

# CS6L047: Advanced Computer Architecture

## Introduction

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# Welcome to ACA!

# Class Introductions

- Name
- What do you hope to gain from this class?

# About me

- **Assistant Professor**, Computer Science, IIT BBS | 2022 - current
- **Postdoc | Associate**, Harvard University, MA, USA | 2021 - current
- **Ph.D**, University Of California, Riverside (UCR), CA, USA '21
  - **Dean's Distinguished Fellowship**
- **M.Tech**, CSIR-CEERI, Pilani '14
  - **Quick-Hire Fellowship by Government of India, CSIR.**
- **B.Tech**, VSSUT, BURLA '12
  - **University Topper**

# My PhD School WORLD Ranking # 5

## CSRankings: Computer Science Rankings



CSRankings is a metrics-based ranking of top computer science institutions around the world. Click on a triangle (▶) to expand areas or institutions. Click on a name to go to a faculty member's home page. Click on a chart icon (the bar chart icon after a name or institution) to see the distribution of their publication areas as a bar chart. Click on a Google Scholar icon (✉) to see publications, and click on the DBLP logo (✉) to go to a DBLP entry. Applying to grad school? Read this first. Do you find CSRankings useful? Sponsor CSRankings on GitHub.

Rank institutions in  by publications from  to

### All Areas [off | on]

#### AI [off | on]

- ▶ Artificial intelligence
- ▶ Computer vision
- ▶ Machine learning & data mining
- ▶ Natural language processing
- ▶ The Web & information retrieval

#### Systems [off | on]

- ▶ Computer architecture
- ▶ Computer networks
- ▶ Computer security
- ▶ Databases
- ▶ Design automation
- ▶ Embedded & real-time systems
- ▶ High-performance computing
- ▶ Mobile computing

#	INSTITUTION	COUNT	FACULTY
1	▶ Univ. of Illinois at Urbana-Champaign	17.7	29
2	▶ Georgia Institute of Technology	13.6	19
3	▶ ETH Zurich	11.3	6
4	▶ North Carolina State University	11.2	9
5	▶ Univ. of California - Riverside	9.9	11
6	▶ University of Michigan	9.5	21
7	▶ University of Chicago	8.7	12
8	▶ Tsinghua University	7.2	15
9	▶ University of Utah	6.3	14
10	▶ University of Wisconsin - Madison	6.2	16
11	▶ Shanghai Jiao Tong University	6.1	14
12	▶ Purdue University	5.9	12
13	▶ Pennsylvania State University	5.8	14

