Computer Science: Past, Present, and Future

Ed Lazowska

Bill & Melinda Gates Chair in
Computer Science & Engineering
University of Washington

Chair, Computing Community Consortium

University of Michigan

October 2012

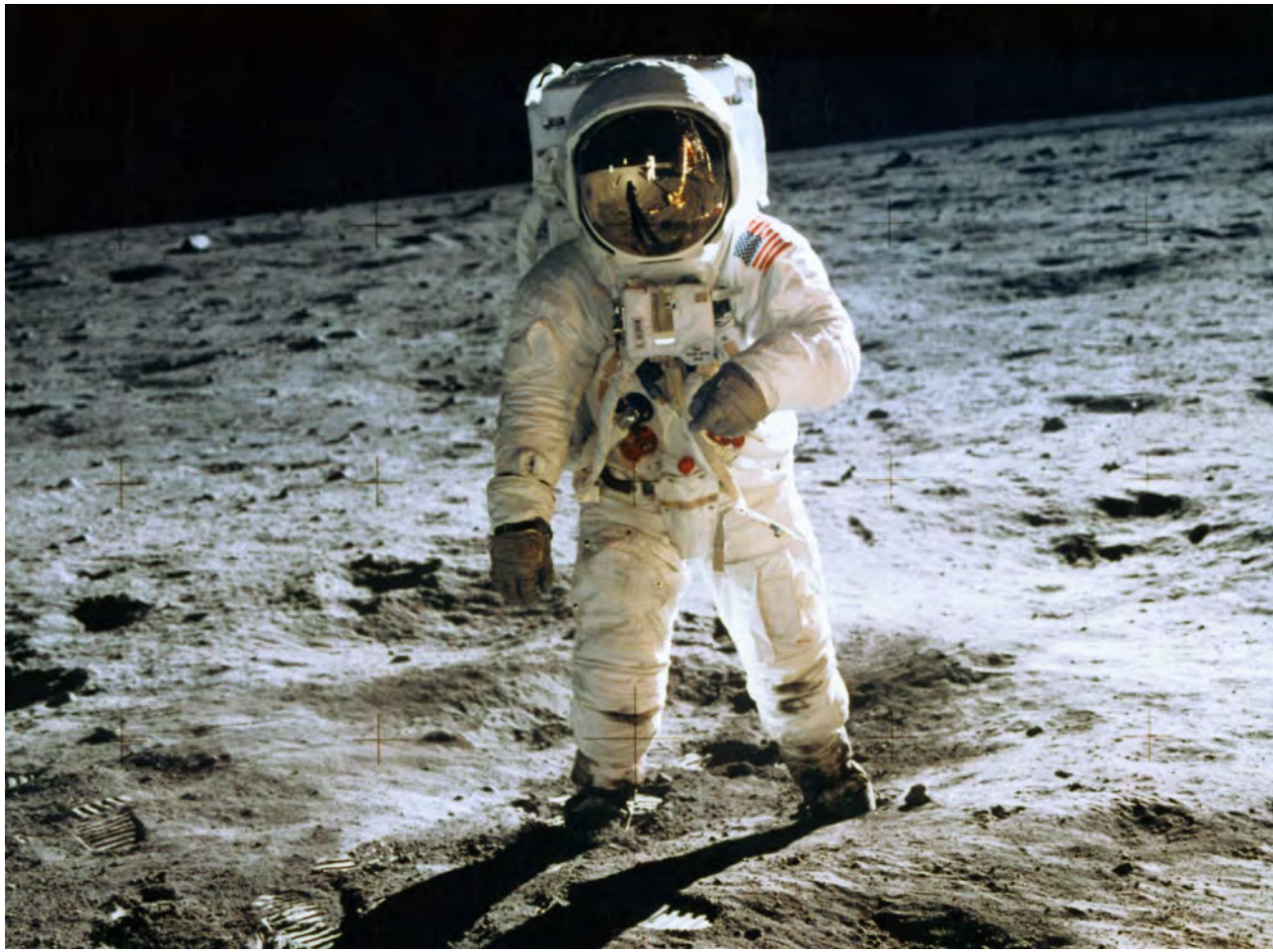
http://lazowska.cs.washington.edu/michigan.pdf

