# Where Do We Go From Here?

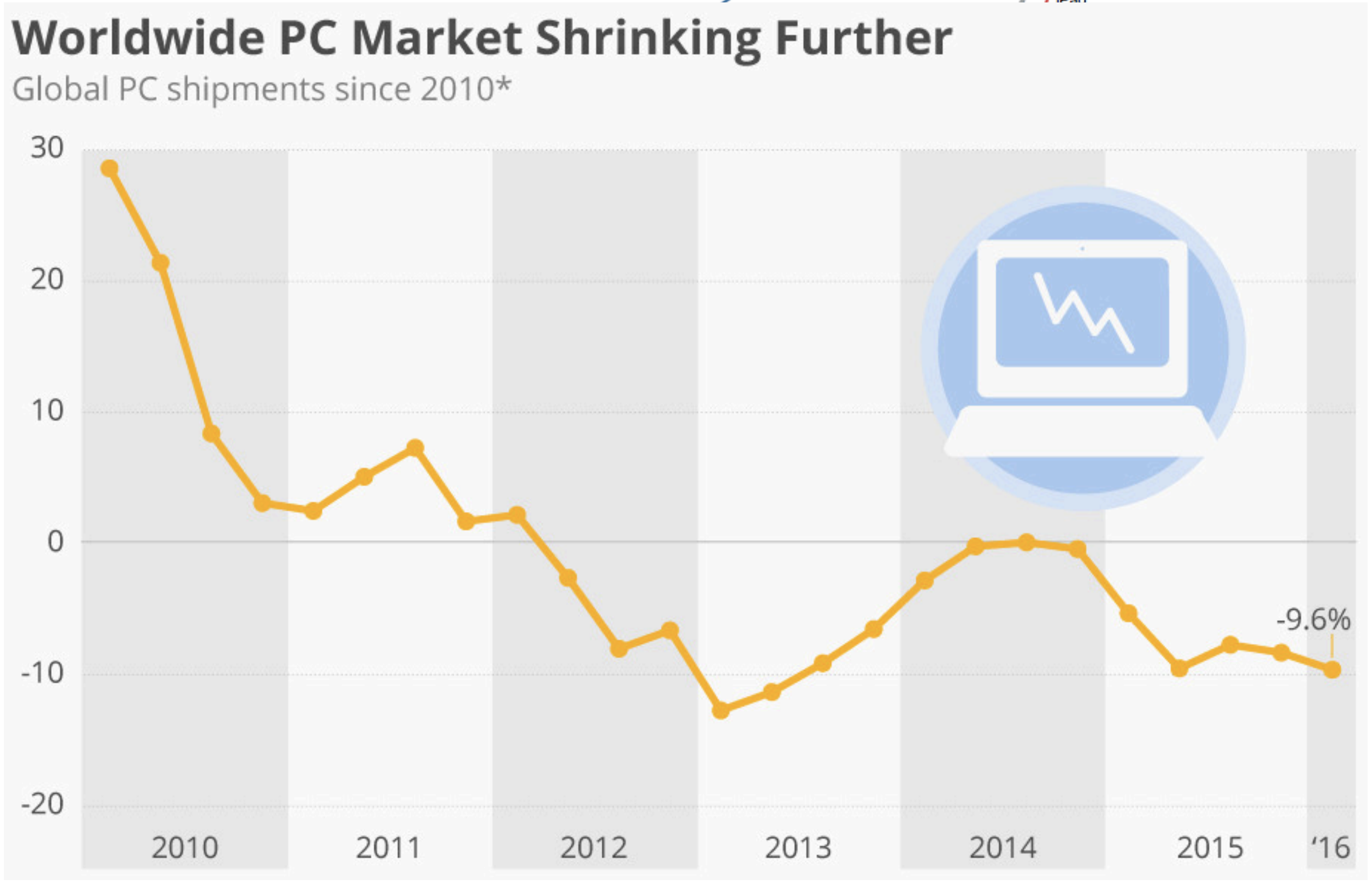
## Administrivia

- Next week:
  - Monday: Fun lecture on the "securing C" arms race
  - Wednesday & Friday: Review sessions
- 5/9: 3-6 PM, location still TBD
  - Those of you on DSP accommodations contact Stephen and Rebecca

