Why Computer Science?
Why UW CSE?

Ed Lazowska

Bill & Melinda Gates Chair in
Computer Science & Engineering

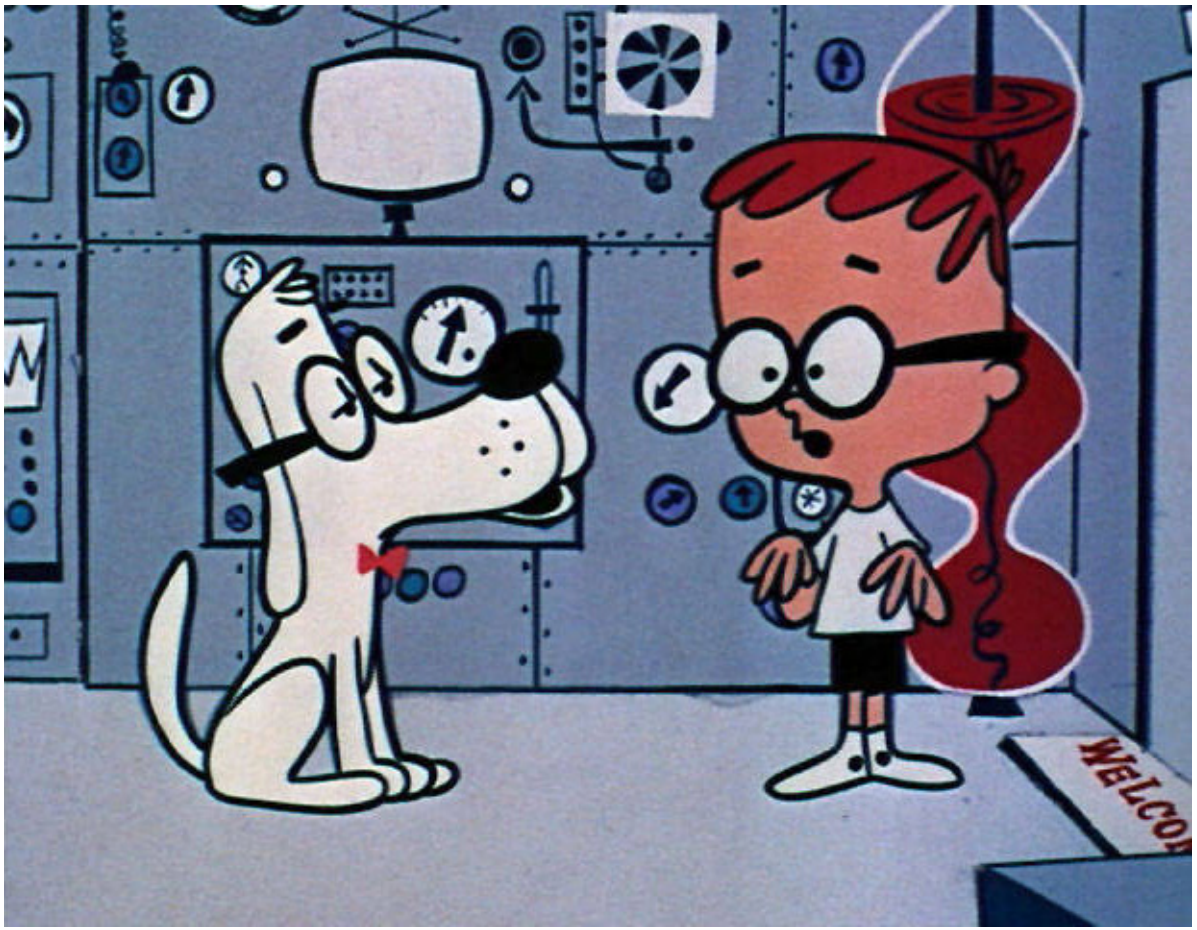
University of Washington

Holy Names Academy

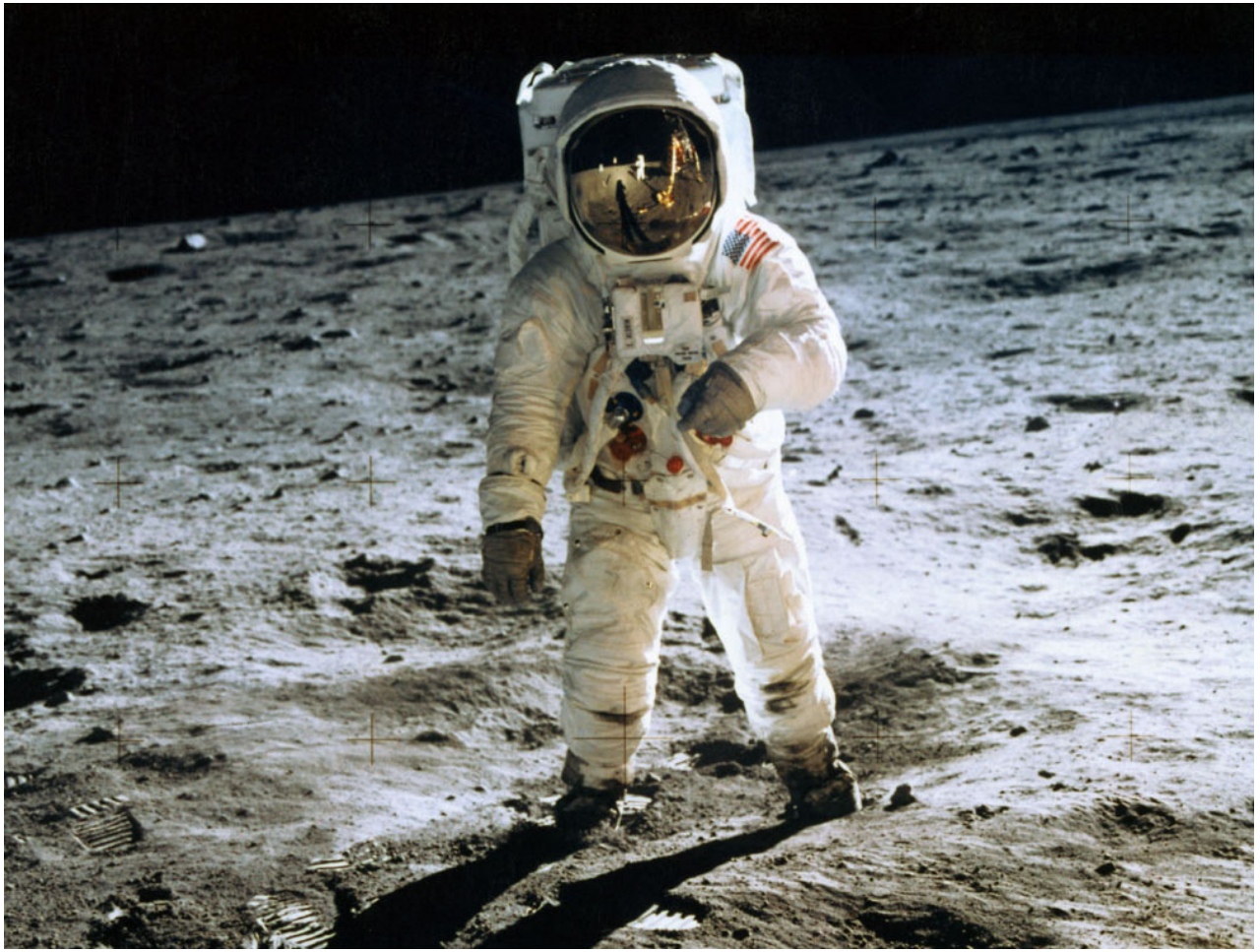
August 2014

http://lazowska.cs.washington.edu/HolyNames.pdf,pptx

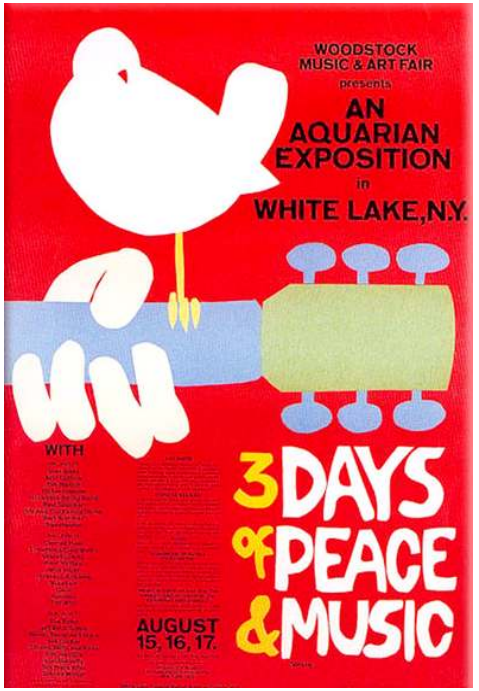
Forty five years ago …



Credit: Peter Lee, Microsoft Research




1969

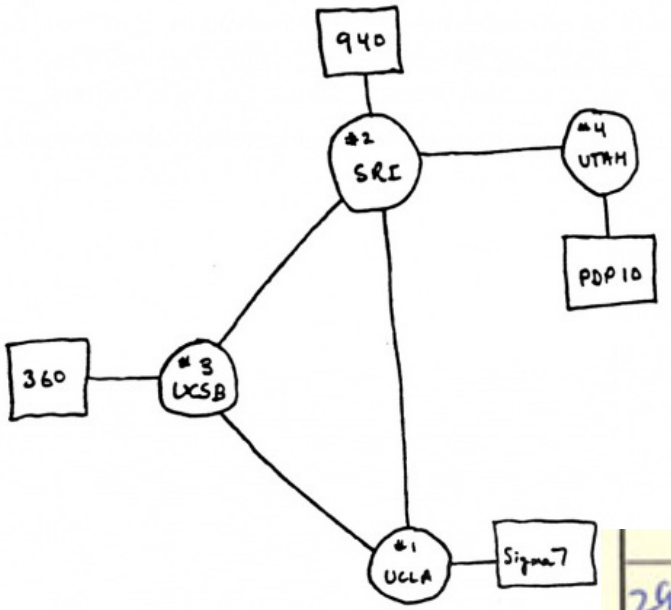

WOODSTOCK
MUSIC & ART FAIR
presents
AN
AQUARIAN
EXPOSITION
in
WHITE LAKE, N.Y.
WITH
3 DAYS
of PEACE
& MUSIC
AUGUST
15, 16, 17.


1969


1969 WORLD SERIES
NEW YORK METS


WORLD
CHAMPIONS
NEW YORK METS
1969


1969



THE ARPA NETWORK
DEC 1969
4 NODES

29OCT69	2100	LOADED OP. PROGRAM FOR BEN BARKER BBN	CSK
	22:30	Talked to SRI Host to Host	CSK
		Left op. imp. program running after sending a host dead message to imp.	CSK

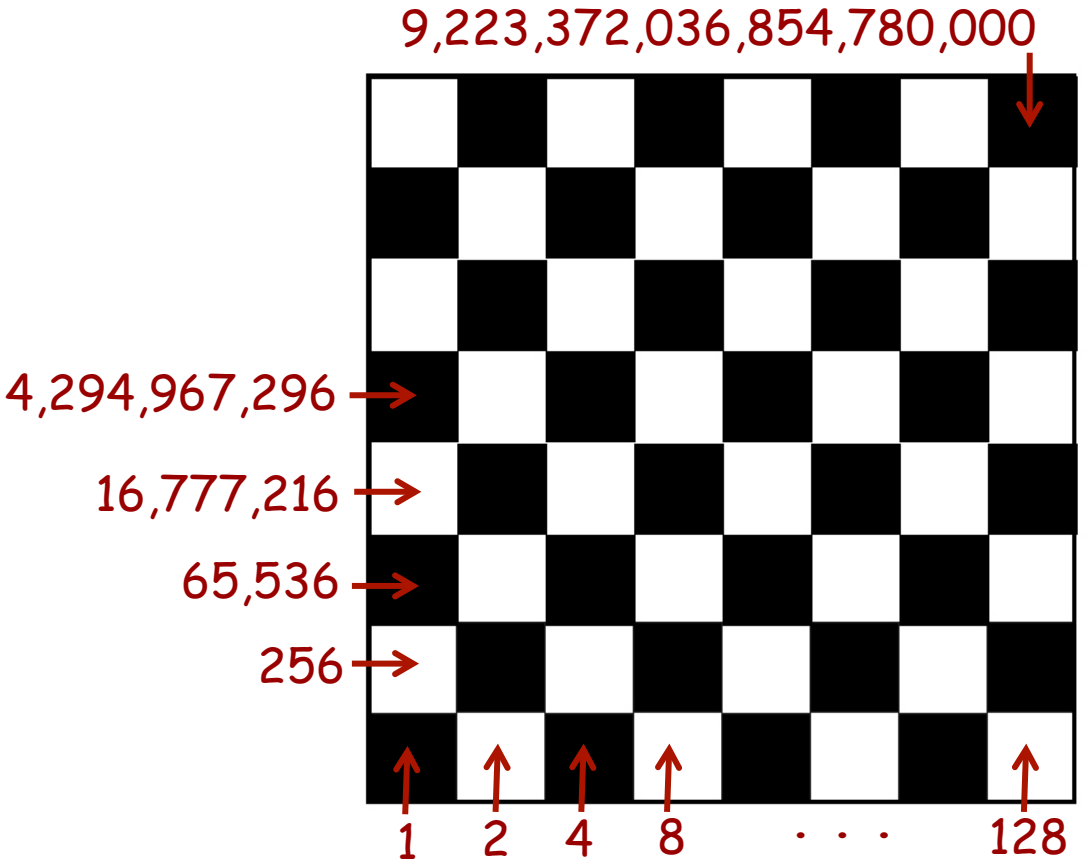
With 4+ decades of hindsight, which had the greatest impact?