Today …

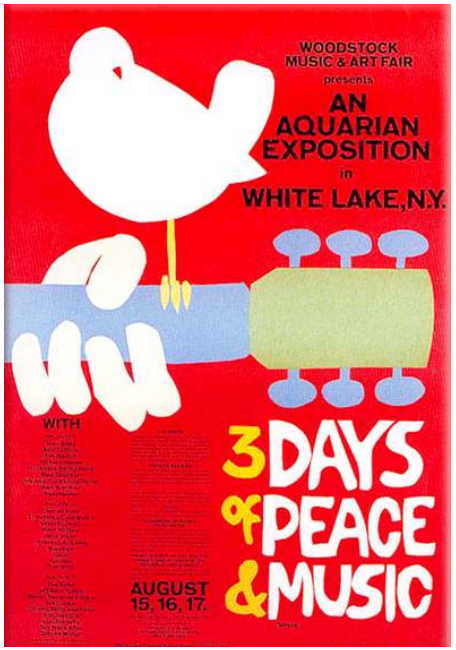
- A quick reminder of what we've accomplished as a field, and of how we got there
- The Computing Community Consortium: origins, goals, recent activities
- The next ten years
- A few exhortations

Forty years ago …

Credit: Peter Lee, Microsoft Research




1969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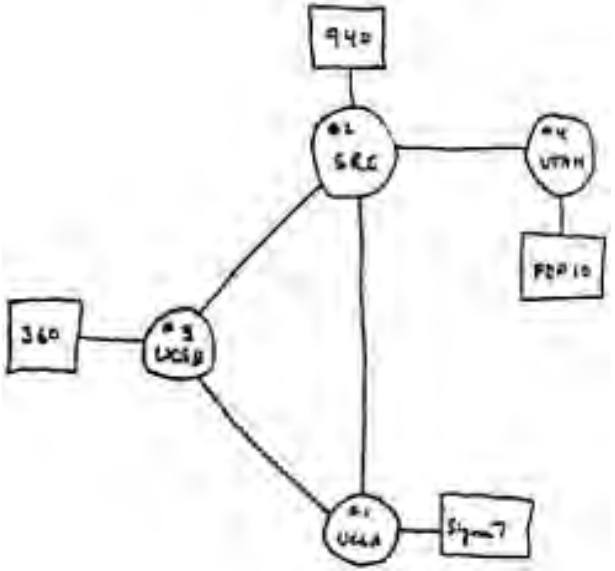
presents
AN
AQUARIAN
EXPOSITION
in
WHITE LAKE, N.Y.
WITH
3 DAYS
of PEACE
& MUSIC
AUGUST
15, 16, 17.

1969


1969 WORLD SERIES
NEW YORK METS

WORLD
CHAMPIONS
NEW YORK METS
1969


1969



THE ARPA NETWORK
DEC 1969
4 NODES

29OCT69	2100	LOADED 1 OP. PROGRAM FOR BEN BARKER BBN	CSK
	22:30	Talked to SRI Host to Host	CSK
		Left up. imp. program running after sending a host dead message to imp.	CSK

With forty years hindsight, which had the greatest impact?

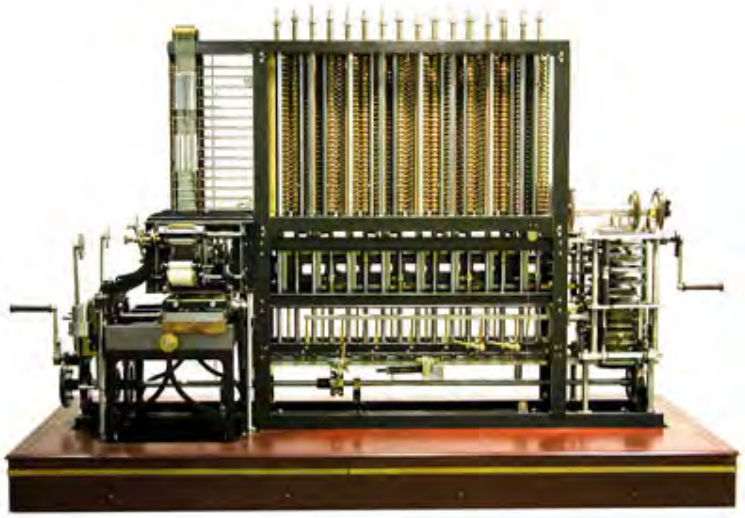
- Unless you're big into Tang and Velcro (or sex and drugs), the answer is clear …