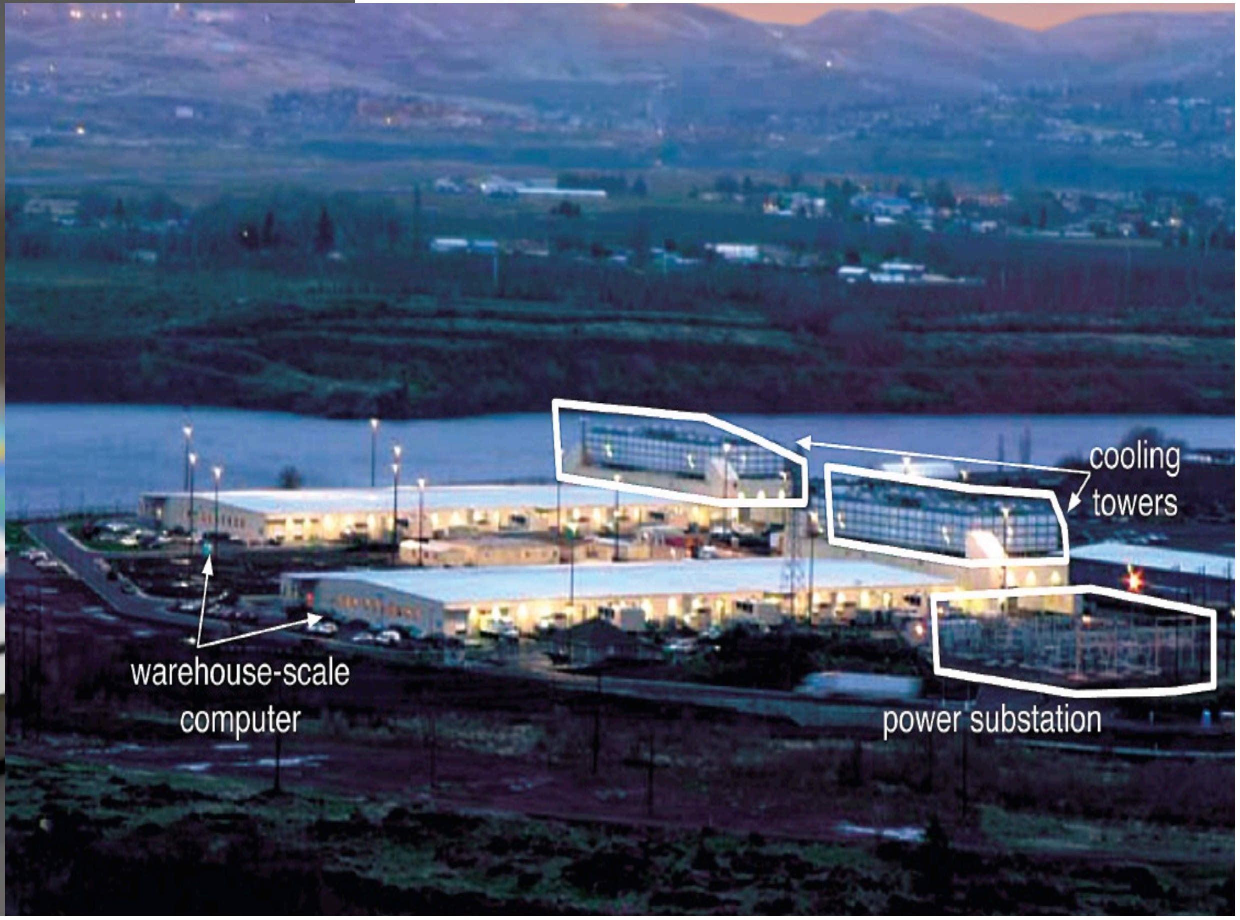
## Where Do We Go From Here?

- A Review of the Class
- A Map of the Future

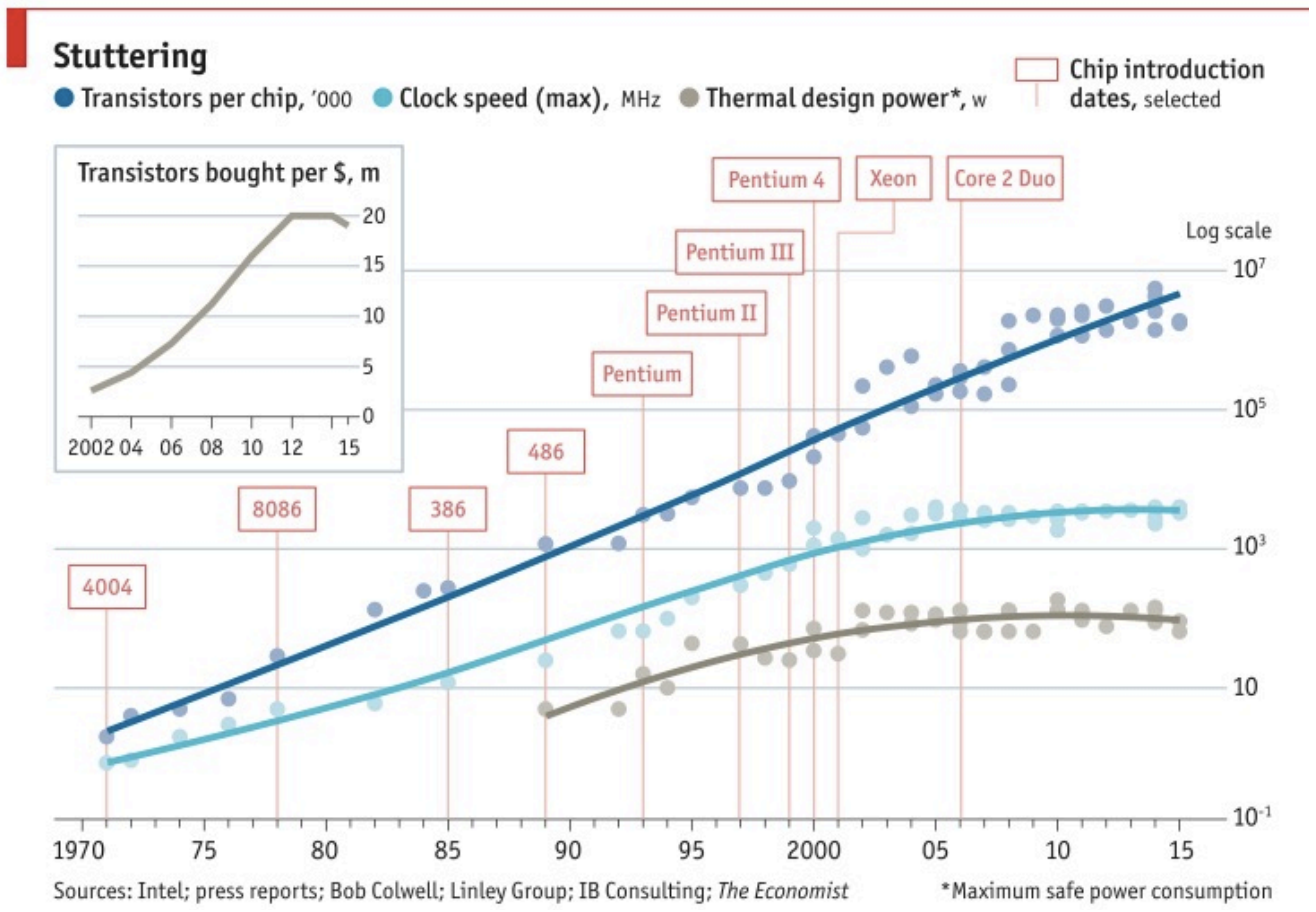
Units Shipped Per Year
1000000
© asymco.com
100000
PC
Android
iPhone
iPad