# Why Computer Architecture?

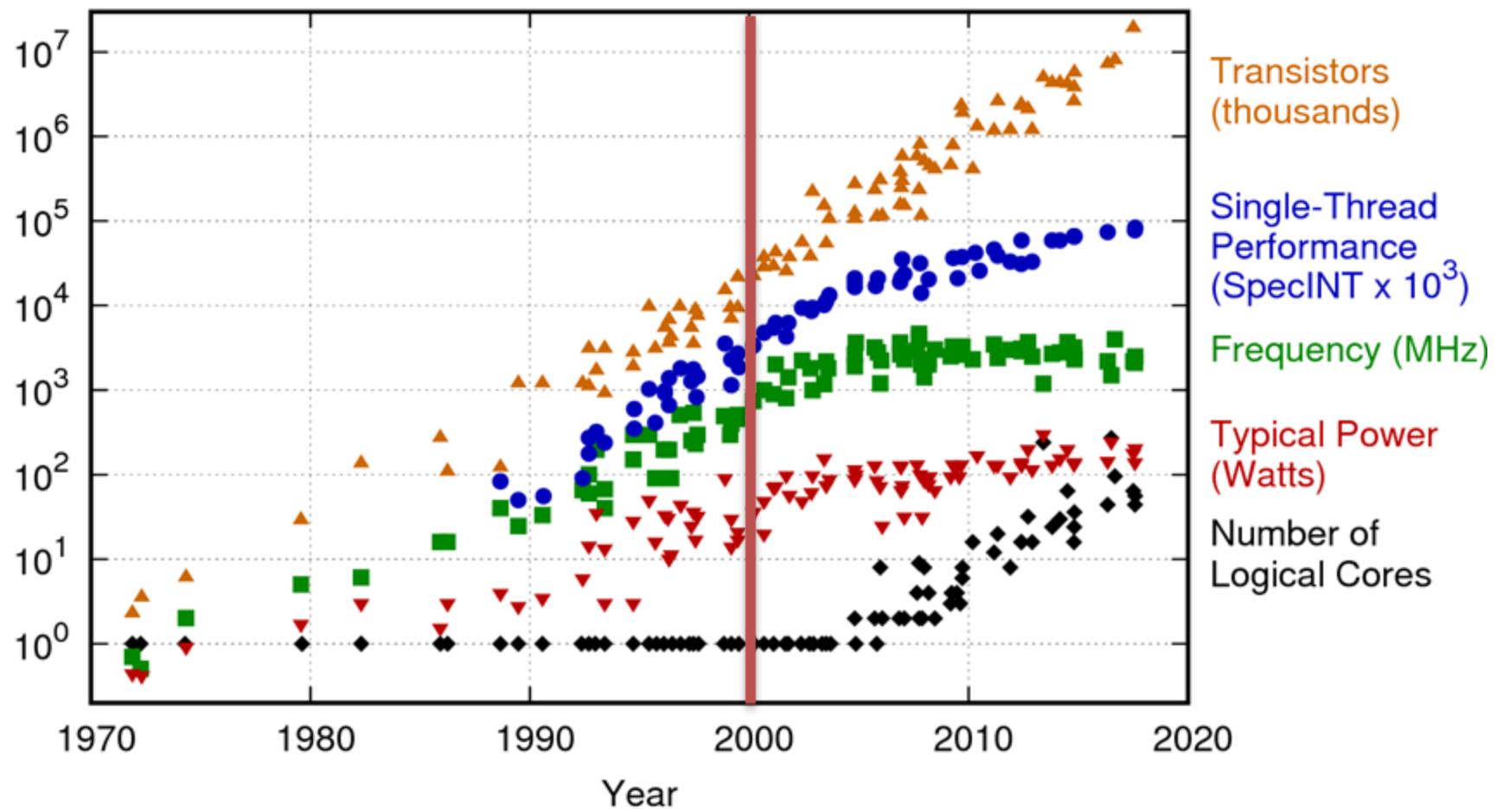


**Lawrence Livermore  
National Laboratory**

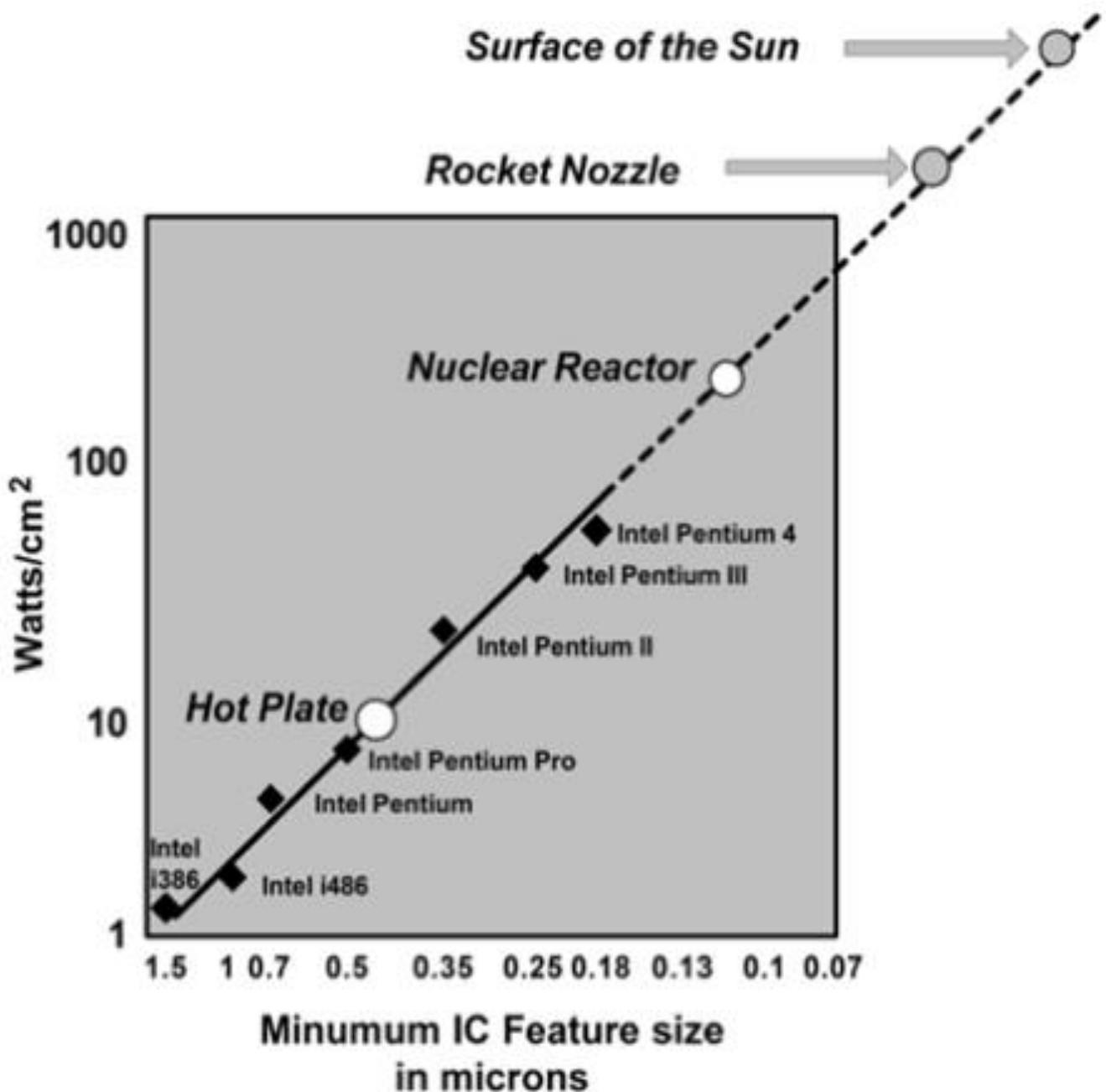