- And so is the reason …

EXPONENTIALS R US

EXPONENTIALS R US

- Mechanical



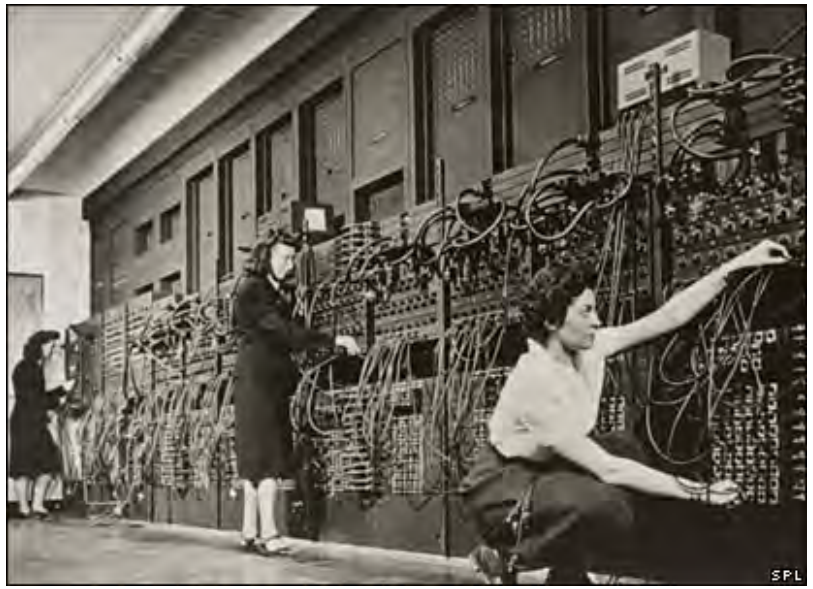
Babbage's Difference Engine No. 2
(designed 1847-1849,
constructed 1989-2000)
[11'x7', 8000 parts, 5 tons]

Vannevar Bush's Differential Analyzer (1931)

Vacuum tube electronic

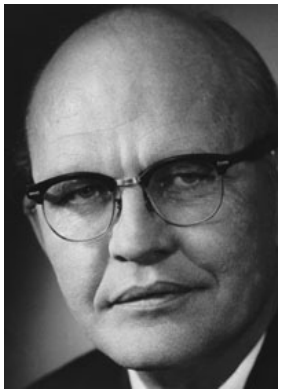
ENIAC (constructed 1943-1946)

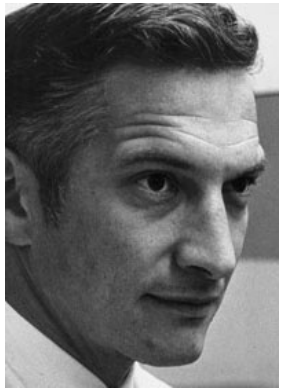
[8.5′ (h) x 3′ (d) x 80′ (linear),
30 tons, 17,468 vacuum tubes,
150 kW of power, 5,000 additions/second]