Worldwide PC Market Shrinking Further
Global PC shipments since 2010*
30
20
10
0
-10
-20
-9.6%
2010
2011
2012
2013
2014
2015
'16

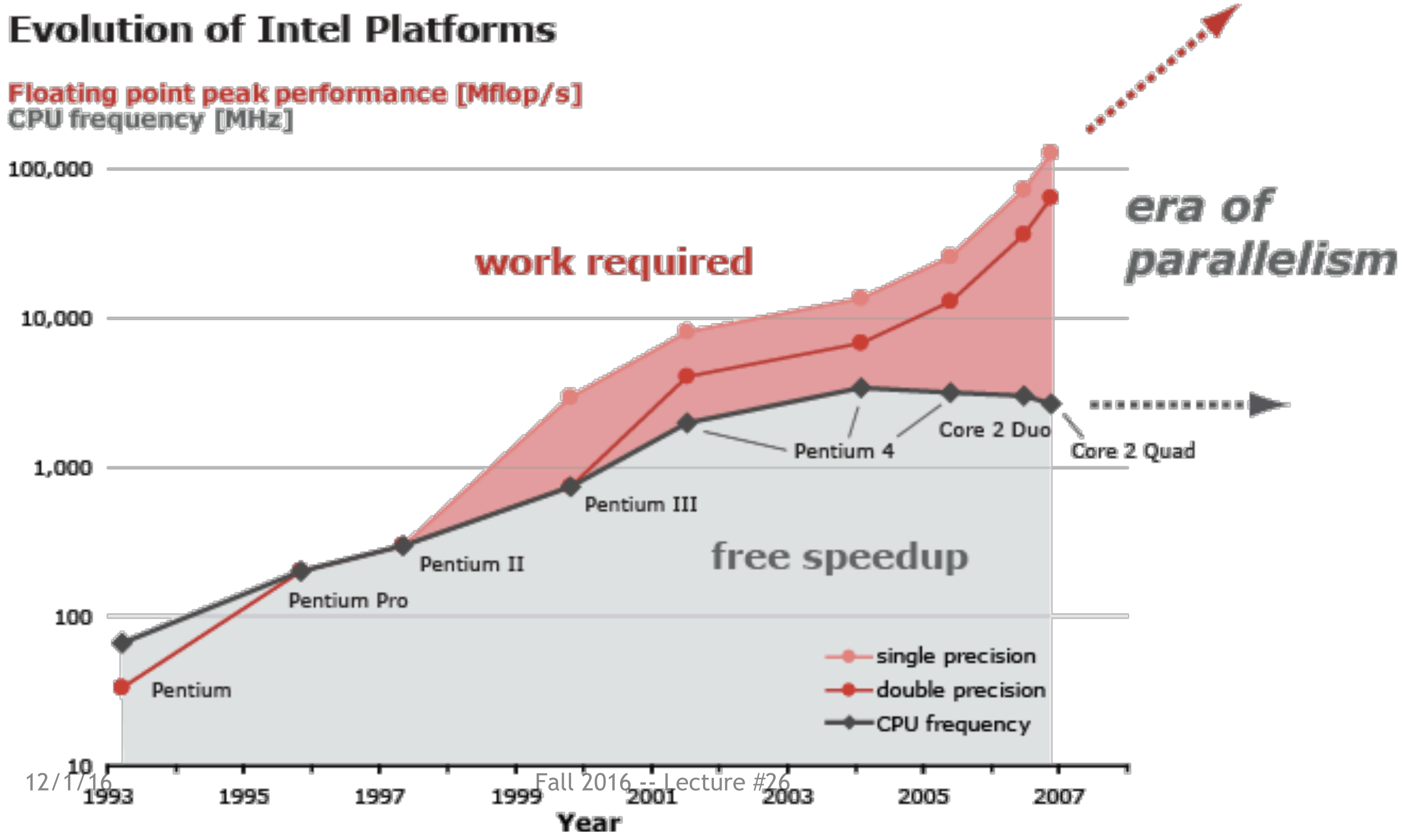
## Current 61C:
## The Same Concepts Over a Mass Scale