# How does Computer Architecture impact you?

## 42 Years of Microprocessor Trend Data

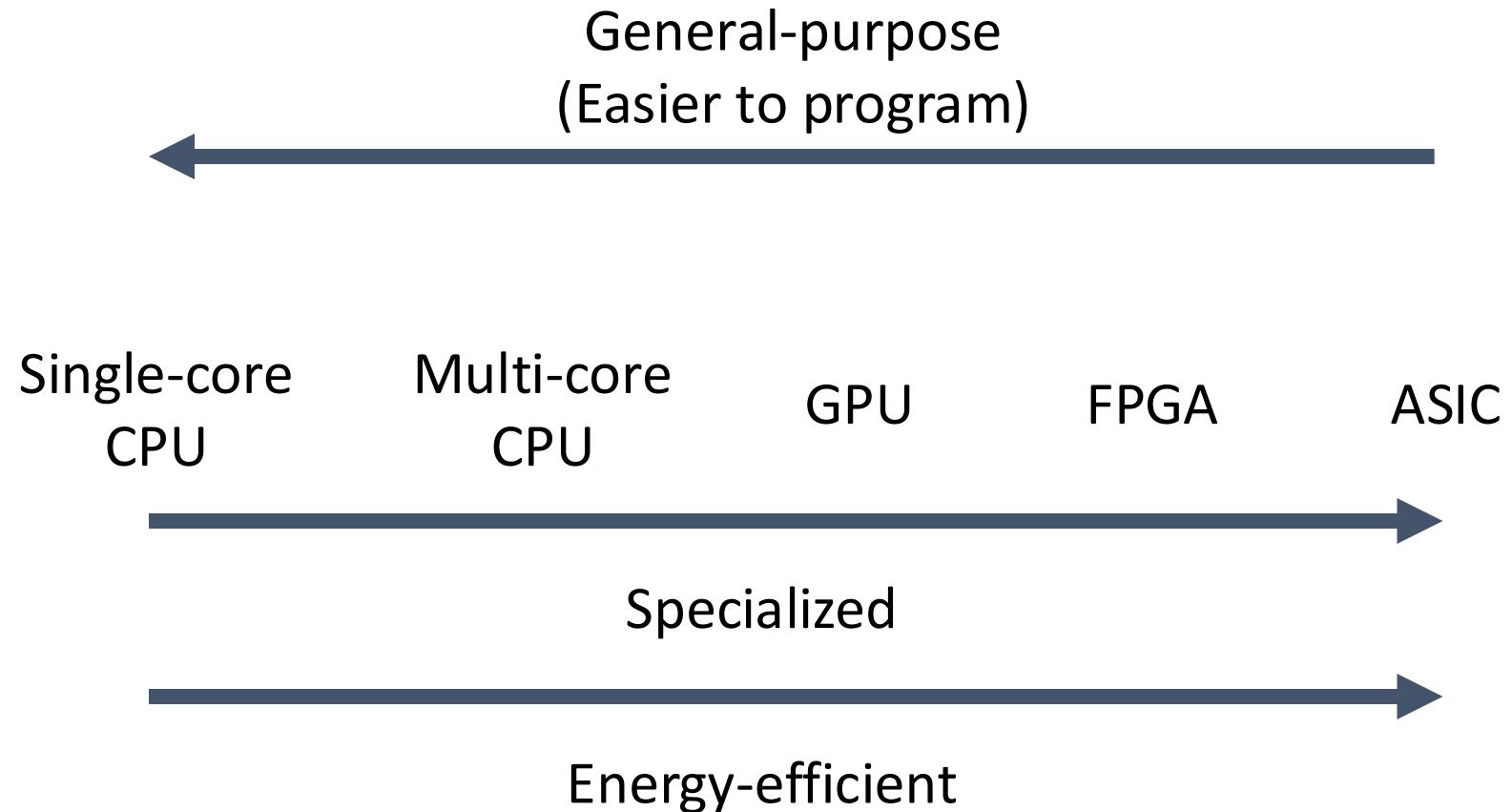


Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten  