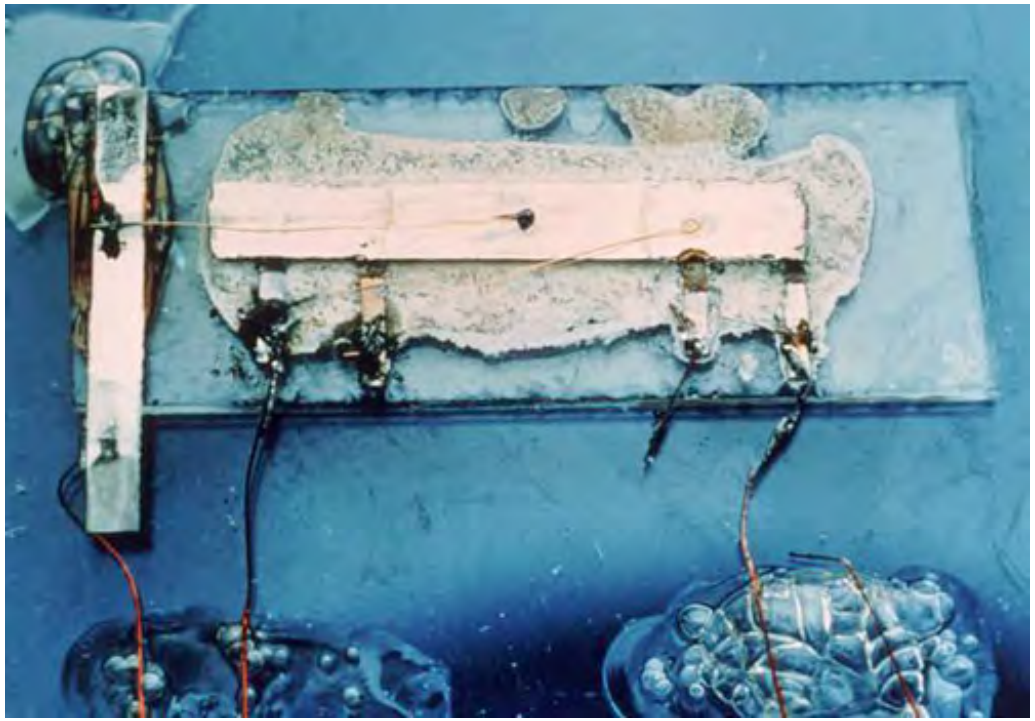


- The transistor (1947)
  - William Shockley, Walter Brattain and John Bardeen, Bell Labs

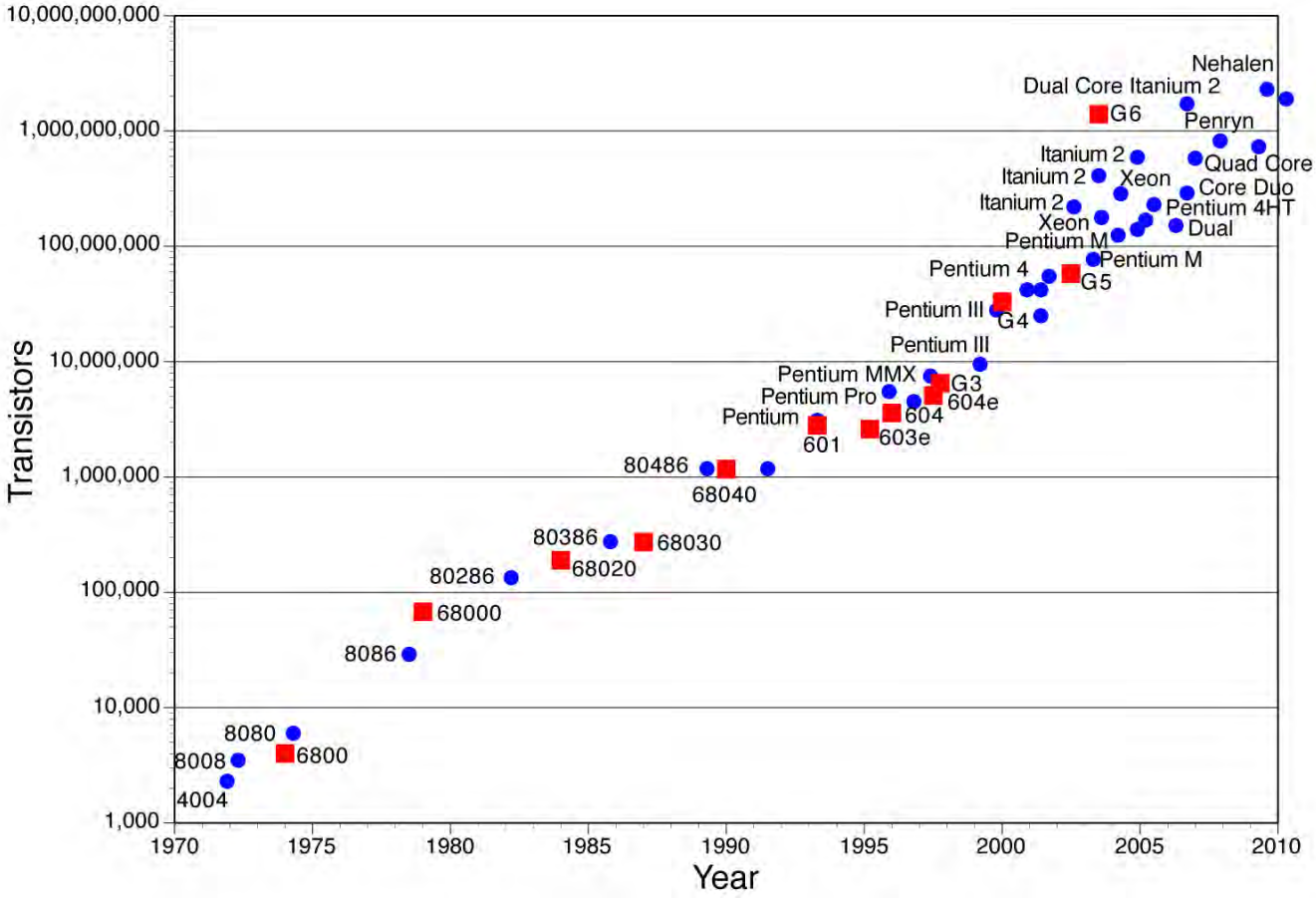
- The integrated circuit (1958)
  - Jack Kilby, Texas Instruments, and Bob Noyce, Fairchild Semiconductor Corporation