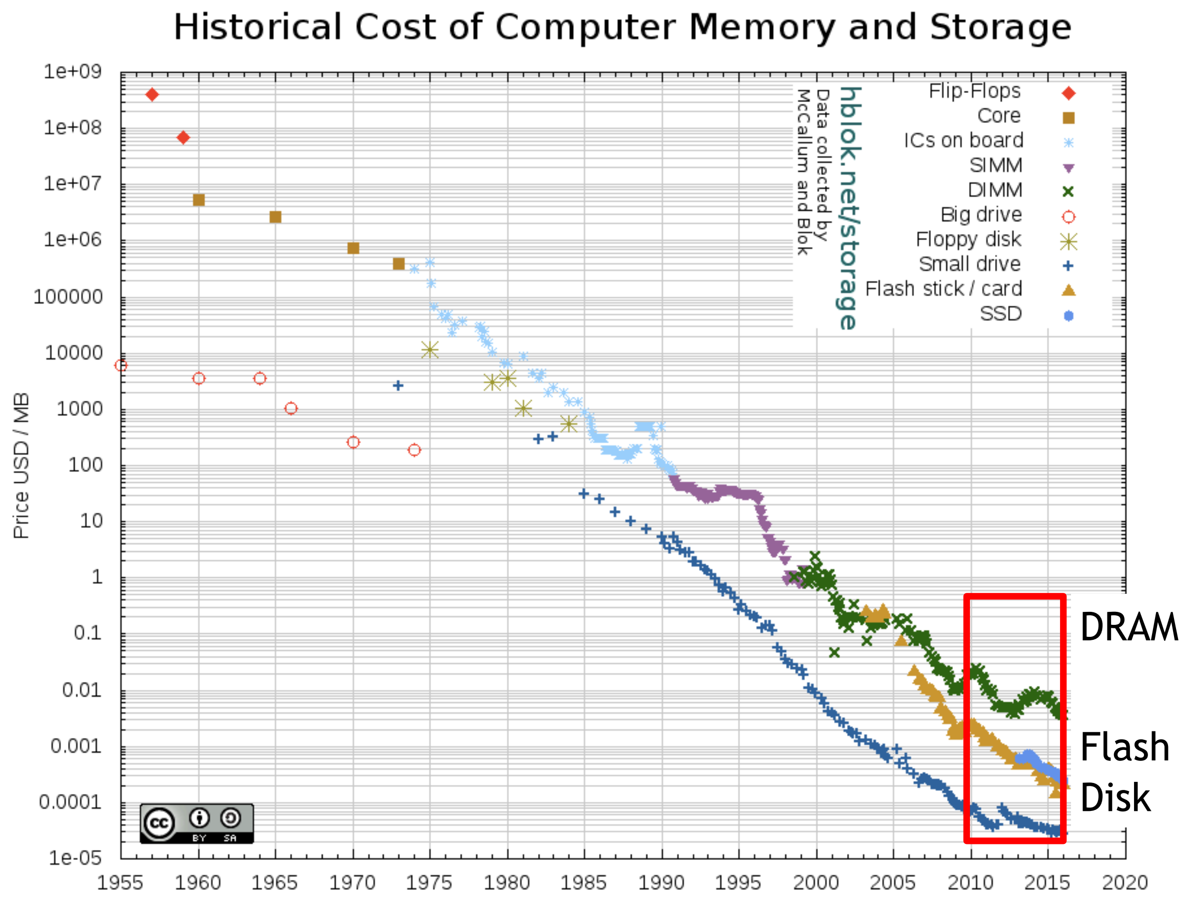
# All Have Hit the Single-Thread Brick Wall