- Unless you're big into Tang and Velcro (or sex and drugs), the answer is clear …

- And so is the reason …

EXPONENTIALS R US

Exponentials are rare – we're not used to them, so they catch us unaware

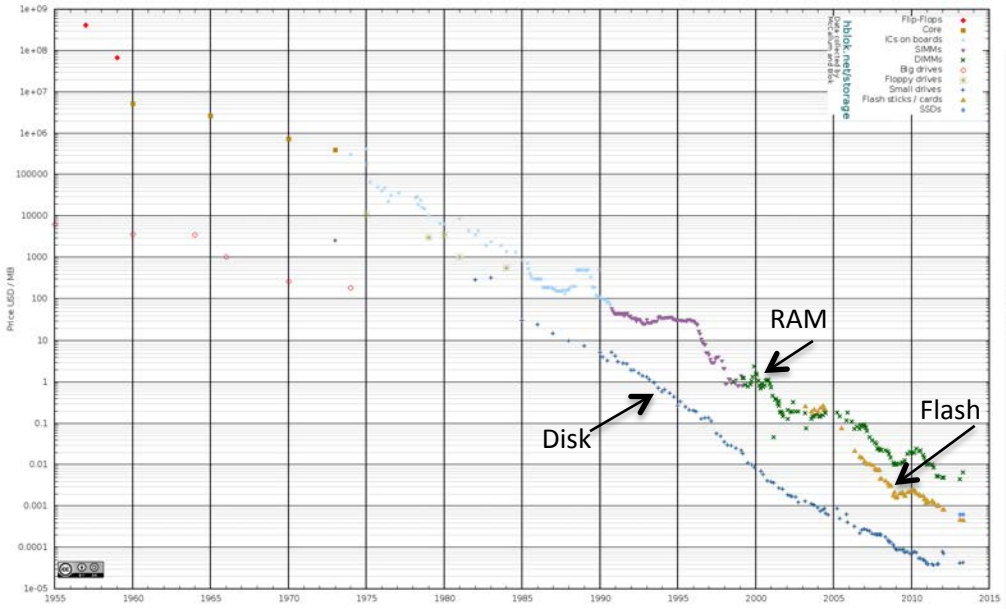


Every aspect of computing has experienced exponential improvement

- Processing capacity
- Storage capacity
- Network bandwidth
- Sensors
- Astonishingly, even algorithms in some cases!

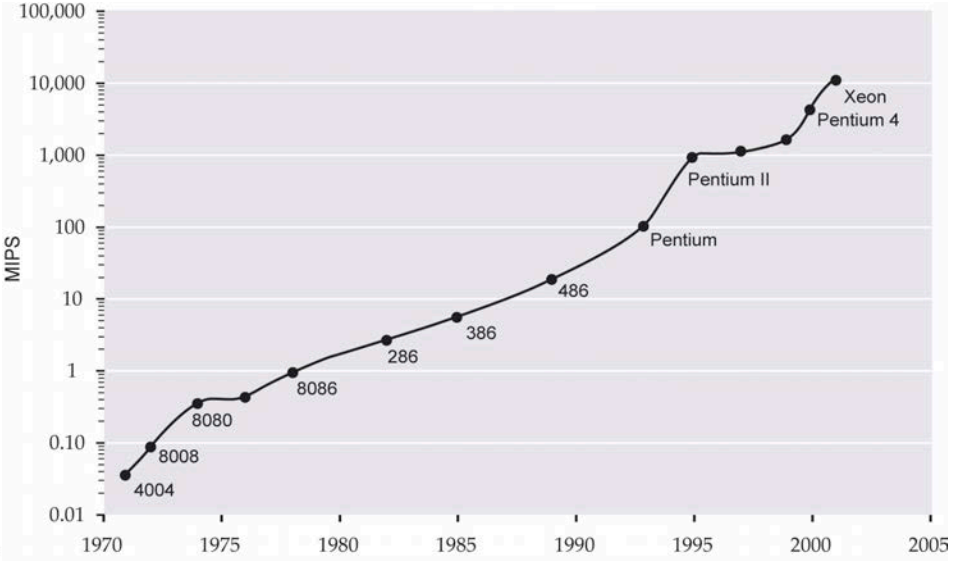
You can exploit these improvements in two ways

- Constant capability at exponentially decreasing cost
- Exponentially increasing capability at constant cost



John McCallum / Havard Blok

Storage Price / MB, USD
(semi-log plot)



Ray Kurzweil

Microprocessor Performance, MIPS
(semi-log plot)


UNIVAC

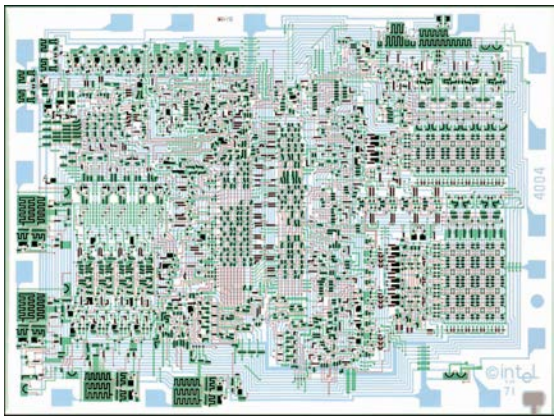
The 1970s to today

1970 Ford Mustang

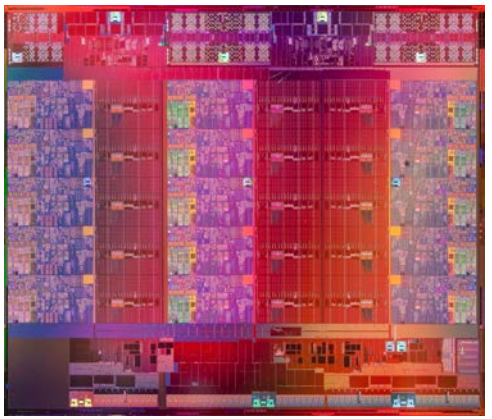
2014 Ford Mustang

Size: roughly comparable
Speed: roughly comparable
Efficiency (MPG): roughly comparable
Value (cost relative to performance): roughly comparable

The 1970s to today



1971 Intel 4004
(2,300 transistors)

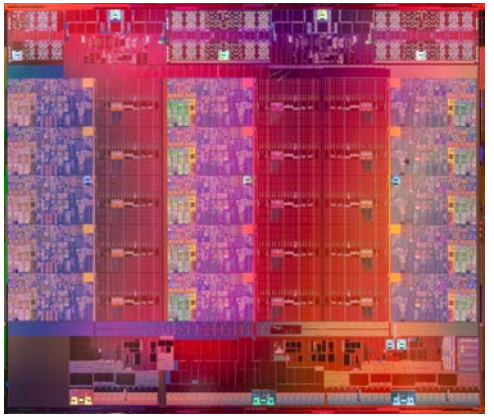


2014 Intel Xeon
(4,300,000,000 transistors)

Size: area occupied by a transistor reduced by 1,000,000x
Speed: operations per second increased by 100,000x
Efficiency (operations per watt): improved by 6,750x
Value (dollars per instruction): improved by 2,700x

The 1970s to today

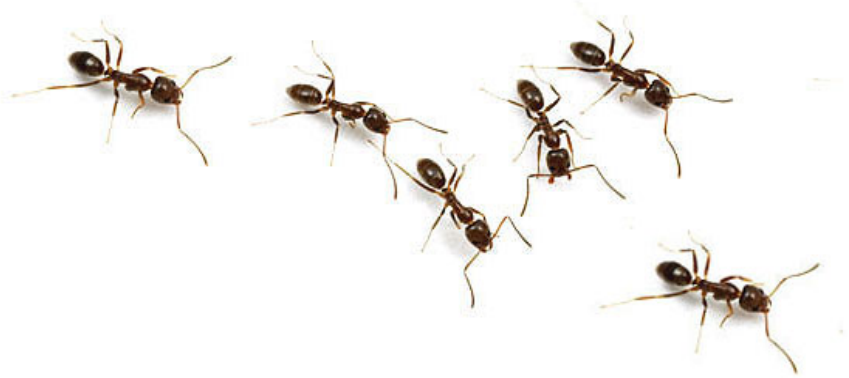
1970 Ford Mustang



2014 Intel Xeon

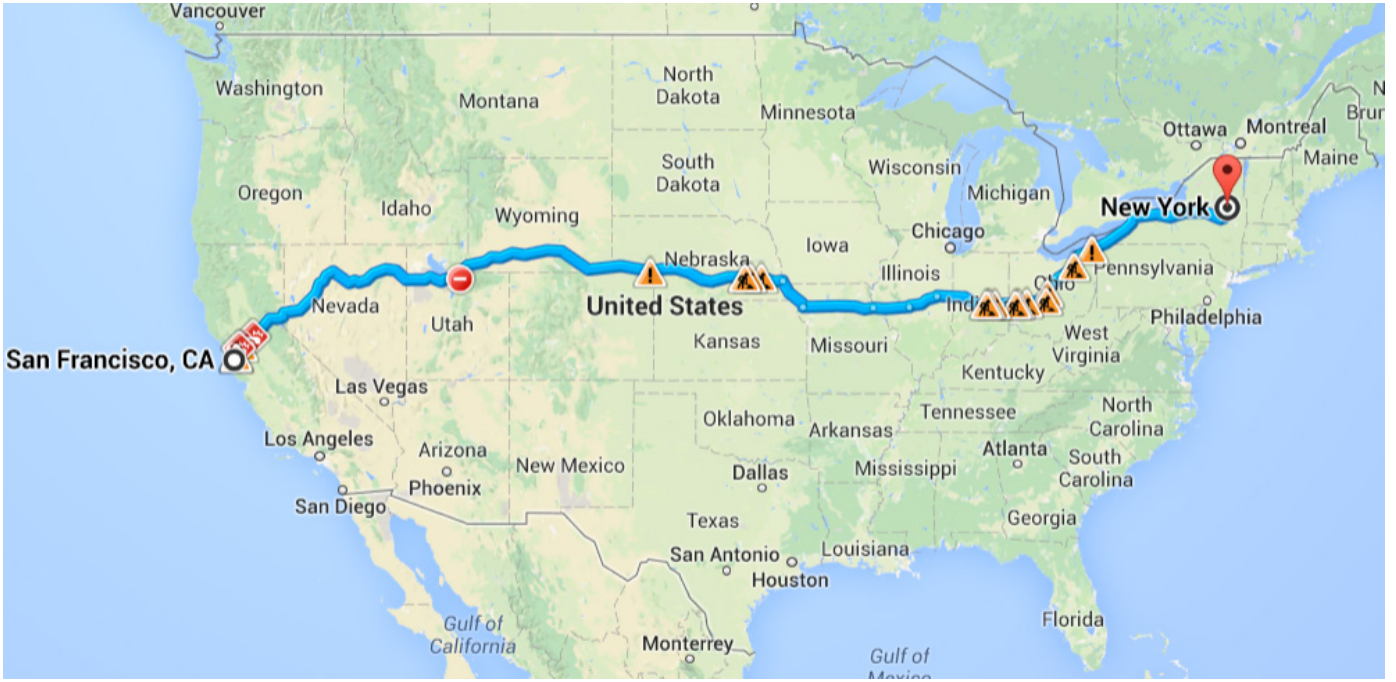
What if cars had improved as rapidly as microprocessors?