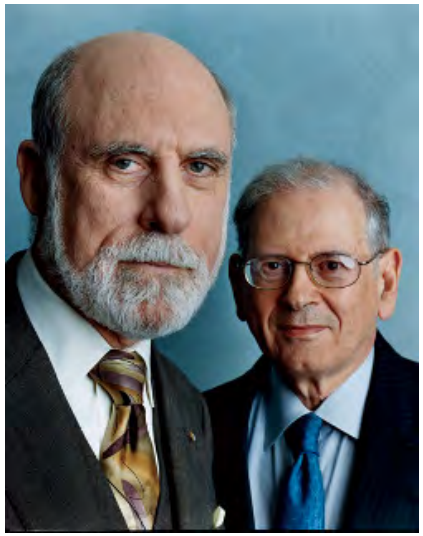


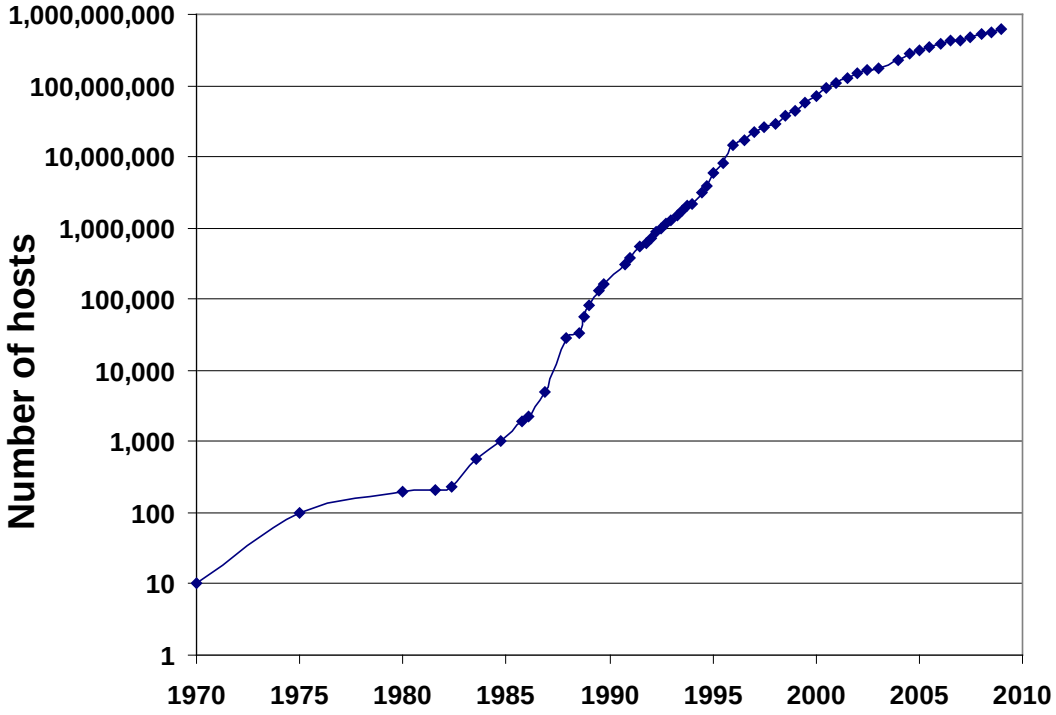
Moore's Law and exponential progress (1965-today)