# Leaving Parallelism the ***only*** way to improve throughput

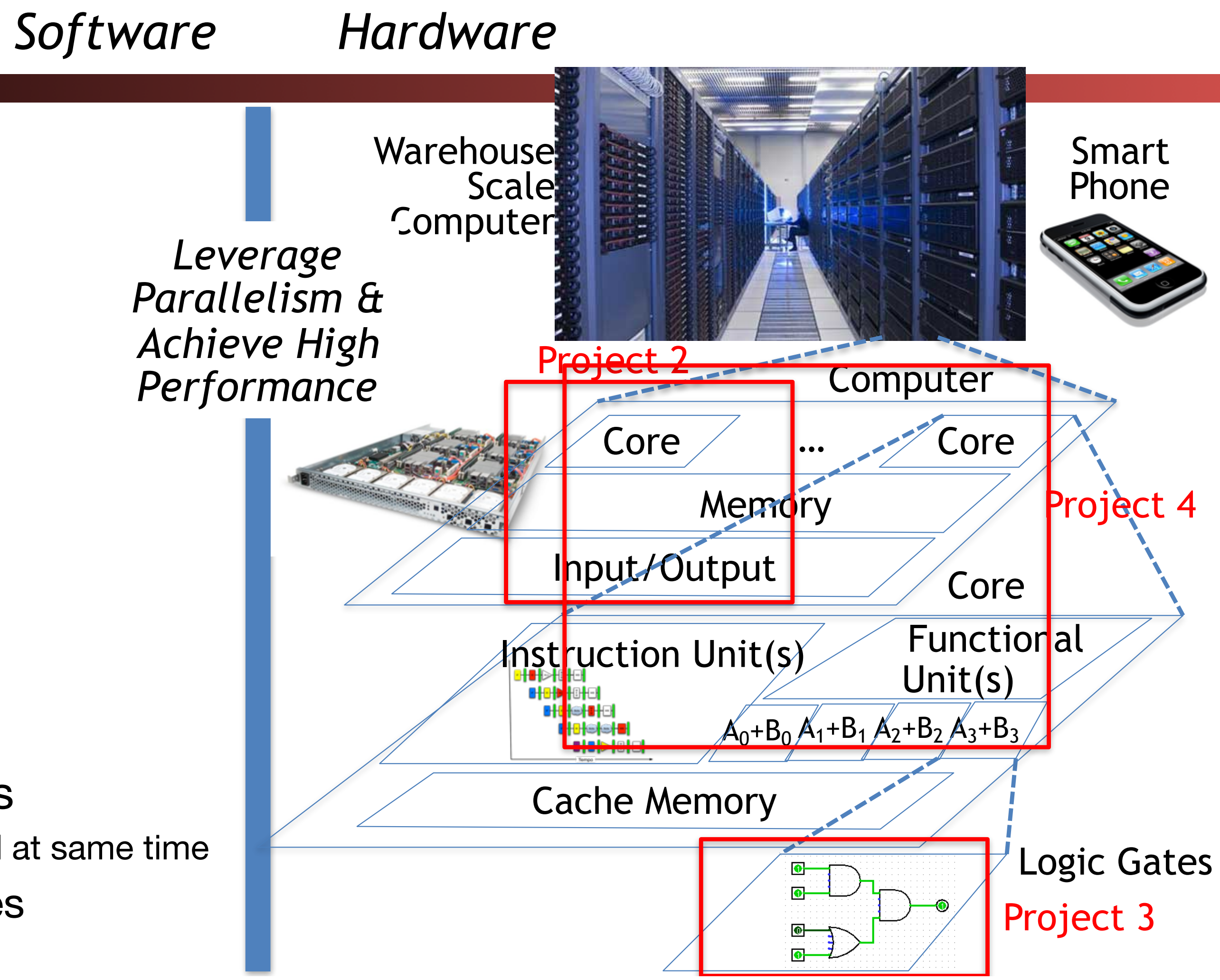


# But Things Are Still Getting Cheaper & Better



# New-School Machine Structures

- Parallel Requests
  Assigned to computer
  e.g., Search "@ncweaver"
- Parallel Threads
  Assigned to core
  e.g., Lookup, Ads
- Parallel Instructions
  >1 instruction @ one time
  e.g., 5 pipelined instructions
- Parallel Data
  >1 data item @ one time
  e.g., Add of 4 pairs of words
- Hardware descriptions
  All gates functioning in parallel at same time
- Programming Languages



# Six Great Ideas in Computer Architecture

- Design for Moore's Law:
  - Multicore & Thread-Level Parallelism (Multicore, Parallelism, OpenMP, Project #4)
- Abstraction to Simplify Design
  - And when in doubt, add another layer of abstraction
- Make the Common Case Fast
  - The design philosophy behind RISC
- Dependability via Redundancy
  - ECC, RAID, and clusters of systems
- Memory Hierarchy
  - Caches, Caches, and More Caches…
- Performance via Parallelism/Pipelining/Prediction

# The Five Kinds of Parallelism

- Request Level Parallelism
  - Google & warehouse scale computers
- Instruction Level Parallelism
  - Pipelining & 152/252 topics: Superscalar, out-of-order execution, branch prediction
- (Fine Grain) Data Level Parallelism:
  - SIMD instructions, graphics cards
- (Course Grain) Data/Task Level Parallelism:
  - Map/Reduce: Hadoop and Spark
- Thread Level Parallelism:
  - Multicore systems, OpenMP (and also take a look at Go)

## Nick’s First Computer:
## 1980, Apple ][+

- MOS 6502 processor:
  - 8b processor with a 16b address bus
- 16kB of RAM
  - Extended it to 32kB with a memory card
- Floppy drive: 140kB disks
- ~$4000 in today’s money!
- Languages supported included BASIC and Logo
  - Logo is remarkably subtle and cool, its remarkably similar to scheme under the hood

