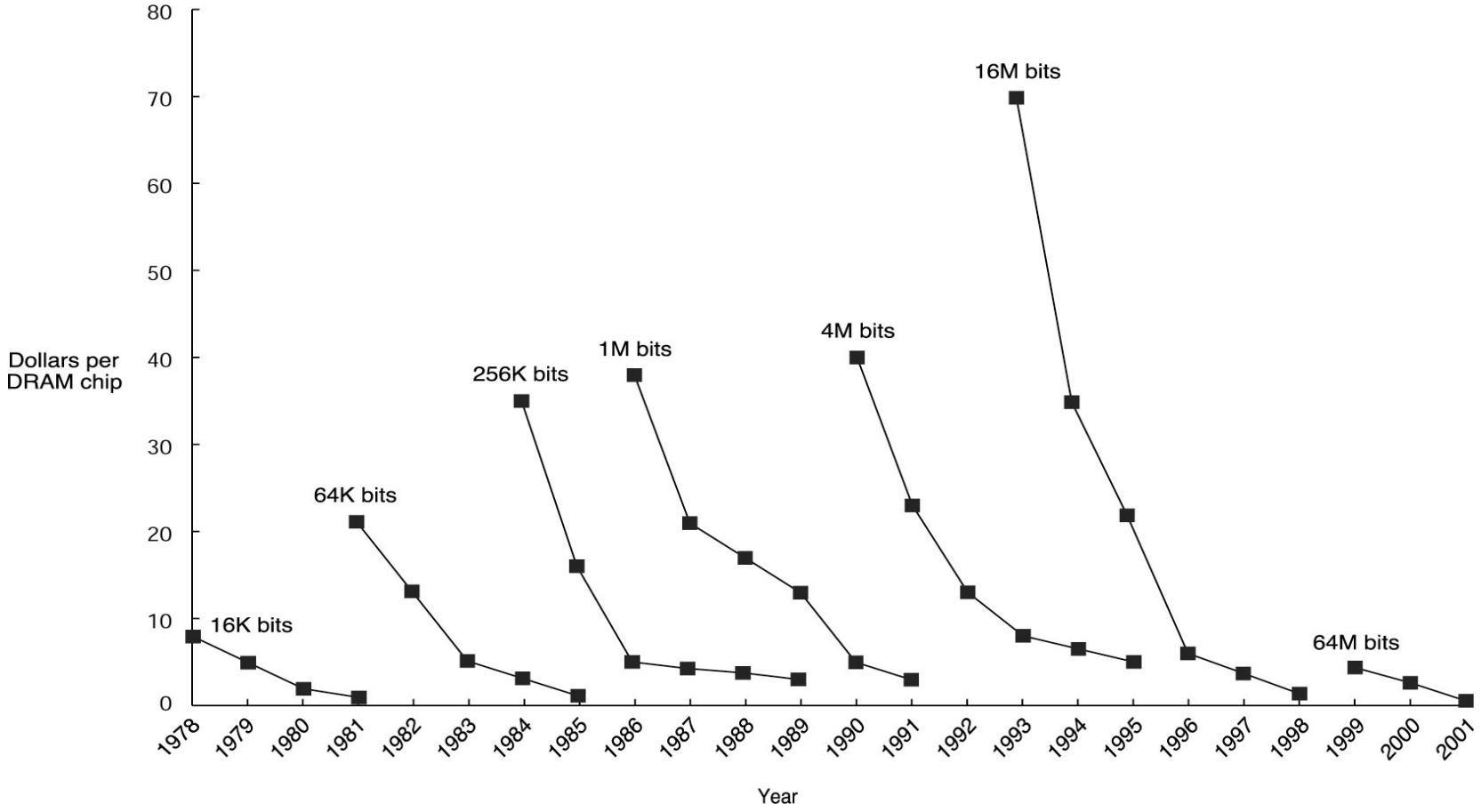
Why Such Changes in 10 years?