UNIVAC

Ditto the Internet

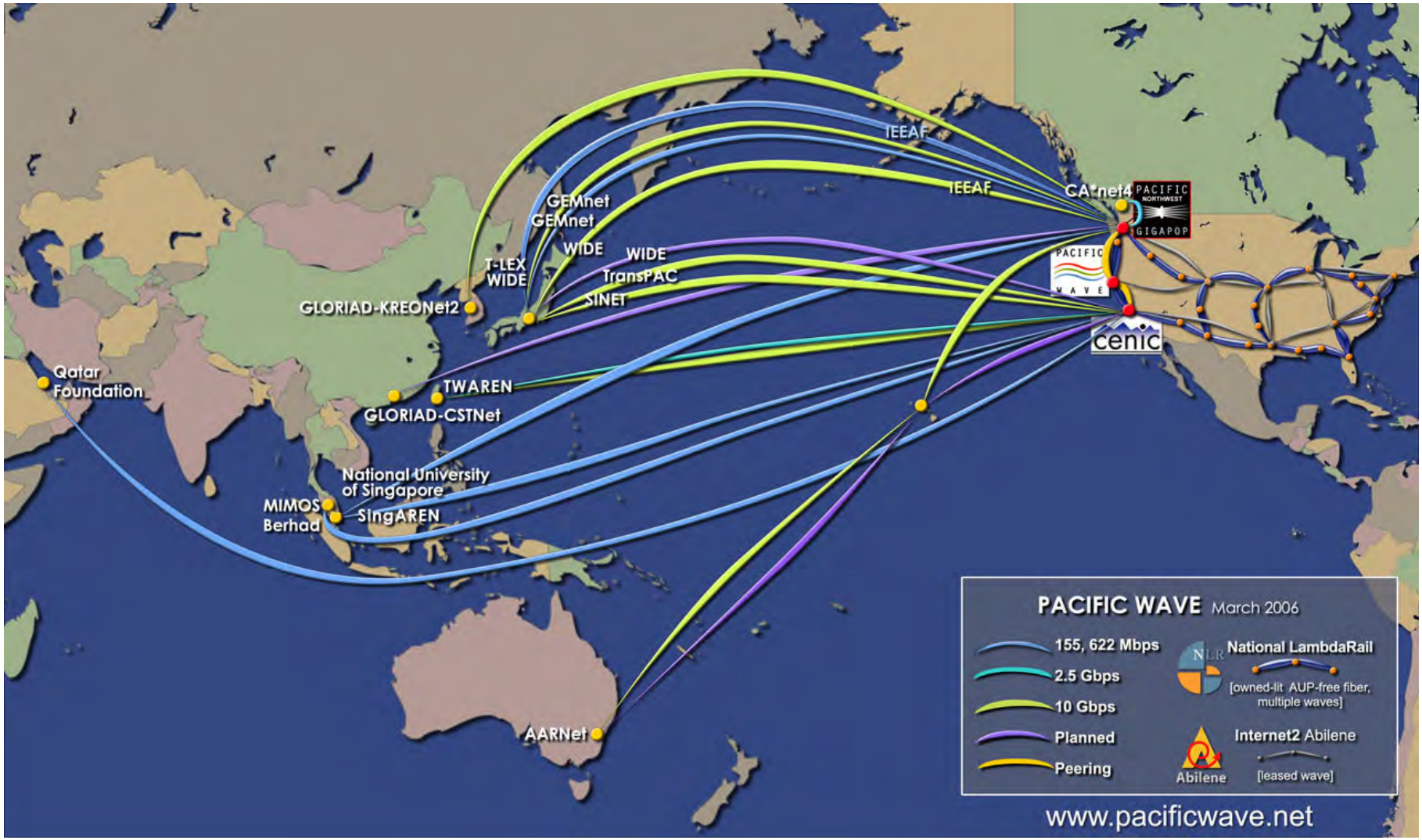




In just the past 20 years (1992-2012), the number of Internet hosts and the number of transistors on a die each have increased 2000x!