New plot and data collected for 2010-2017 by K. Rupp



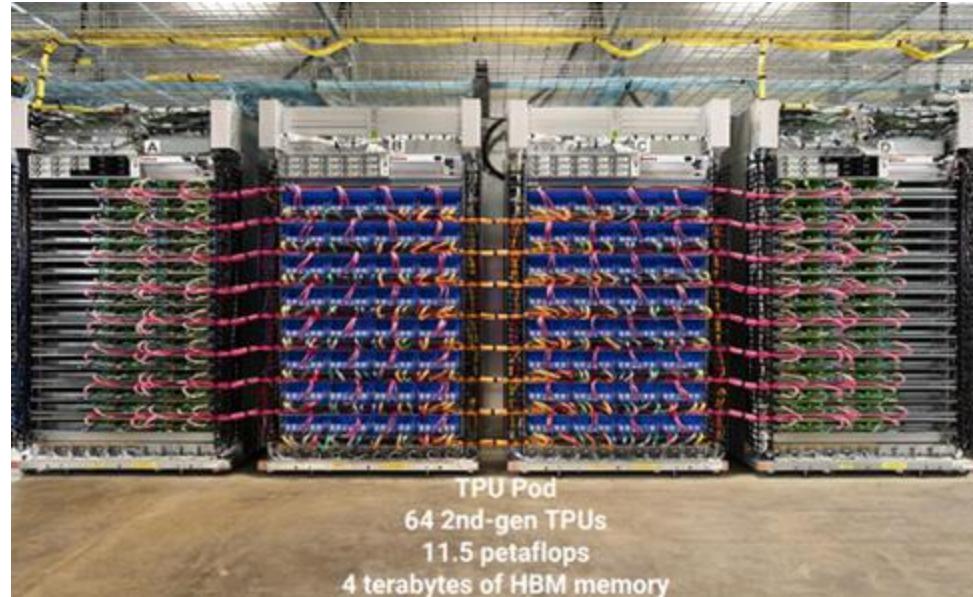
Modern computer architecture is limited by:

- Process Technology / Transistor density  
(End of Moore's Law)
- Power  
(End of Dennard Scaling)
- Temperature



# Examples of Specialization

## Google TPU - Tensor Processing Unit



# Examples of Specialization

## GPUs - Supercomputers



Rank	Site	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	DOE/SC/Oak Ridge National Laboratory United States	Summit - IBM Power System AC922, IBM POWER9 22C 3.07GHz, <b>NVIDIA Volta GV100</b> , Dual-rail Mellanox EDR Infiniband IBM	2,282,544	122,300.0	187,659.3	8,806
2	National Supercomputing Center in Wuxi China	Sunway TaihuLight - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway NRCPC	10,649,600	93,014.6	125,435.9	15,371
3	DOE/NNSA/LLNL United States	Sierra - IBM Power System S922LC, IBM POWER9 22C 3.1GHz, <b>NVIDIA Volta GV100</b> , Dual-rail Mellanox EDR Infiniband IBM	1,572,480	71,610.0	119,193.6	
4	National Super Computer Center in Guangzhou China	Tianhe-2A - TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000 NUDT	4,981,760	61,444.5	100,678.7	18,482
5	National Institute of Advanced Industrial Science and Technology (AIST) Japan	AI Bridging Cloud Infrastructure (ABCi) - PRIMERGY CX2550 M4, Xeon Gold 6148 20C 2.4GHz, <b>NVIDIA Tesla V100 SXM2</b> , Infiniband EDR Fujitsu	391,680	19,880.0	32,576.6	1,649
6	Swiss National Supercomputing Centre (CSCS) Switzerland	Piz Daint - Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect, <b>NVIDIA Tesla P100</b> Cray Inc.	361,760	19,590.0	25,326.3	2,272
7	DOE/SC/Oak Ridge National Laboratory United States	Titan - Cray XK7, Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, <b>NVIDIA K20x</b> Cray Inc.	560,640	17,590.0	27,112.5	8,209
8	DOE/NNSA/LLNL United States	Sequoia - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM	1,572,864	17,173.2	20,132.7	7,890

# CS6L047: ACA Goal

- Introduction to Computer Architecture
  - Familiarity with processor components (pipeline, caches, registers, etc. )
  - Provide foundation for further comp arch courses
    - Parallel Processing Architectures
    - Seminars in CS/ECE/EE on special topics
    - GPU Architecture and Parallel Programming
- Learning by doing

# Topics Covered

Prerequisite: Computer Architecture and Organization (CS3L002)