- Performance
  - Technology Advances
    - CMOS VLSI dominates older technologies in cost and performance
  - Computer architecture advances improves low-end
    - RISC, superscalar, RAID, …
- Cost: Lower costs due to …
  - Simpler development
    - CMOS VLSI: smaller systems, fewer components
  - Higher volumes
    - CMOS VLSI : same dev. cost 10,000 vs. 10,000,000 units
  - Lower margins by class of computer, due to fewer services
- Function
  - Rise of networking/local interconnection technology

Growth in Microprocessor Performance



Six Generations of DRAMs



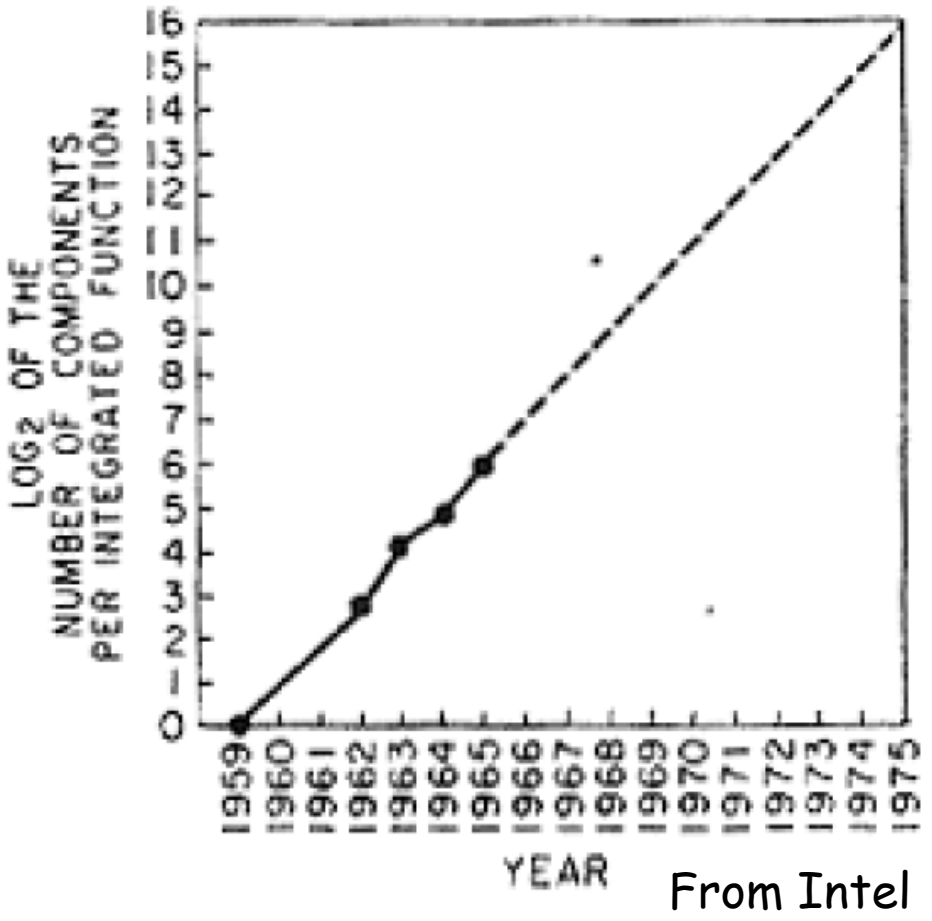
Technology ⇒ dramatic change

- Processor
  - transistor number in a chip: about 55% per year
  - clock rate: about 20% per year
- Memory
  - DRAM capacity: about 60% per year
  - Memory speed: about 10% per year
  - Cost per bit: improves about 25% per year
- Disk
  - capacity: about 60% per year
  - Total use of data: 100% per 9 months!
- Network Bandwidth
  - 10 years: 10Mb → 100Mb
  - 5 years: 100Mb → 1 Gb

Updated Technology Trends (Summary)

	Capacity	Speed (latency)
Logic	**4x in 4 years**	**2x in 3 years**
DRAM	**4x in 3 years**	**2x in 10 years**
Disk	**4x in 2 years**	**2x in 10 years**
Network	**(bandwidth) 10x in 5 years**	