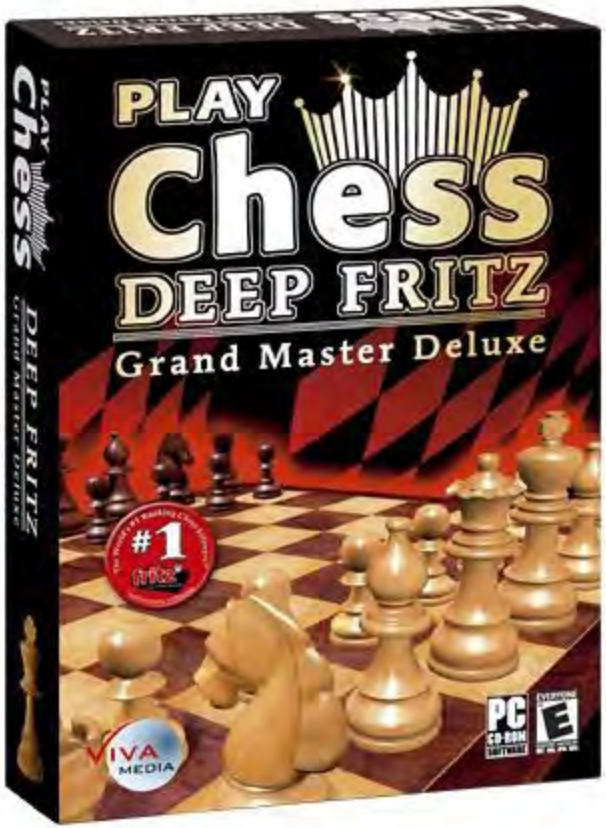
A connected region – then

A connected region – now



- Ditto software

Deep Blue, 1997



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