## Nick’s Freshman Year Computer: 1991

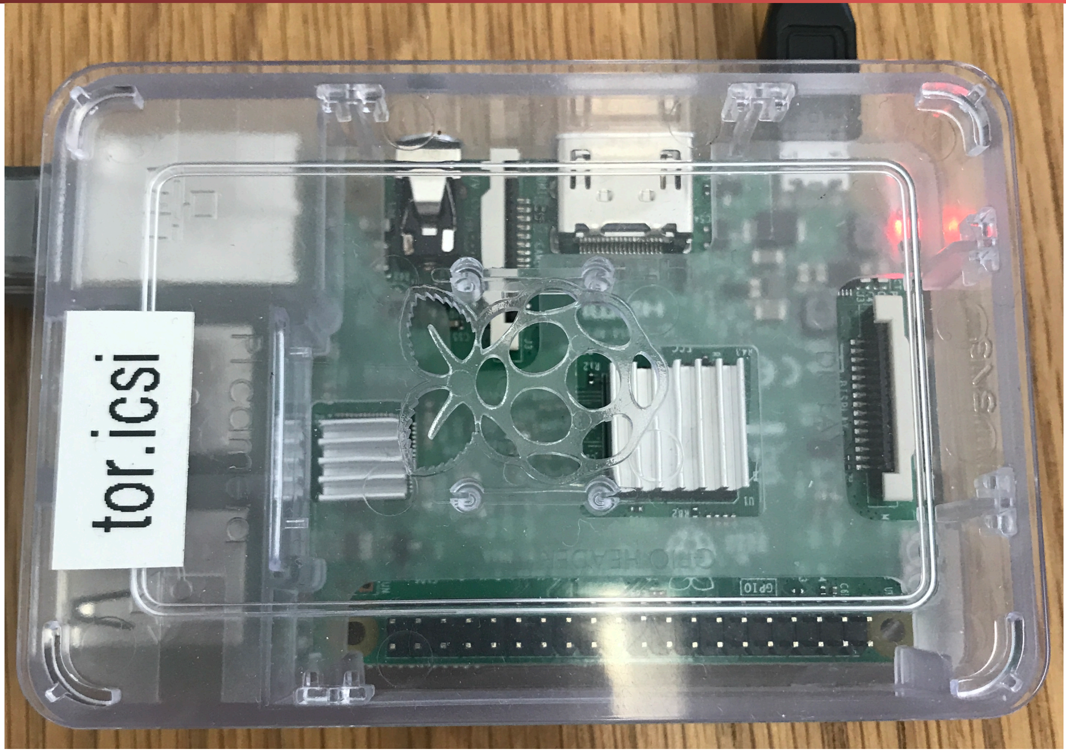
- 25MHz 68040, 32b processor
- 20 MB of memory
    - I expanded it from the original 8 MB
- 1120x832 2-bit grayscale display
    - But I’d rather have a sharp grayscale display than an ugly color display at the time
- ~100 MB hard drive, 2.88MB floppy drive
    - About $9k in today’s dollars

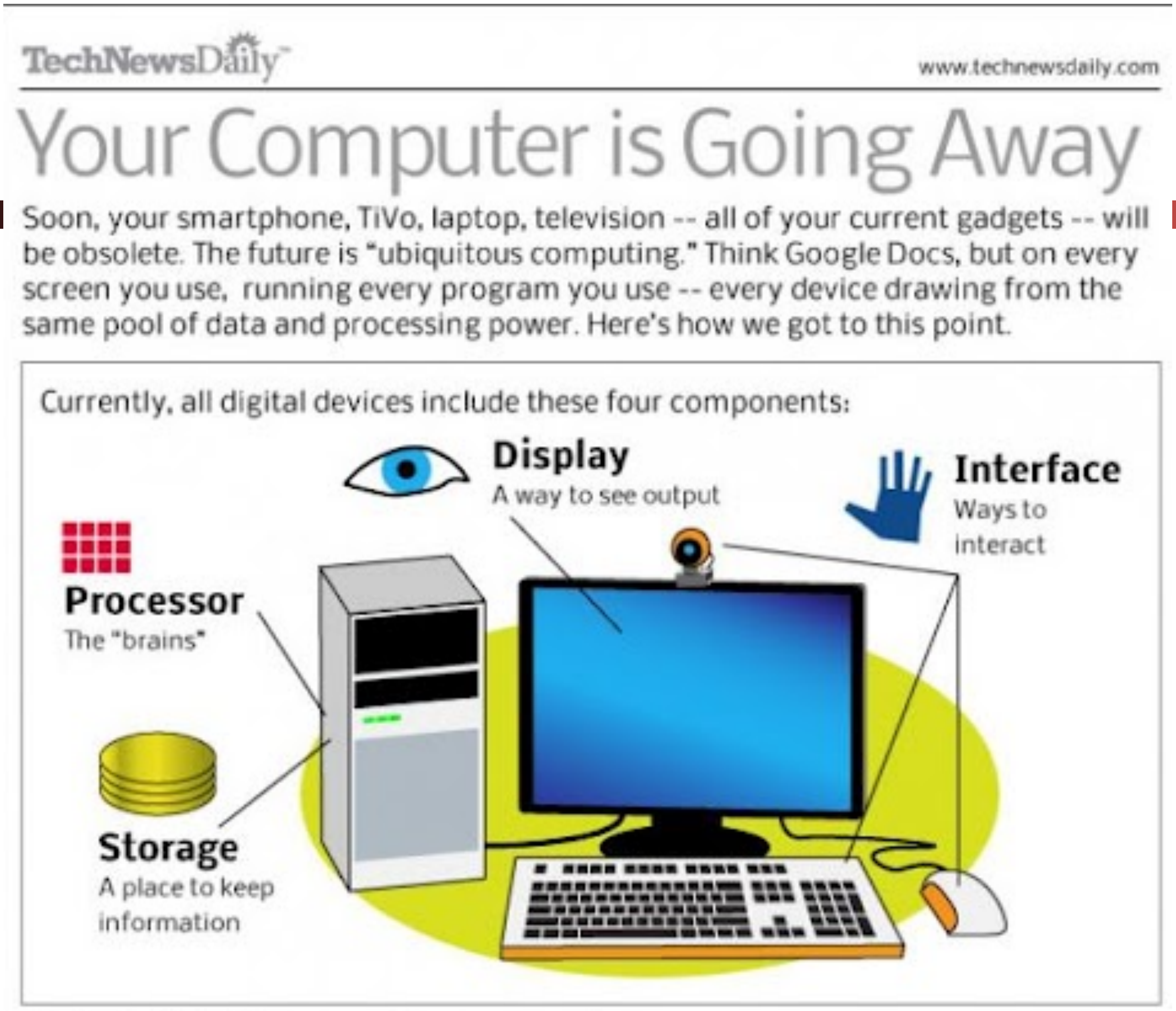
## But That Was Sufficient For 60B…

- The predecessor to current 61C
  - Added more learning of C
  - Didn't include parallel programming, data-center stuff, RAID, etc…
- But otherwise, the contents looked rather familiar