The 1970s to today



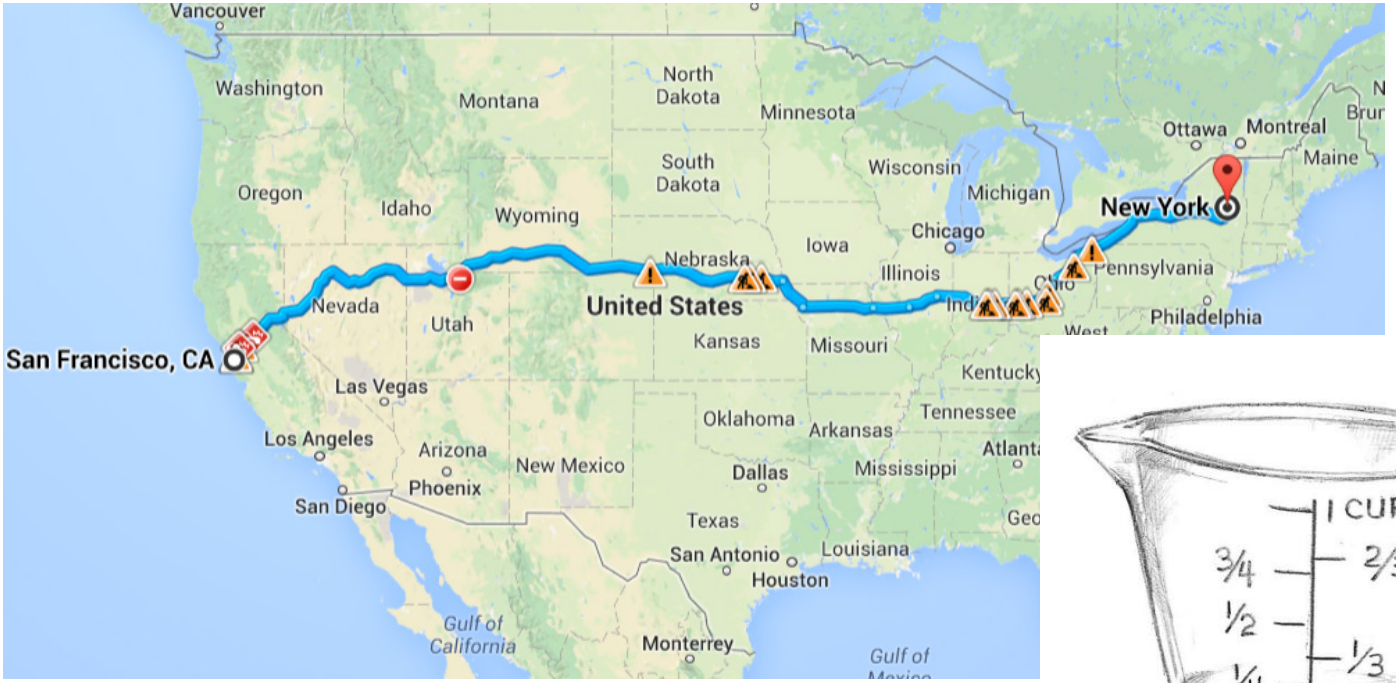
Size: A car would be smaller than an ant!
(About 1/5th of an inch long!)

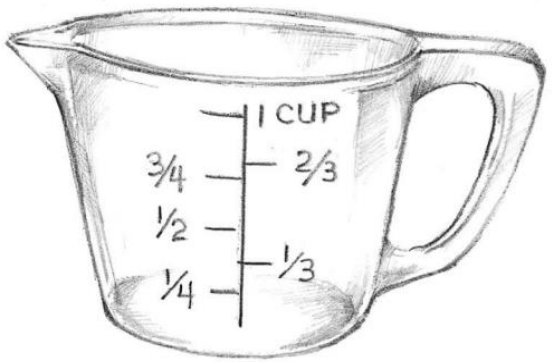
The 1970s to today



Speed: A car would go 6,000,000 miles per hour!
(San Francisco to New York in 1.7 seconds!)

The 1970s to today





Efficiency: A car would get 100,000 miles per gallon!
(San Francisco to New York on 1/2 cup of fuel!)

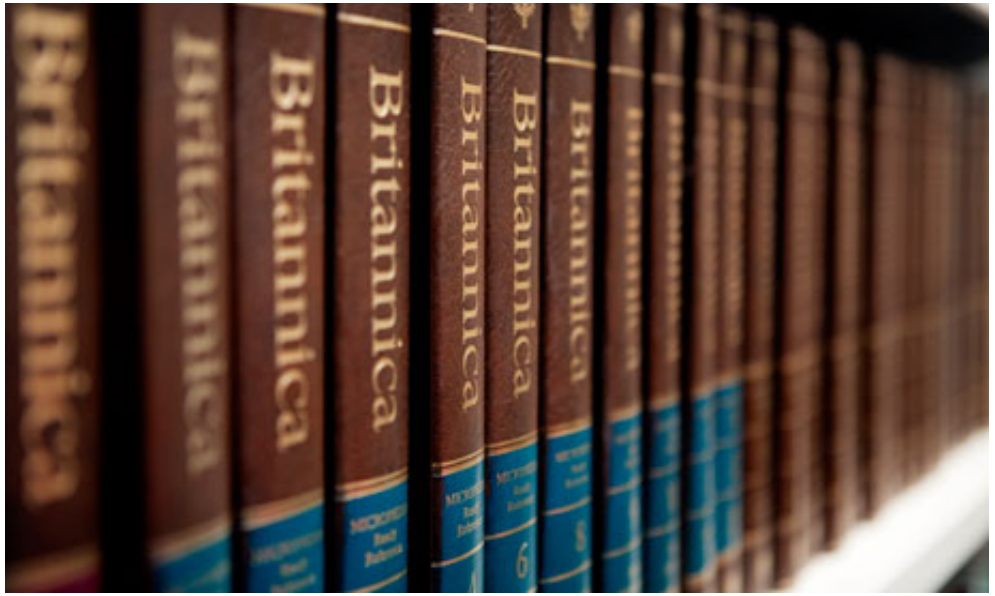
The 1970s to today

Cost: A car would cost less than $10!

More then and now …

- 20 years ago, microprocessors had 4 million transistors
  - Today they have 4 billion
- 20 years ago, the Internet had 1 million users
  - Today, it has 1 billion
- 20 years ago, only 15% of households had a computer
  - Today, nearly everyone owns a mobile phone
  - In the past year, more than half of all mobile phones purchased worldwide were smartphones – putting the Internet in the owner's pocket

Searching for information



Google

WIKIPEDIA

Credit: Jeannette Wing, Microsoft Research

Searching for directions

Searching for love

Reading books

Listening to music

Watching movies

During the decade of the 2000's …

xconomy
Business + Technology in the Exponential Economy

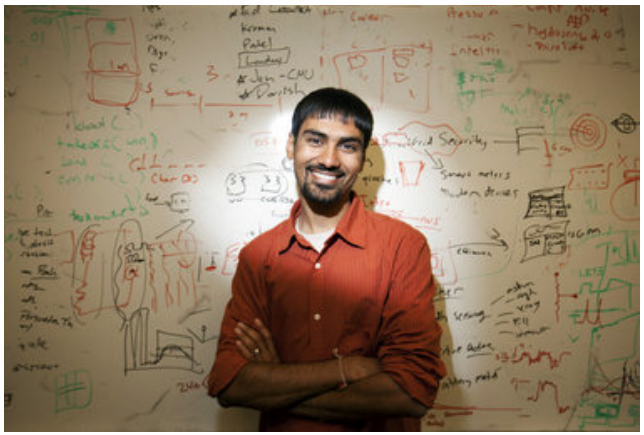
- Search
- Scalability
- Digital media
- Mobility
- eCommerce
- The Cloud
- Social networking and crowd-sourcing

During the current decade …

xconomy
Business + Technology in the Exponential Economy

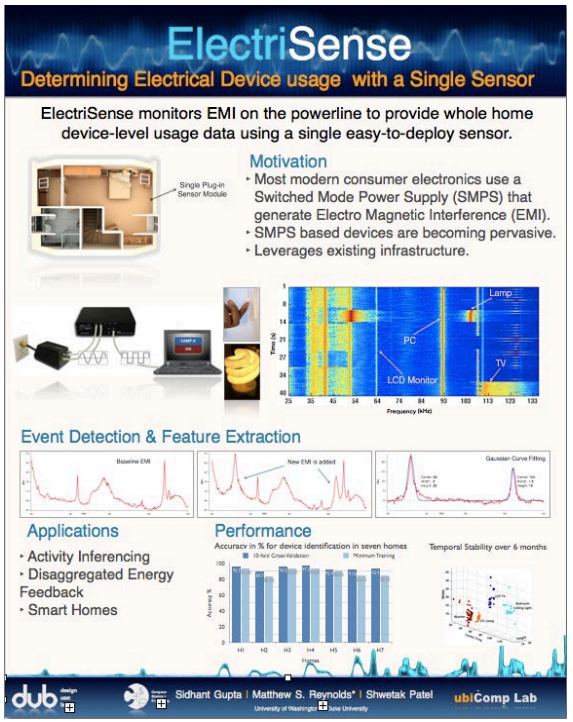
- Smart homes
- Smart cars
- Smart health
- Smart robots
- Smart crowds and human-computer systems
- Smart interaction (virtual and augmented reality)
- Smart cities
- Smart discovery (exploiting the data deluge)

Smart homes (the leaf nodes of the smart grid)



Shwetak Patel,
University of Washington
2011 MacArthur Fellow

MACARTHUR
The John D. and Catherine T. MacArthur Foundation



belkin echo

Smart cars

DARPA Grand Challenge

DARPA Urban Challenge

Google Self-Driving Car

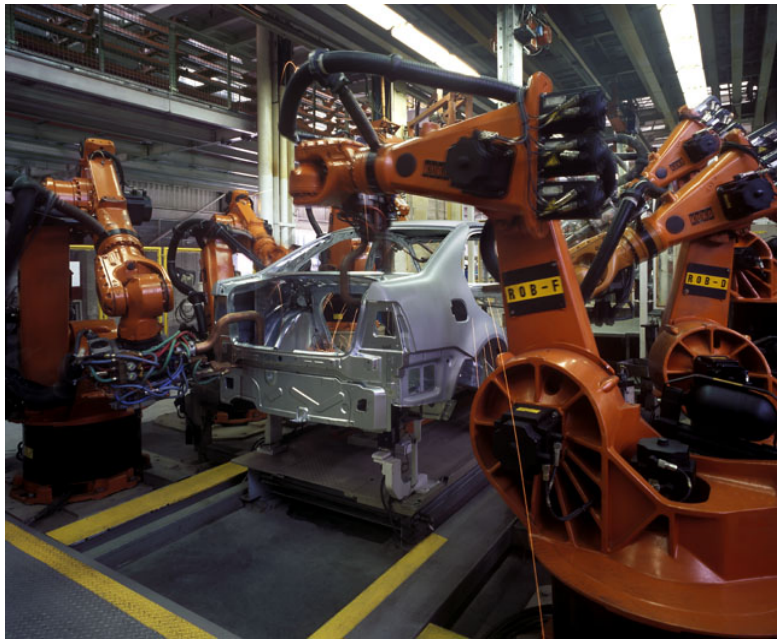
Smart health

Larry Smarr – "quantified self"