Amazing Underlying Technology Change



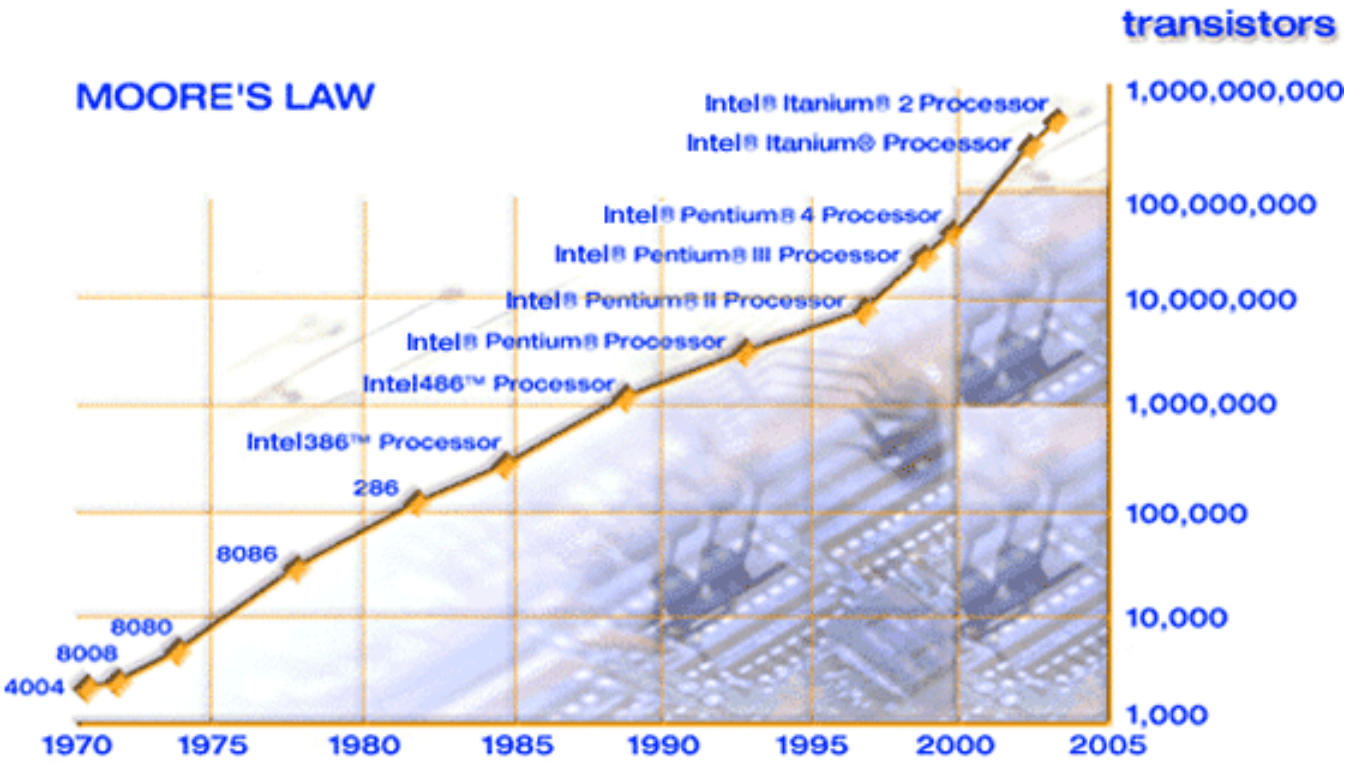
- **In 1965, Gordon Moore sketched out his prediction of the pace of silicon technology.**

- **Moore's Law: The number of transistors incorporated in a chip will approximately double every 24 months.**

- **Decades later, Moore's Law remains true.**

Technology Trends: Moore's Law

- Gordon Moore observed in 1965 that the number of transistors on a chip doubles about every 24 months.
- In fact, the number of transistors on a chip doubles about every 18 months.