## One of Nick's Research Computers…

- Yeup, an RPi3
  - ~50x single-thread performance
  - ~200x multi-threaded performance
  - 50x the RAM
- Only difference from what you might have:
  - I stuck in a 128GB SDCARD



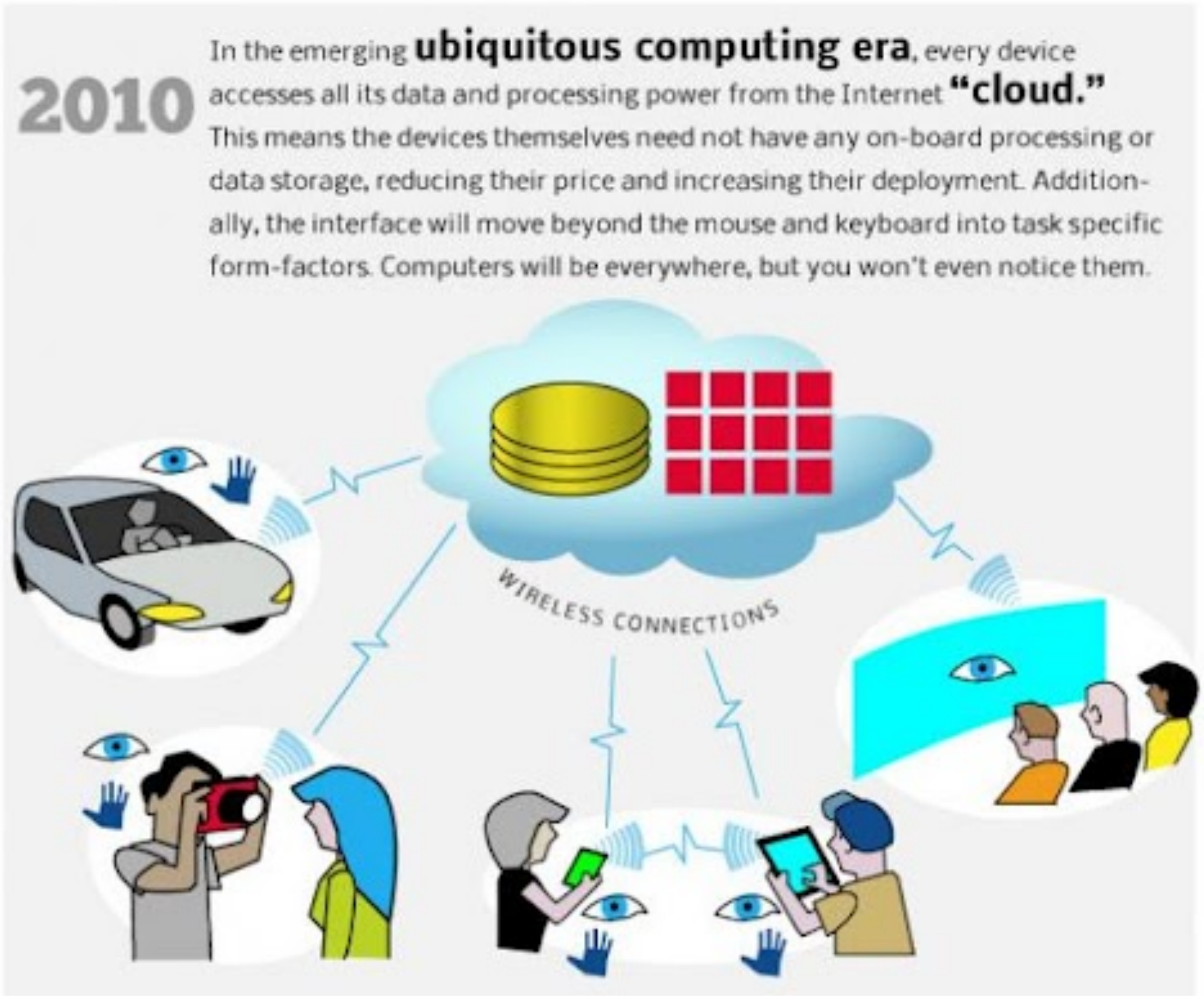


TechNewsDaily www.technewsdaily.com

# Your Computer is Going Away

Soon, your smartphone, TiVo, laptop, television -- all of your current gadgets -- will be obsolete. The future is "ubiquitous computing." Think Google Docs, but on every screen you use, running every program you use -- every device drawing from the same pool of data and processing power. Here's how we got to this point.

Currently, all digital devices include these four components:



**2010**

In the emerging **ubiquitous computing era**, every device accesses all its data and processing power from the Internet **"cloud."** This means the devices themselves need not have any on-board processing or data storage, reducing their price and increasing their deployment. Additionally, the interface will move beyond the mouse and keyboard into task specific form-factors. Computers will be everywhere, but you won't even notice them.