Evidence-based medicine

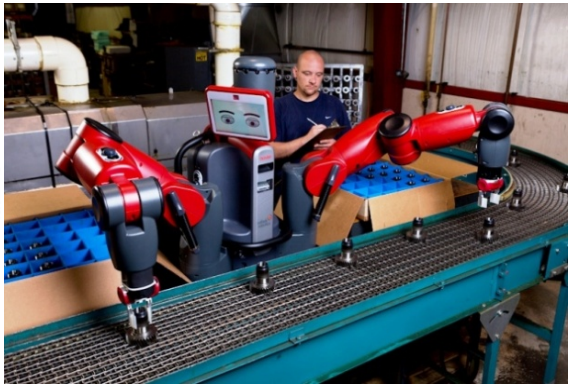
P4 medicine

Smart robots



iRobot

rethink robotics

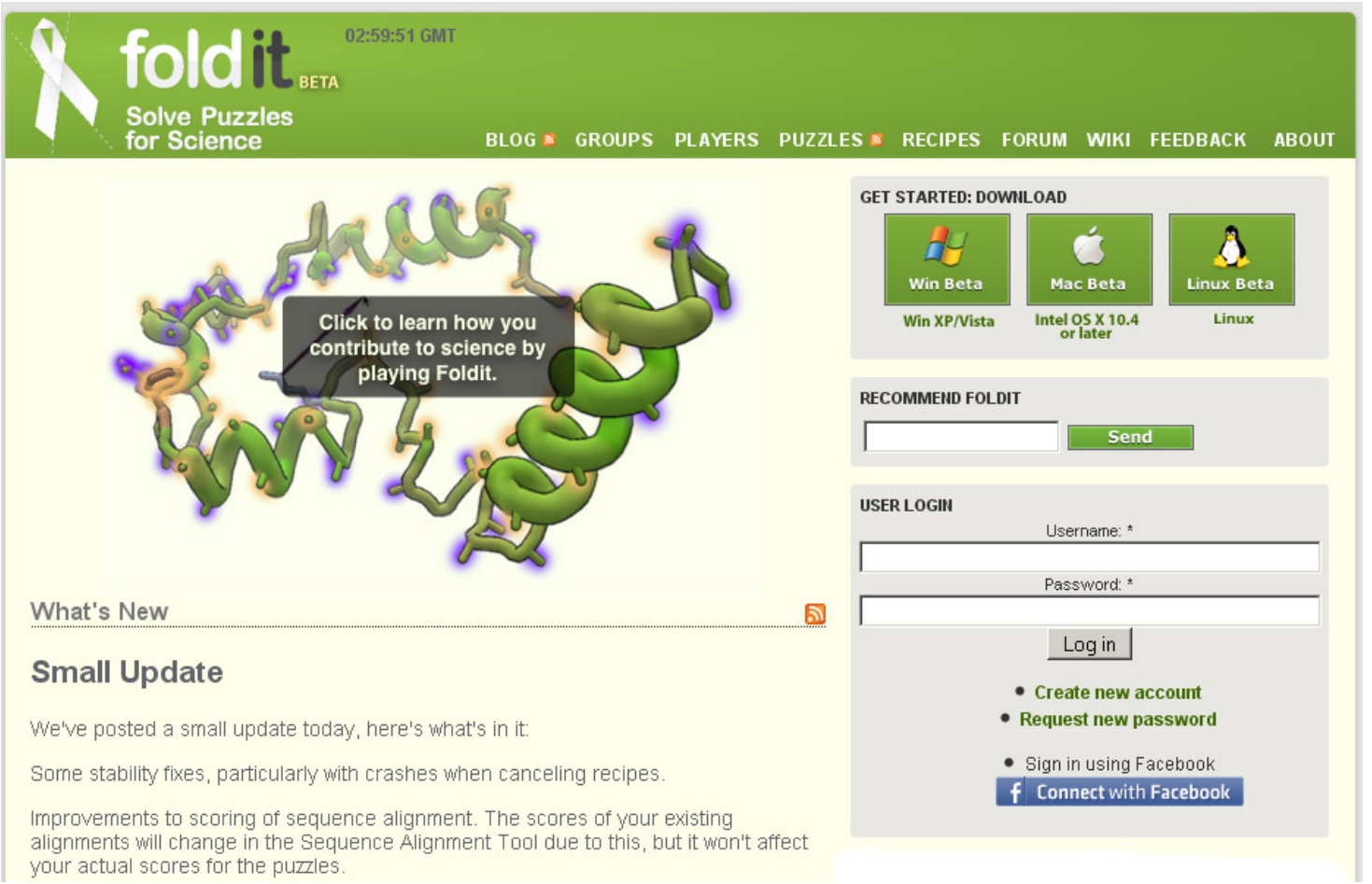


Smart crowds and human-computer systems

(+ smart education)

Zoran Popovic,
UW Computer Science & Engineering

David Baker,
UW Biochemistry



Smart crowds and human-computer systems
(+ smart education)

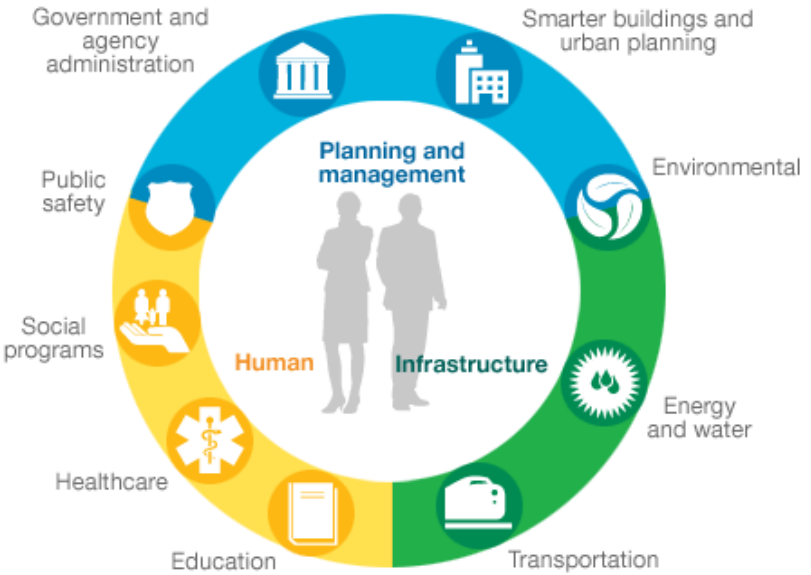
Zoran Popovic,
UW Computer Science & Engineering

CGS Center for Game Science

Smart interaction

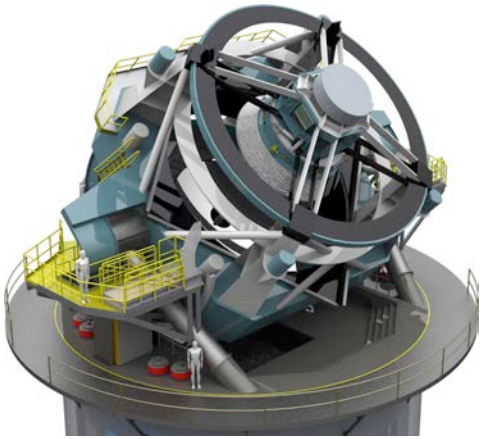
KINECT™
for XBOX 360

Smart cities

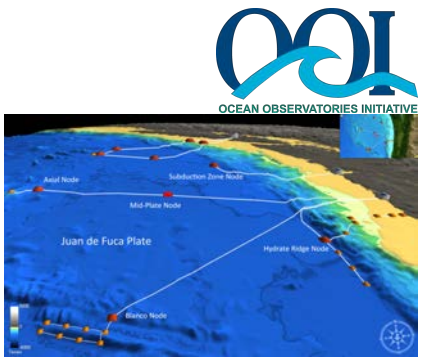


Smart discovery (data-intensive discovery, or *eScience*)

Nearly every field of discovery is transitioning from "data poor" to "data rich"

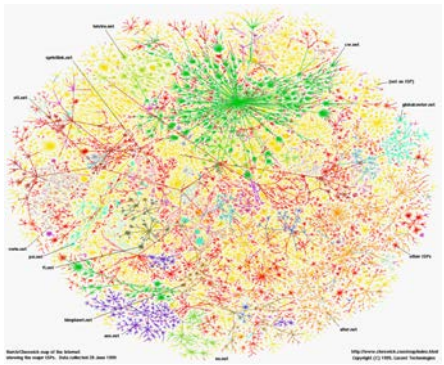


Astronomy: LSST



Oceanography: OOI

Physics: LHC



Sociology: The Web

Biology: Sequencing

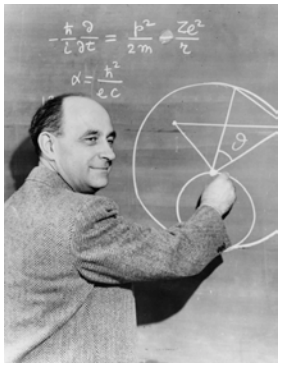
Economics: POS terminals

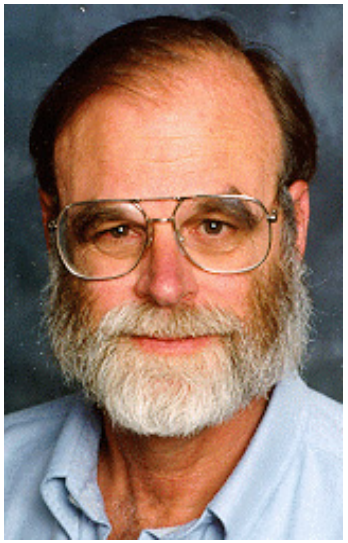
Neuroscience: EEG, fMRI

Smart discovery (data-intensive discovery, or *eScience*)

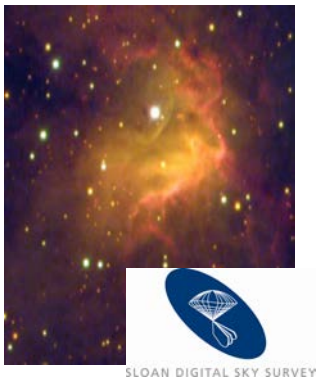
The Fourth Paradigm

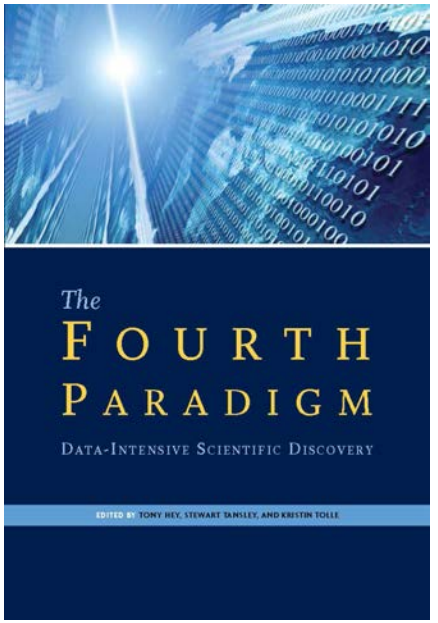
1. Empirical + experimental
2. Theoretical
3. Computational
4. Data-Intensive