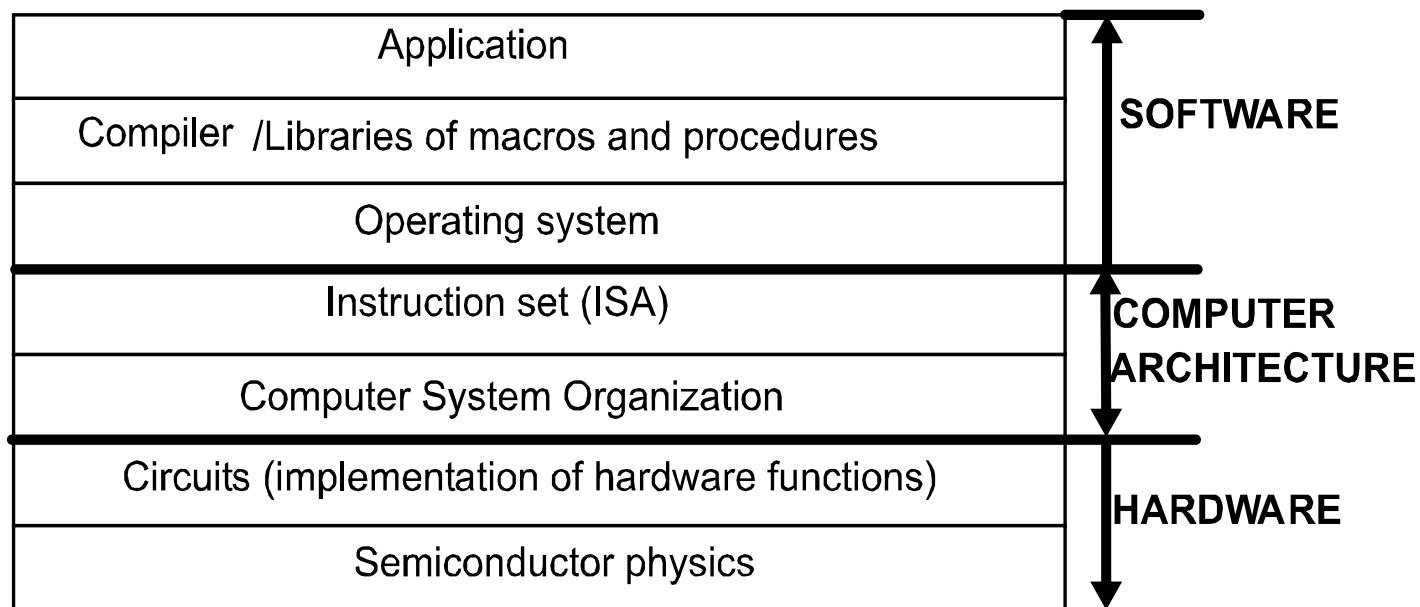
- Background
  - Quantifying Performance, Technology Trends, ...
- Pipelining
  - 5-stage pipeline
- Instruction Level Parallelism
  - Dynamic scheduling, Branch prediction
- Memory hierarchy
  - Memory, Cache, Virtual Memory
- Parallelism
  - Multi-threading, Vector, GPU

# Why learn Comp Arch?

- Computer Architecture is the glue that binds software and hardware
  - Inter-disciplinary in nature
  - Devices, Circuits, OS, Runtime, PL, Compilers
- Advancement of computer architecture is vital to all other areas of computing
  - IoT, Embedded
  - Mobile
  - Data centers, HPC

# What is Computer Architecture?

- Hardware organization of computers
  - how to build computers
- Layered view of computer systems



- Role of the computer architect:
  - To make design trade-offs across the hw/sw interface to meet functional, performance and cost requirements

# Textbook

- (Required) Computer Architecture: A Quantitative Approach, 6th Edition  
By Hennessy and Patterson
  - Ebook:  
[http://acs.pub.ro/~cpop/SMPA/Computer%20Architecture,%20Sixth%20Edition\\_%20A%20Quantitative%20Approach%20\(%20PDFDrive%20\).pdf](http://acs.pub.ro/~cpop/SMPA/Computer%20Architecture,%20Sixth%20Edition_%20A%20Quantitative%20Approach%20(%20PDFDrive%20).pdf)

# Grading Policy

- End Sem
- Mid Sem
- Reading Assignments
- Attendance
  - 100% attendance expected.
  - You are responsible for keeping up with course lectures and reading assignments.

# Google Classroom for official communication

- You can use this workspace ([Google Classroom Code: twtrrtd4](#)) to find lecture slides or project groups. We also encourage you to use it if you run into issues or questions on the course, so that both the course staff and other students can chime in with help and suggestions.

# Contact

- Instructor: Dr. Devashree Tripathy
  - Email: devashreetripathy@iitbbs.ac.in
  - Homepage: <https://devashreetrip.github.io/>
  - Office: SES A-207
- TA coordinator
  - Jyotirman Behera: **a25cs09003@iitbbs.ac.in**
- Other TAs
  - Renuka Acharya: **a23cs09005@iitbbs.ac.in** [lab only]

# Contact

Please always start the subject line with " CS6L047 :<rest of the message>". Otherwise, your message may be lost in my inbox's black hole. This will assist me in keeping track of your communications, and I will do my best to respond promptly.

Please also cc the TAs:

Jyotirman Behera **a25cs09003** [@iitbbs.ac.in](mailto:@iitbbs.ac.in)

More TAs will be added next week.

# Questions?