## But A Dissent From The Cloudy Future…

- The “Cloud” is really just a name for someone else’s computer…
- And you are therefore trusting them to do right by your data…
- It could be because you pay them
  - Amazon EC2
- It could be because you bought “ohh shiny”
  - Apple
- It could be because they are ~~selling your soul~~ using your data for their own profit
  - Google

## Nick's Happy Prediction: The Fabrication Revolution…

- We've seen incredibly powerful and cheap compute modules with built-in networking
  - RPi 3: $35
  - RPi-0: $10
- Amdahl's Law applies to cost optimization…
  - If you have a $15 RPi 0 + SD Card to drive your product…
  - The rest of the cost has to be pretty damn low before its worth replacing with something cheaper
- So the compute & communication to make a device is effectively free

## But It's Not Just The Compute & Control…

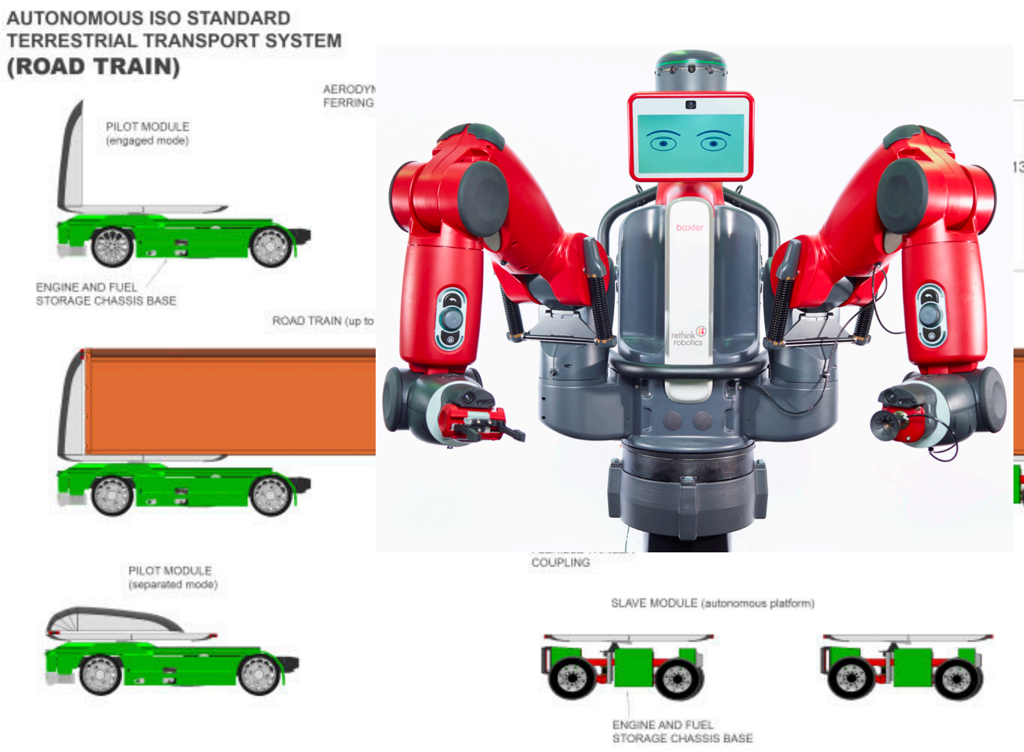
- 3D printers, laser cutters, C&C Machines all make prototyping stuff cheap
  - And direct paths to go from 1 to 10 to 1000 to 100,000 thingies
- And logistics
  - Time from manufacturer to me doesn't actually care where I am in the US
- And direct to consumer marketing

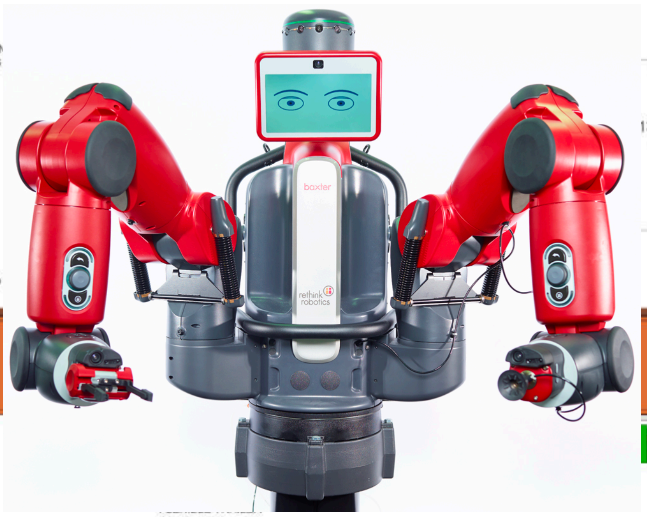
FedEx®

KICKSTARTER

# Nick's Gloomy Prediction: Automation and Its Discontents…

- We are getting damn close to the autonomous long-haul truck
  - If it costs $100K to automate a semi-truck it will pay for itself in <2 years!
- And a lot of jobs with robots
  - EG, the $20k Baxter human-safe robot: One robot only needs to replace .2 humans to pay for itself in 2 years
- Plus all the AI-related dislocation
- Scary Prediction: 20 years from now we will have >20% unemployment





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