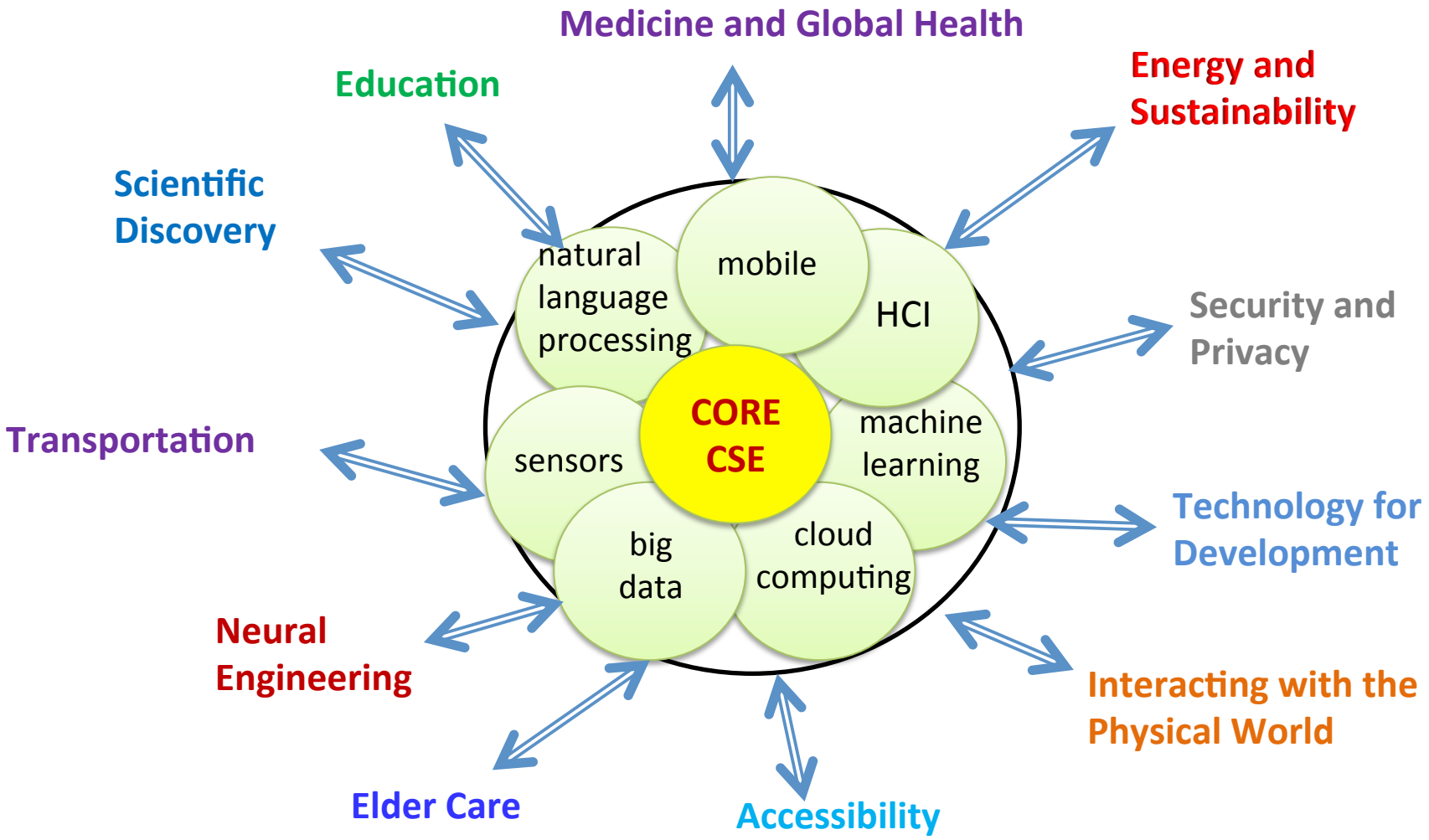


Jim Gray,
Microsoft Research

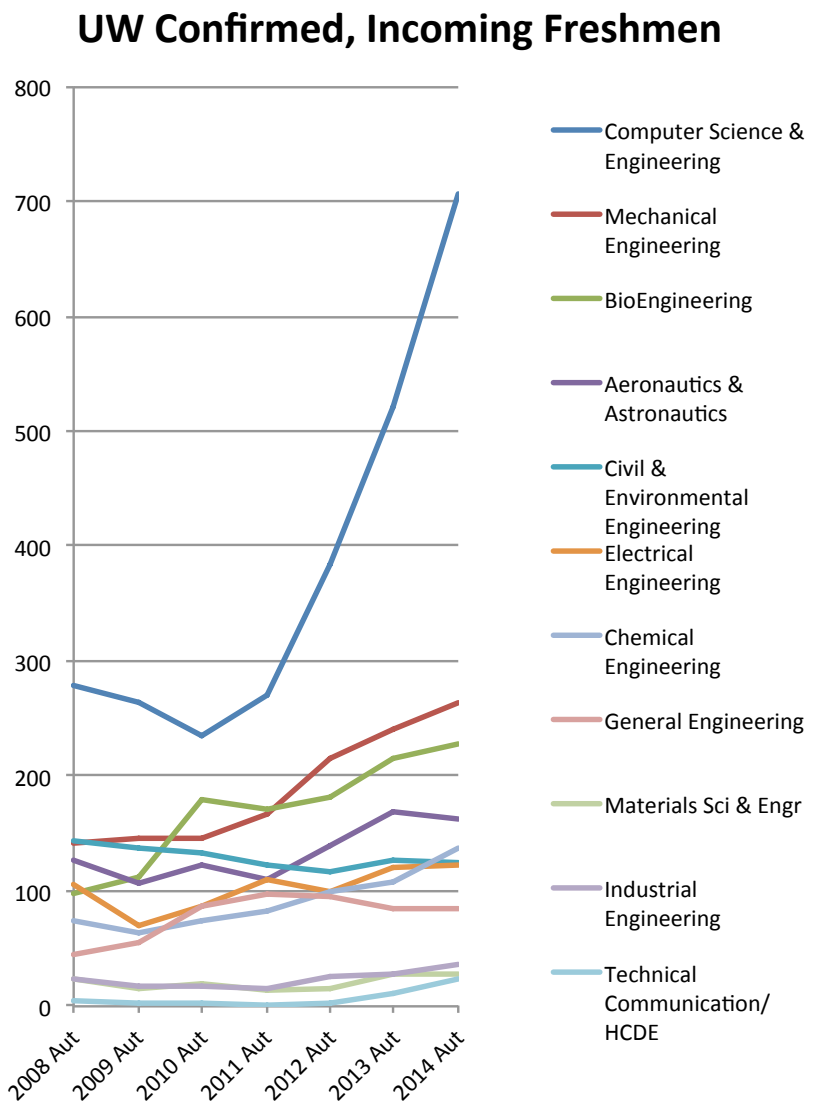


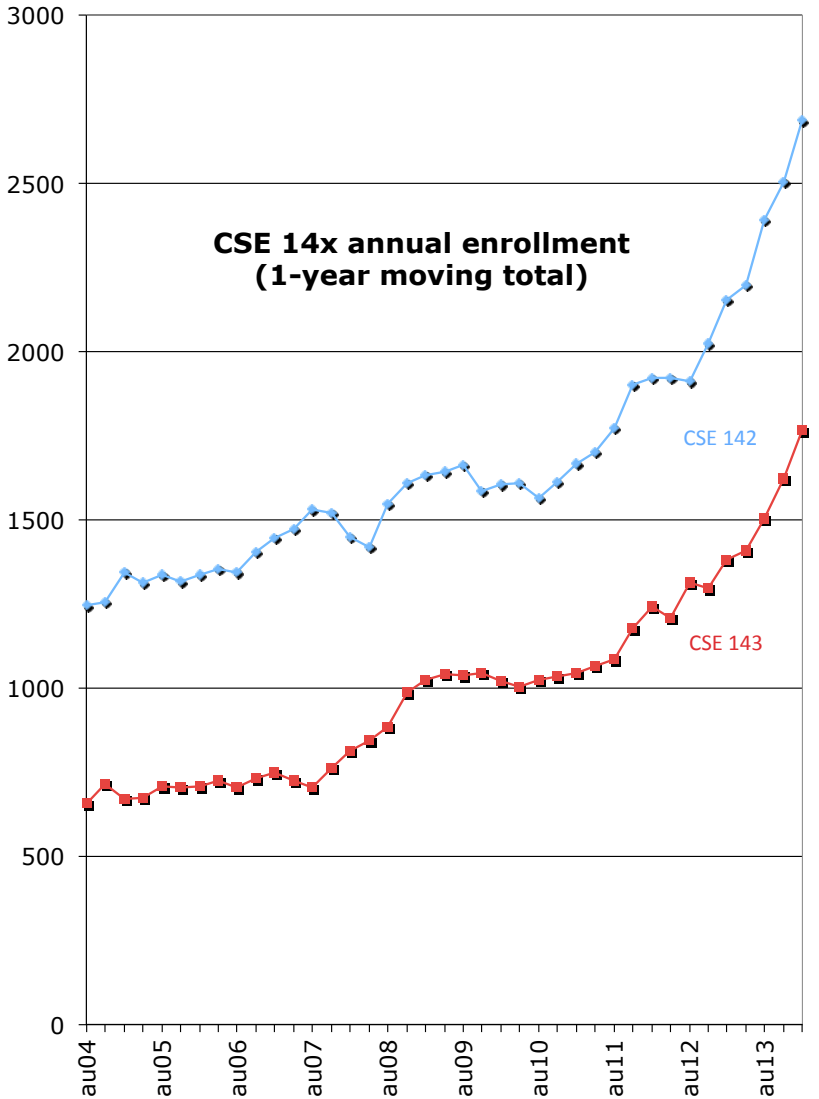


Computer science is unique in its societal impact



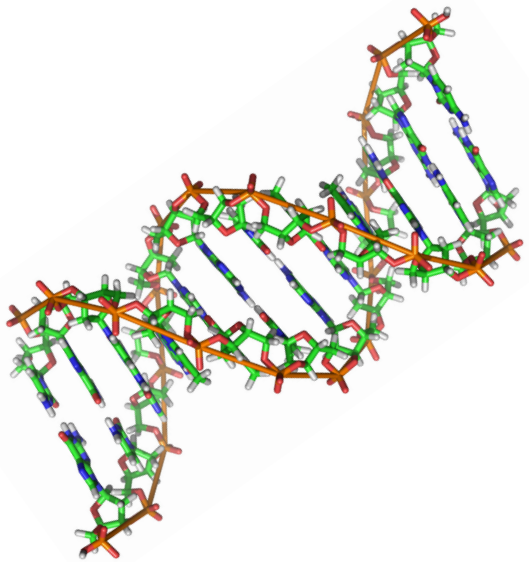
Student interest is booming





- Students are realizing that every 21st century citizen needs to have facility with "computational thinking" – problem analysis and decomposition (stepwise refinement), abstraction, algorithmic thinking, algorithmic expression, stepwise fault isolation (debugging), modeling
  - Computational thinking is not "this particular operating system" or "that particular programming language."
  - Computational thinking is not even programming. It's a mode of thought – a way of approaching the world.
  - Programming is the hands-on, inquiry-based way that we teach computational thinking and the principles of computer science.

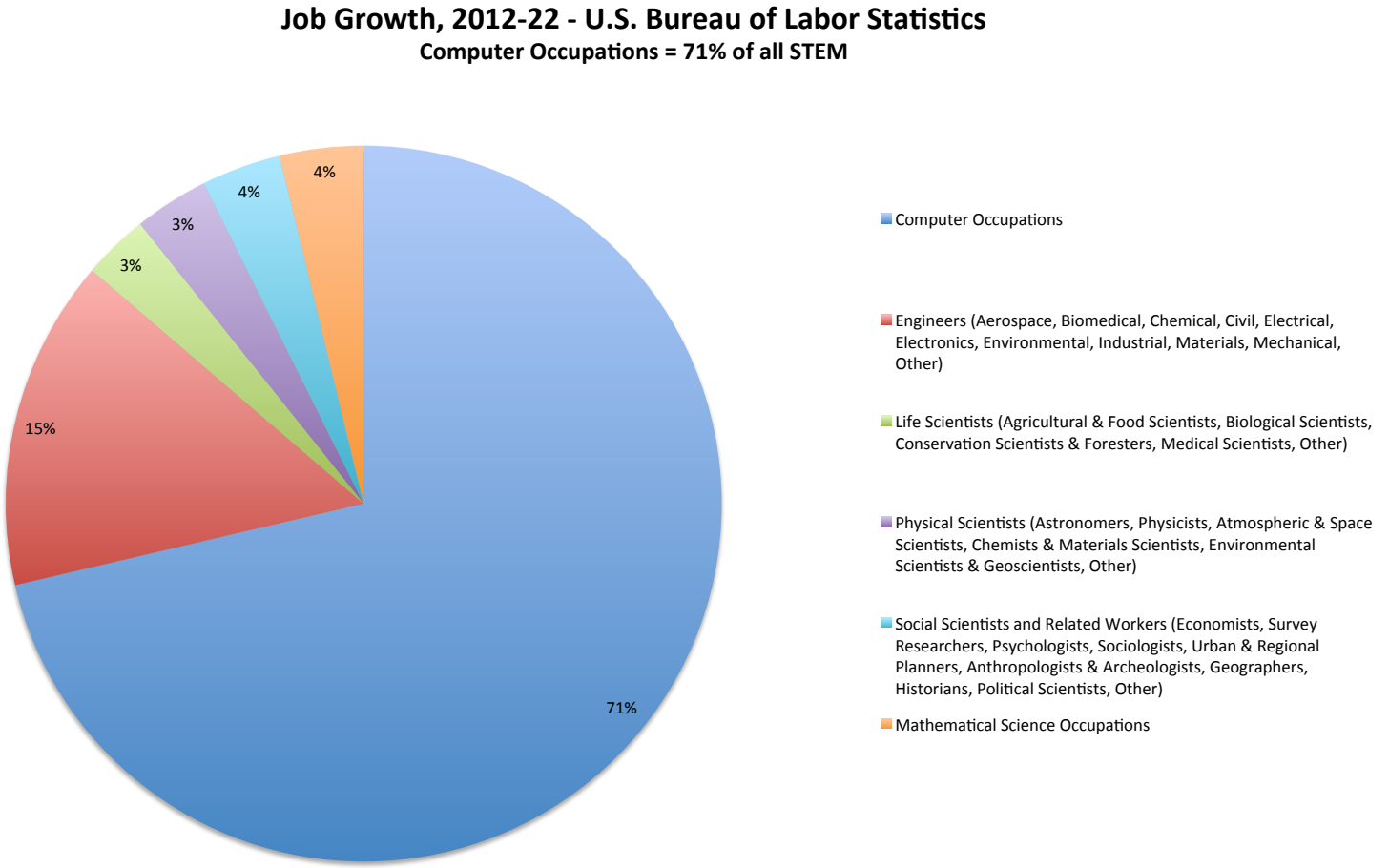
- Students are realizing that computer science is great preparation for anything! Fields from Anthropology to Zoology are becoming *information* fields, and that those who can bend the power of the computer to their will – computational thinking, but also computer science in greater depth – will be positioned for greater success than those who can't