From Intel

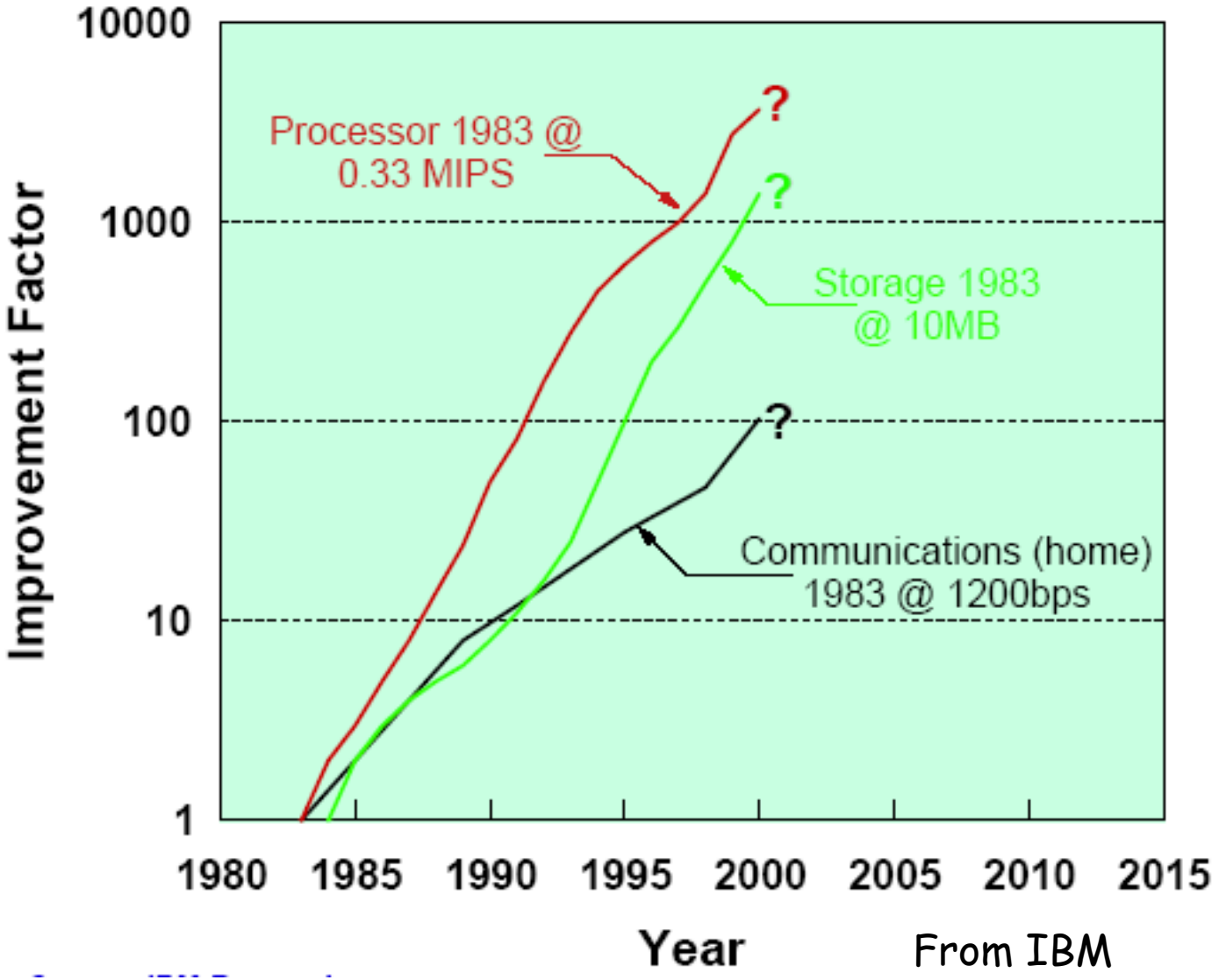
Why Study Computer Architecture

- Aren't they fast enough already?
  - Are they?
  - Fast enough to do everything we will EVER want?
    - Protein sequencing, computational materials, graphics

Answer: Requirements are always changing

Understand where computers are going

Technology ⇒ dramatic change



From IBM

Why Study Computer Architecture (cont.)

Based on SPEED, the CPU has increased dramatically, but memory and disk have increased only a little. This has led to dramatic changed in architecture, Operating Systems, and programming practices.

Answer: Technology playing field is always changing

Understand hardware for software tuning

Why Study Computer Architecture (cont.)

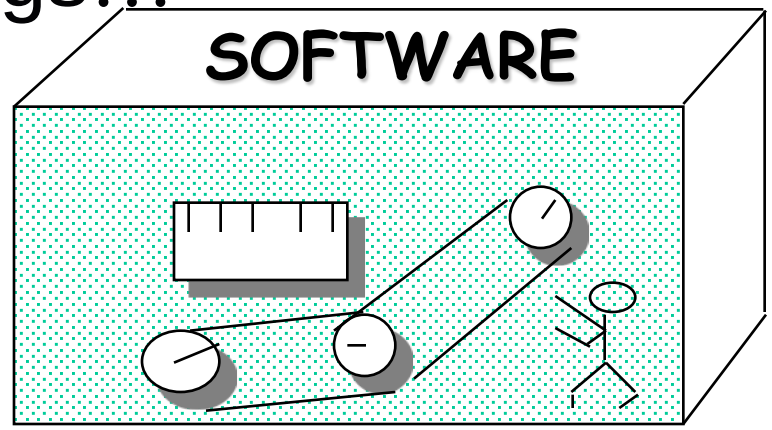
- Is speed the only goal?
  - Power: heat dissipation + battery life
  - Cost
  - Reliability
  - Etc.

Exposure to high-level design

- Get a job (design or research)

What is Computer Architecture ?

- The science and art of selecting and interconnecting hardware components to create computers that meet functional, performance and cost goals.
- An analogy to architecture of buildings…



For Next Time…

1. Read Chapter 1 - Fundamentals of Computer Design

2. Please show me your transcript of CS 370 or equivalent in our next class (Aug. 30, Wednesday).