- Students are realizing that computer science is not Dilbert – it's an intellectually exciting, highly creative and interactive, "power to change the world" field

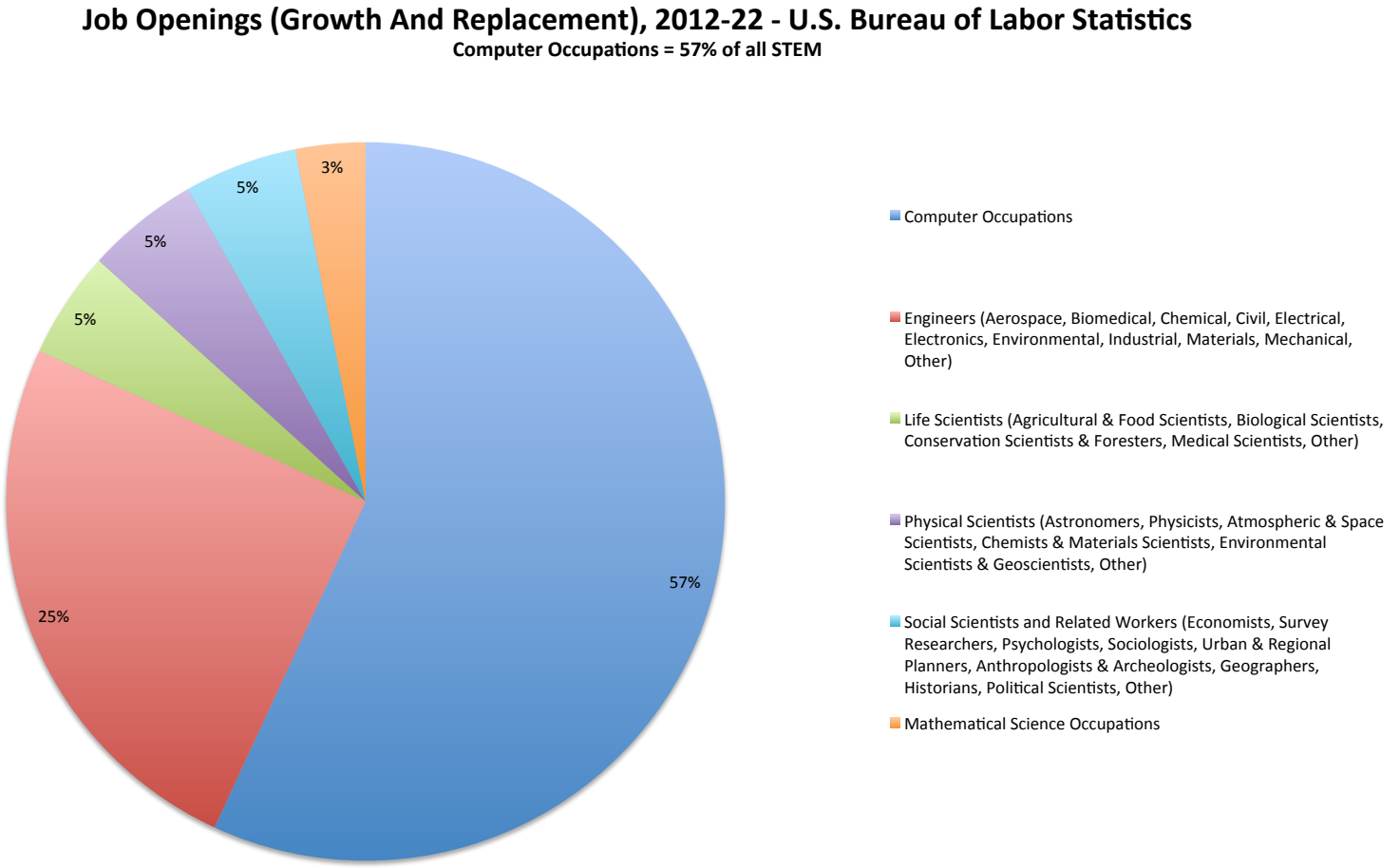
- Students are realizing that pretty much all of the STEM jobs are in computer science
  - While fluency with computational thinking and with computer science are important to all fields, *the job prospects in the field of computer science itself are extraordinary*
    - The U.S. Bureau of Labor Statistics recently released its job projections for the decade 2012-2022. Computer occupations will be responsible for 71% of *all* the job growth in *all* fields of STEM (Science, Technology, Engineering, and Mathematics) – the many dozens of fields that comprise the life sciences, the physical sciences, the social sciences, engineering, and the mathematical sciences – and for 57% of all available jobs, whether newly-created or available due to replacement
    - In Washington State, the workforce gap in computer science is greater than the workforce gap in *all other fields* (not just STEM fields!) combined

- Students are realizing that nearly all STEM jobs are in computer science



Data from the spreadsheet linked at http://www.bls.gov/emp/ep_table_102.htm

- Students are realizing that nearly all STEM jobs are in computer science



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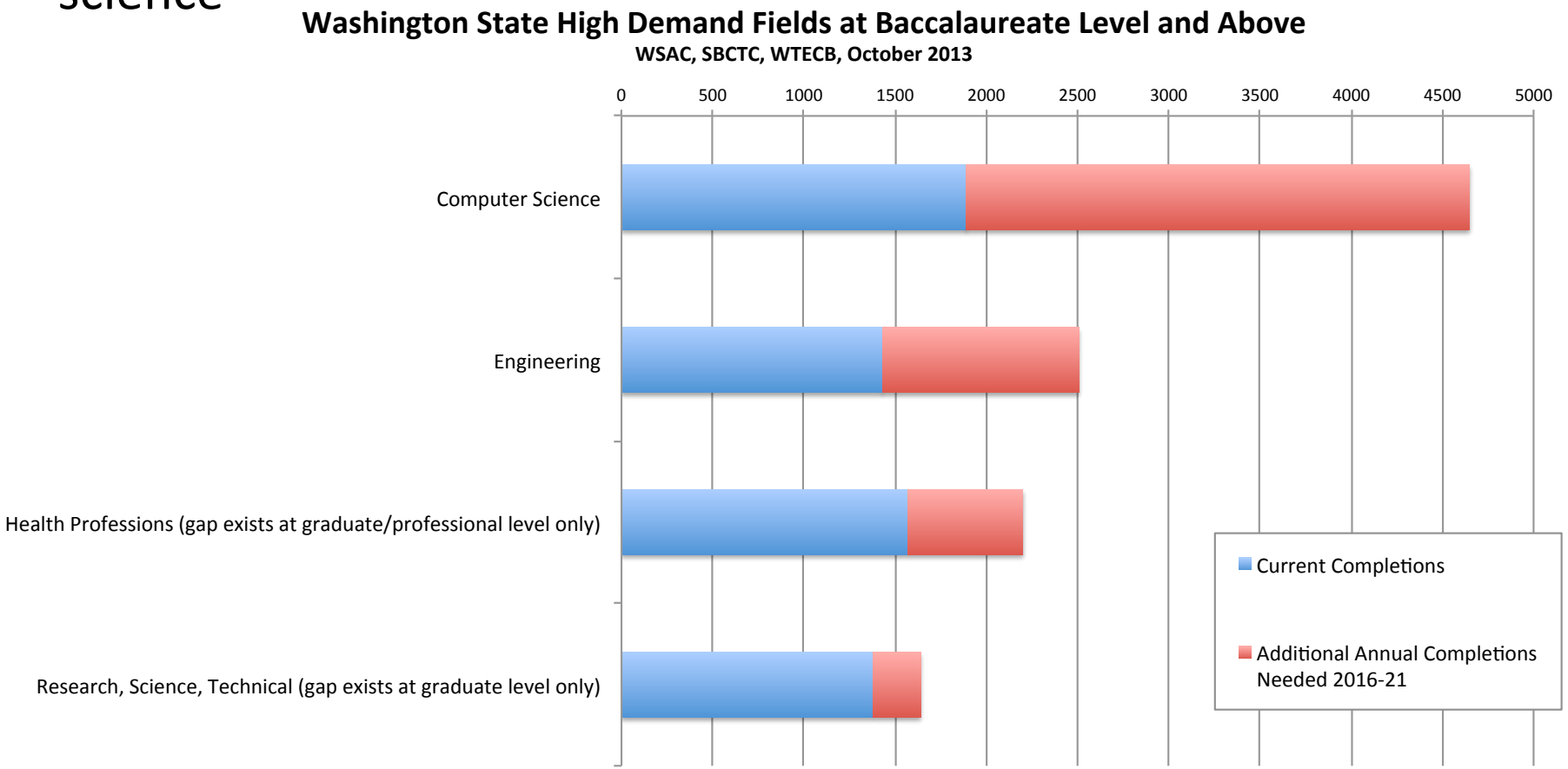


Data from Table 2 of the report linked at http://www.wsac.wa.gov/sites/default/files/2013.11.16.Skills.Report.pdf

Every high school should offer computer science
(and every student should take it!)

- *Not* because programming is a valuable skill (although it certainly is that)
- But because *every field is becoming an information field*
- And because *"computational thinking" is an essential 21st century capability*

Computer Science in K-12, 1983

A Nation At Risk

Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility.

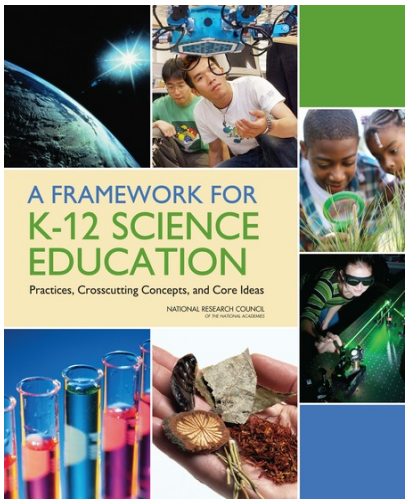
If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves.

Recommendation A: Content

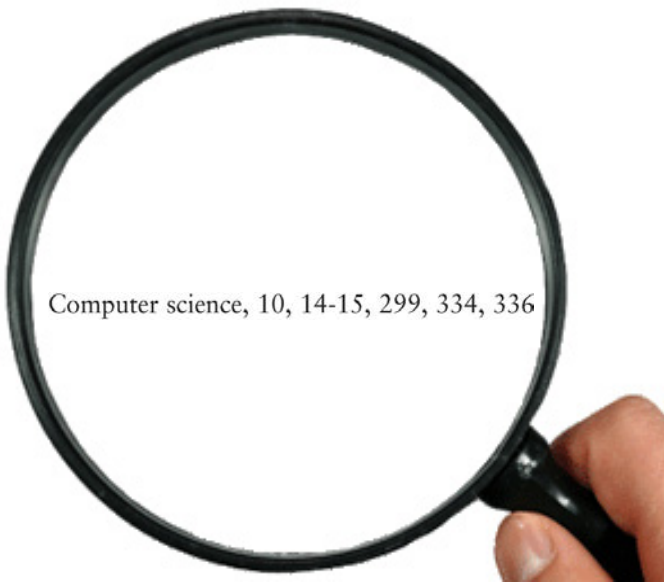
We recommend *that State and local high school graduation requirements be strengthened and that,* at a minimum, all *students seeking a diploma be required to lay the foundations in the Five New Basics by taking the following curriculum during their 4 years of high school: (a) 4 years of English; (b) 3 years of mathematics; (c) 3 years of science; (d) 3 years of social studies; and (e) one-half year of computer science.*

IBM PC XT
4.77 MHz 8088
128 KB RAM
PC DOS 2.0

Computer Science in K-12, 2013



401 page report
15 page index



Elementary (K–5)

Storylines: K–2 3–5 PDFs: K 1 2 3 4 5

K. Forces and Interactions: Pushes and Pulls
K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment
K. Weather and Climate
1. Waves: Light and Sound
1. Structure, Function and Information Processing
1. Space Systems: Patterns and Cycles
2. Structure and Properties of Matter
2. Interdependent Relationships in Ecosystems
2. Earth's Systems: Processes that Shape the Earth
K-2. Engineering Design
3. Forces and Interactions
3. Interdependent Relationships in Ecosystems
3. Inheritance and Variation of Traits
3. Weather and Climate
4. Energy
4. Waves
4. Structure, Function, and Information Processing
4. Earth's Systems: Processes that Shape the Earth
5. Structure and Properties of Matter
5. Matter and Energy in Organisms and Ecosystems
5. Earth's Systems
5. Space Systems: Stars and the Solar System
3-5. Engineering Design

PS: Physical Sciences

Middle School (6–8) Storyline PDF	High School (9–12) Storyline PDF
MS. Structure and Properties of Matter	**HS.** Structure and Properties of Matter
MS. Chemical Reactions	**HS.** Chemical Reactions
MS. Forces and Interactions	**HS.** Forces and Interactions
MS. Energy	**HS.** Energy
MS. Waves and Electromagnetic Radiation	**HS.** Waves and Electromagnetic Radiation

LS: Life Sciences

Middle School (6–8) Storyline PDF	High School (9–12) Storyline PDF
MS. Structure, Function, and Information Processing	**HS.** Structure and Function
MS. Matter and Energy in Organisms and Ecosystems	**HS.** Matter and Energy in Organisms and Ecosystems
MS. Interdependent Relationships in Ecosystems	**HS.** Interdependent Relationships in Ecosystems
MS. Growth, Development, and Reproduction of Organisms	**HS.** Inheritance and Variation of Traits
MS. Natural Selection and Adaptations	**HS.** Natural Selection and Evolution

ESS: Earth and Space Sciences

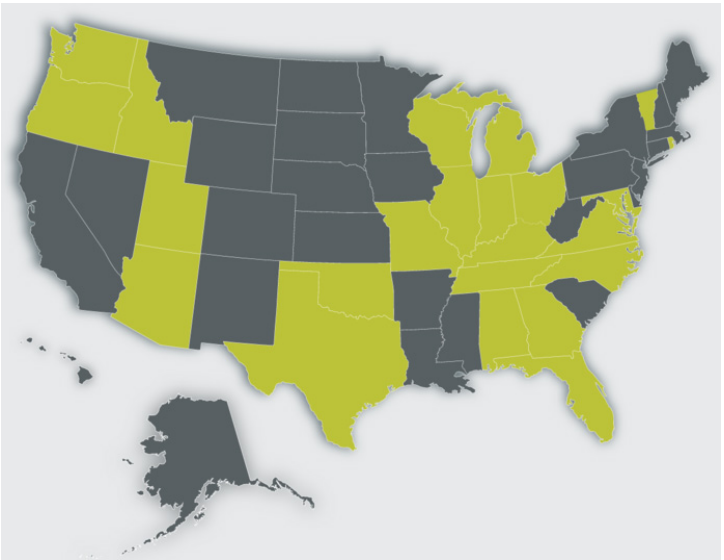
Middle School (6–8) Storyline PDF	High School (9–12) Storyline PDF
MS. Space Systems	**HS.** Space Systems
MS. History of Earth	**HS.** History of Earth
MS. Earth's Systems	**HS.** Earth's Systems
MS. Weather and Climate	**HS.** Weather and Climate
MS. Human Impacts	**HS.** Human Sustainability

ETS: Engineering, Technology, and Applications of Science

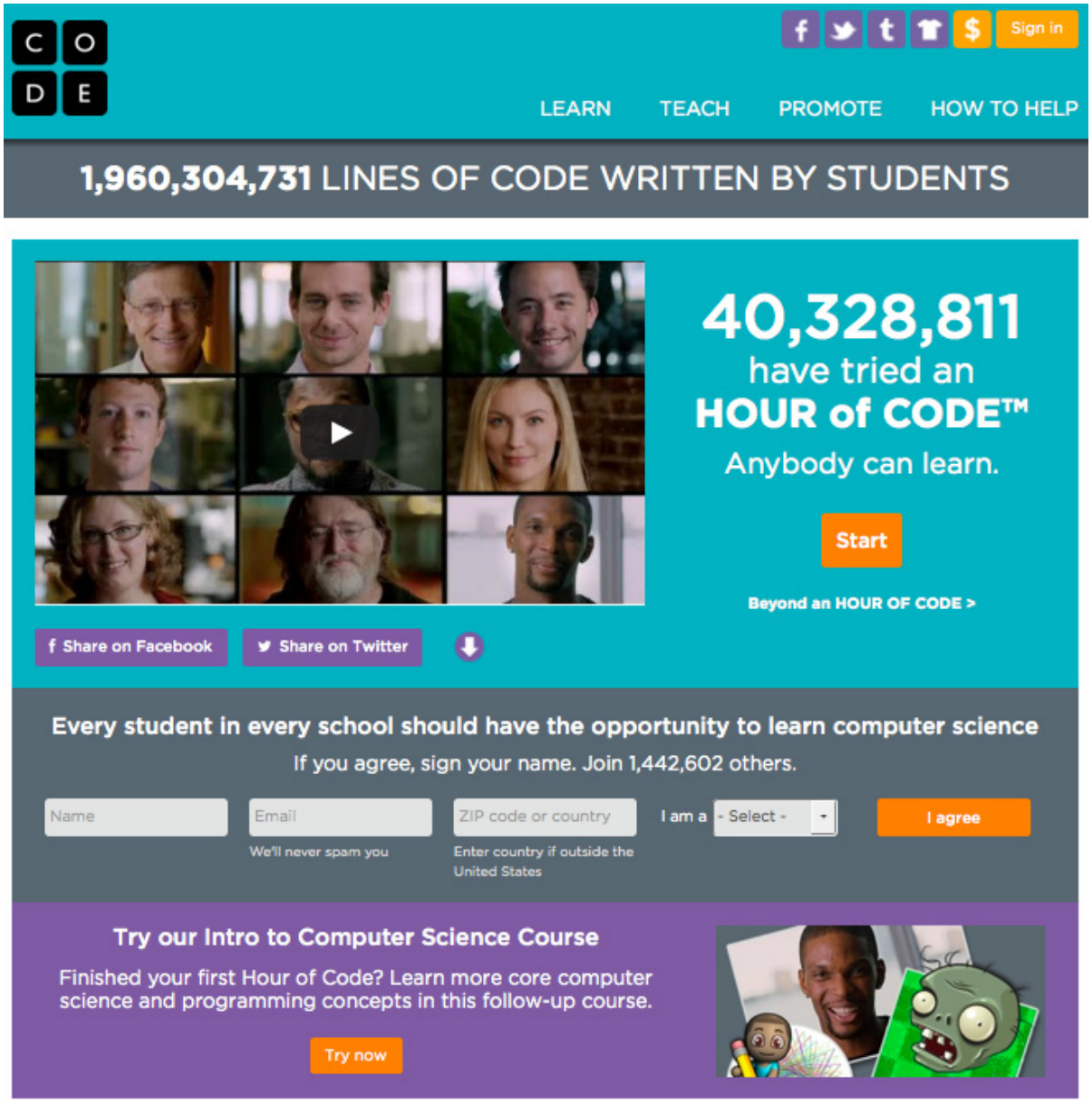
Middle School (6–8) Storyline PDF	High School (9–12) Storyline PDF
MS. Engineering Design	**HS.** Engineering Design

- In 9 out of 10 high schools nationwide, computer science is not offered

- In 27 of the 50 states, computer science does not count towards the math or science graduation requirement



Yet computer science – "computational thinking" – is a key capability for just about every 21st century endeavor



Hadi Partovi
Code.org

UW Computer Science & Engineering

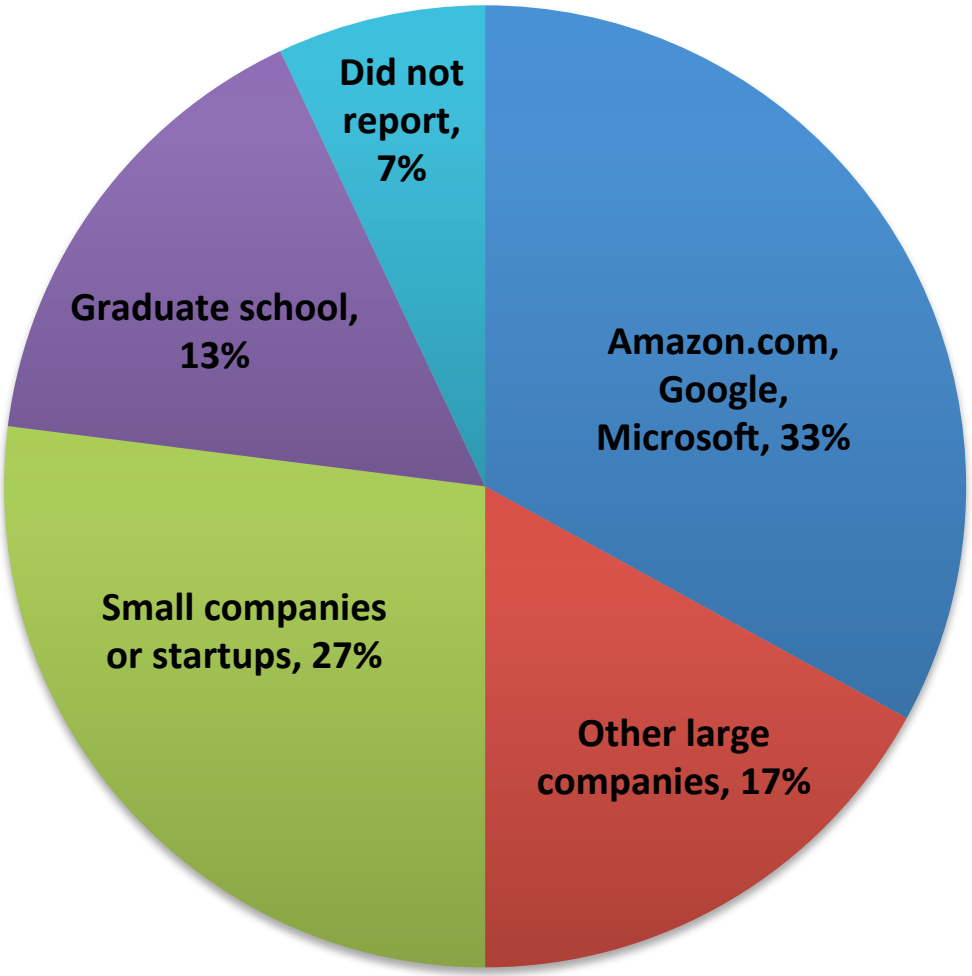
- Ranked among the top 10 programs in the nation (of >200)
  - MIT, Stanford, Berkeley, Carnegie Mellon, Illinois, Cornell, Washington, Princeton, Georgia Tech, Texas, Caltech, Wisconsin, UCLA, Michigan, Columbia, UCSD …
- Two undergraduate programs
  - Computer Science (College of Arts & Sciences)
  - Computer Engineering (College of Engineering)
- > 300 degrees per year
  - ~200 Bachelors (growing to ~250)
  - ~85 Masters
  - ~25 Ph.D.

- Extraordinary students
  - Fully 1/3 of the UW class medalists since 2000 have been CSE majors
    - Our “fair share” would be 2%
  - 3 of the past 5 Graduate School Medal recipients
    - “Academic expertise and social awareness”

- A deep commitment to providing a top-tier education
  - Winner of 5 UW Distinguished Teaching Awards
  - Winner of the inaugural UW Brotman Award for Instructional Excellence
  - Winner of two UW Distinguished Graduate Mentor Awards
  - In a typical quarter, CSE has 2/3's of the top-performing instructors in the 10-department UW College of Engineering, according to student course evaluations
    - 9 of the top 10 instructors in the most recent quarter

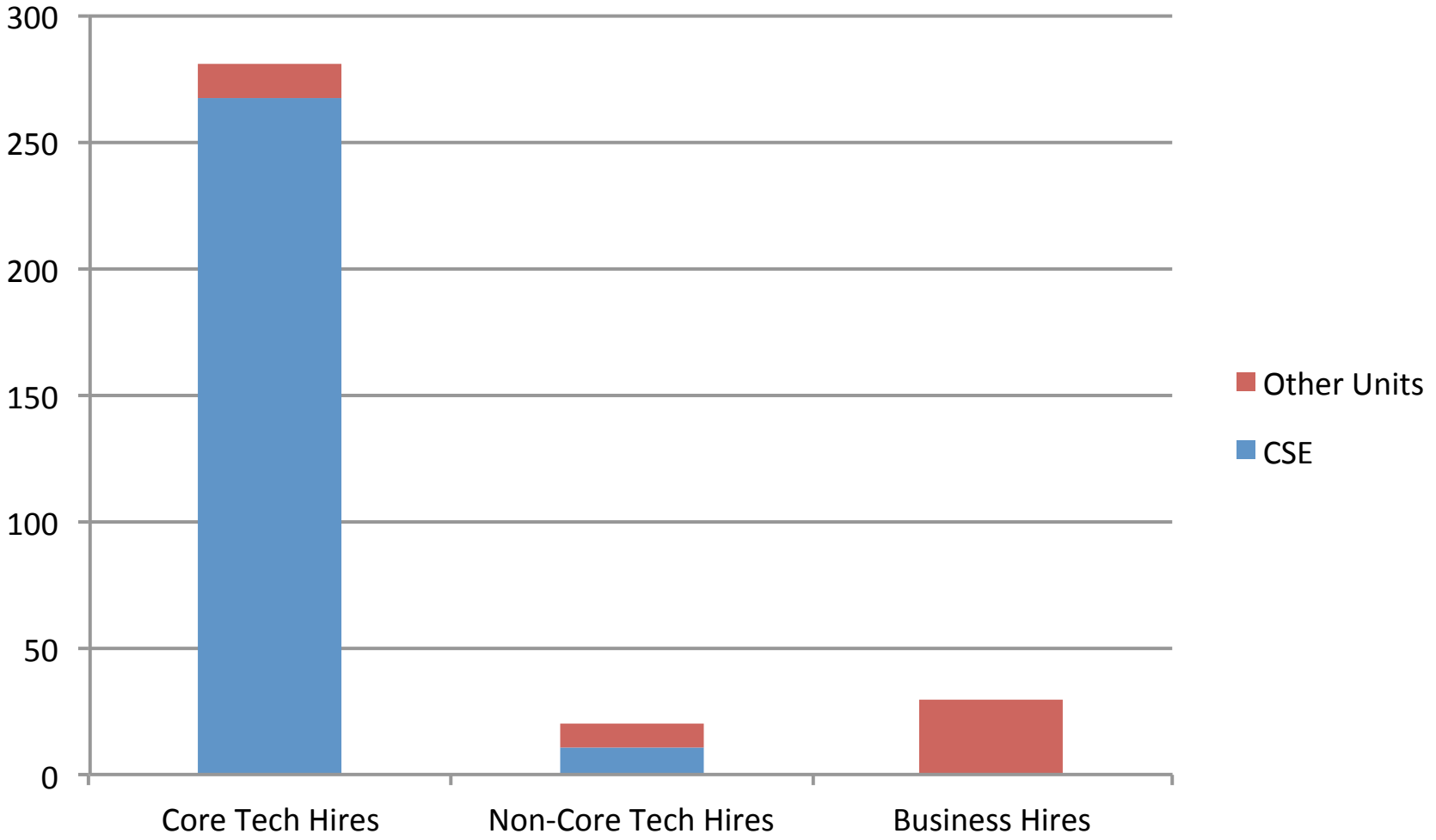
- We produce students who can *design and build stuff*
  - Emphasis on teamwork and design
  - 80% of undergraduates do at least one internship
  - 50% of undergraduates participate in faculty-guided research
    - #1 school in the nation in students recognized in the past 10 years in the Computing Research Association "Outstanding Undergraduate Researchers Award" competition
  - A top-5 supplier of students to Amazon.com, Google, and Microsoft (along with MIT, Stanford, Berkeley, and Carnegie Mellon)
  - The predominate supplier to many leading smaller firms headquartered here

2012-13 UW CSE Student Destinations



Tech companies that can be choosy, choose CSE

2011-12 Permanent & Internship Hires from UW by Amazon.com, Facebook, Google, and Microsoft



Why a research-intensive university?

What can we uniquely do?

- Get students into the lab
- Make them our partners in discovery
- Prepare them for life-long learning at the forefront of knowledge and society
    - *There is no field in which this is more important!*

Community: Undergraduate TAs

Community: Grace Hopper Celebration of Women in Computing

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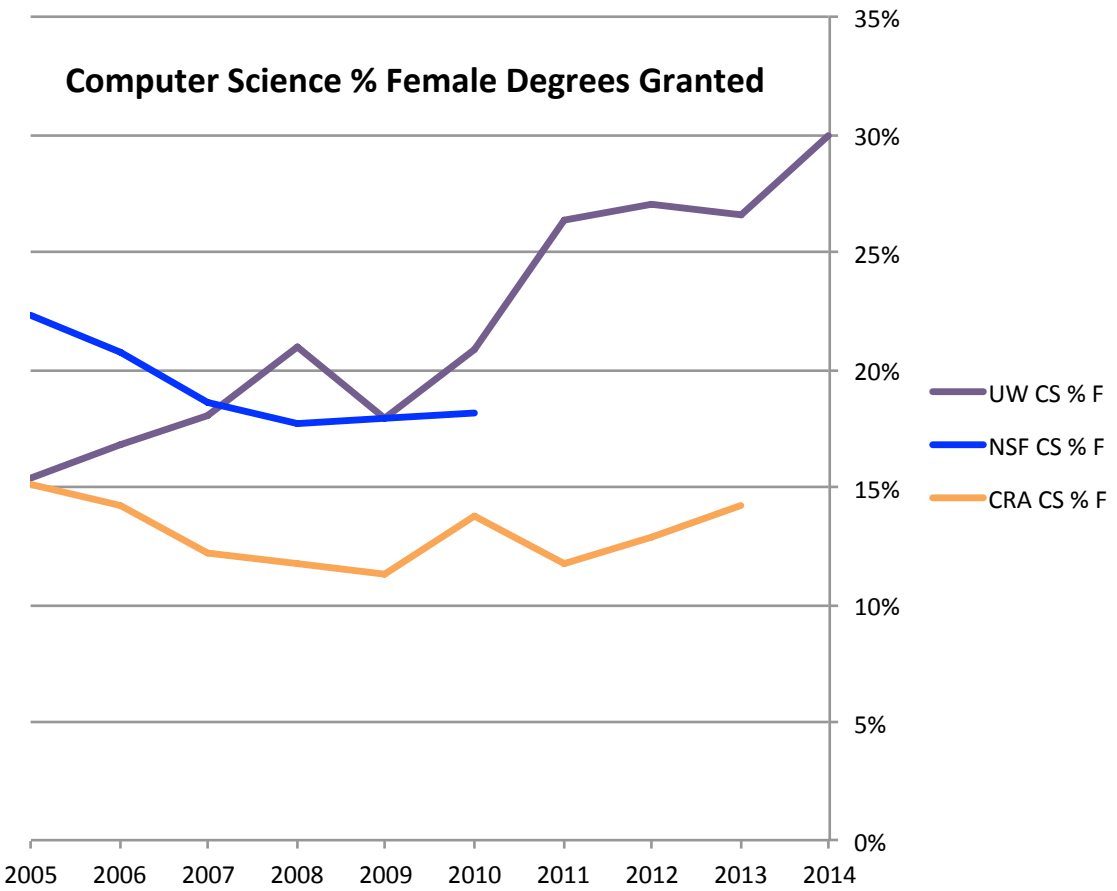


Community: Spring picnic

Community: Summer Day Camps for Middle School Girls

DAWG BYTES

A TASTE OF CSE

There are some OK reasons to go out-of-state for college

- Get away from your boyfriend/girlfriend
- Get away from your parents
- Get away from the rain

Getting a better Computer Science education is not one of them!

- Erin Earl
  - Overlake School -> Robinson Center Transition School -> Robinson Center Early Entrance Program
  - Triple major in Music, Piano Performance, Computer Science
  - UW Dean's Medal for the Arts
  - Indiana University Conservatory (3 months)
  - Google (5 years)
  - Harvard Law School
  - Clerkship in the United States District Court for the Eastern District of Virginia
  - Clerkship in the United States Court of Appeals for the Ninth Circuit
  - Headed home to Seattle this fall to focus on privacy and security in Perkins Coie's commercial litigation group

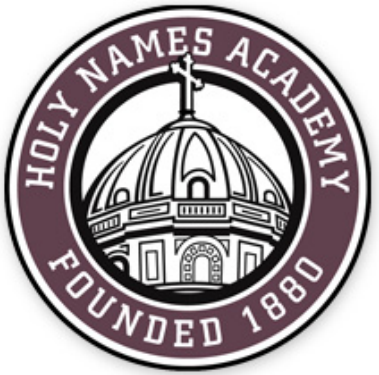
- Raymond Zhang
  - Robinson Center Transition School -> Robinson Center Early Entrance Program
  - Double major in Biology, Computer Science
    - Undergraduate research in computational biology
  - Goldwater Scholar
  - Piano performances at Carnegie Hall, Lincoln Center, Benaroya Hall
  - 2013 UW Dean's Medal in Engineering
  - Google

- Christophe Bisciglia
  - Gig Harbor High School
  - UW CSE
  - Google (5 years)
  - Cloudera, Inc. (Founder) (2.5 years)
  - WibiData (Founder and CEO)

- Emma (Lynch) Nixon
  - Ballard High School ‘07
  - UW CSE ‘11
    - Undergraduate research on Games for Learning – Refraction
    - SDE intern at Microsoft
  - SDE at Microsoft

UW CSE and Holy Names

- Caitlin Lustig, 2008 / Ph.D. student, Informatics, UC Irvine
- Kathryn Winglee, 2009 / Ph.D. student, Cellular and Molecular Medicine, Johns Hopkins University
- Allie Rutherford, 2011 / Program Manager, Microsoft
- Krysta Yousoufian, 2011 / Software Engineer, Microsoft
- Jenny Abrahamson, 2012 / Software Engineer, Facebook
- Christine Acuario, 2012 / Software Engineer, Expedia
- Ally Gale, 2013 / Associate Product Manager, Google (Zürich)
- Jennifer Apacible , 2014 / Software Engineer, Google
- Micaela Montstream
- Karolina Pyszkiewicz
- Abby Gray
- Madeline Wessels



Preparing for CSE

- Not necessarily a high school computer science course!

- Deep comfort with algebra
- Scientific reasoning
- Reading comprehension

- Attention span
- Resilience when faced with challenges

Is this a great time or what?

http://lazowska.cs.washington.edu/HolyNames.pdf,pptx