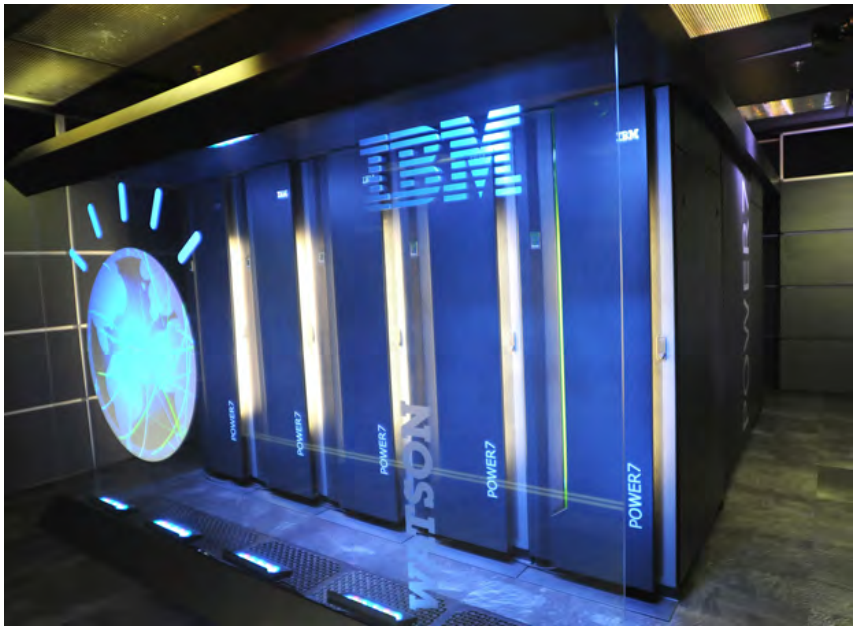
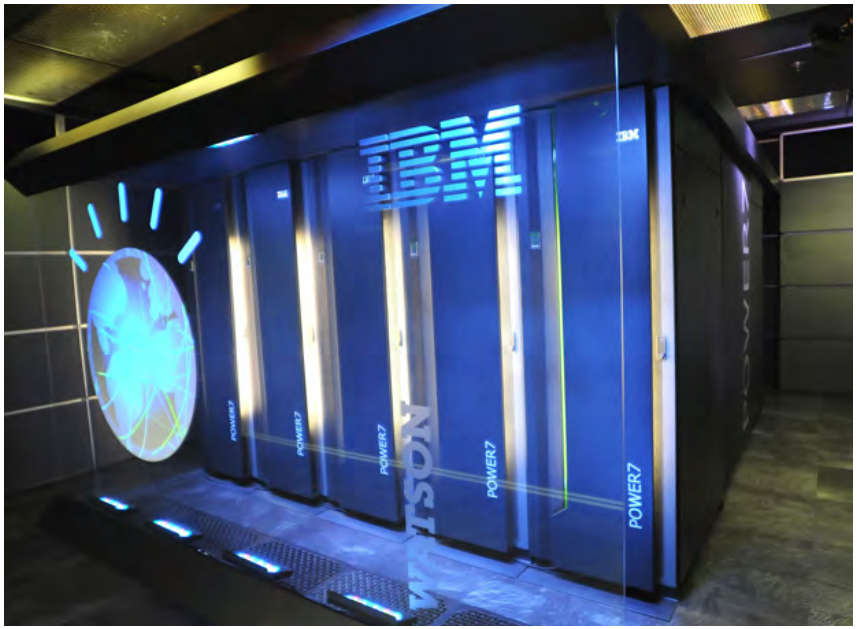
Deep Fritz, 2002



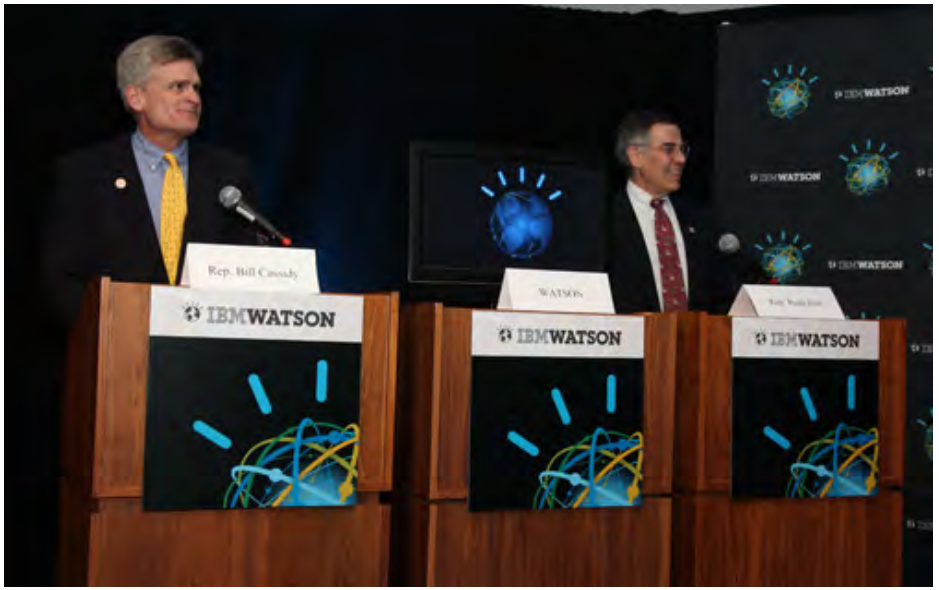
Watson, 2011

Ken Jennings, Watson, Brad Rutter

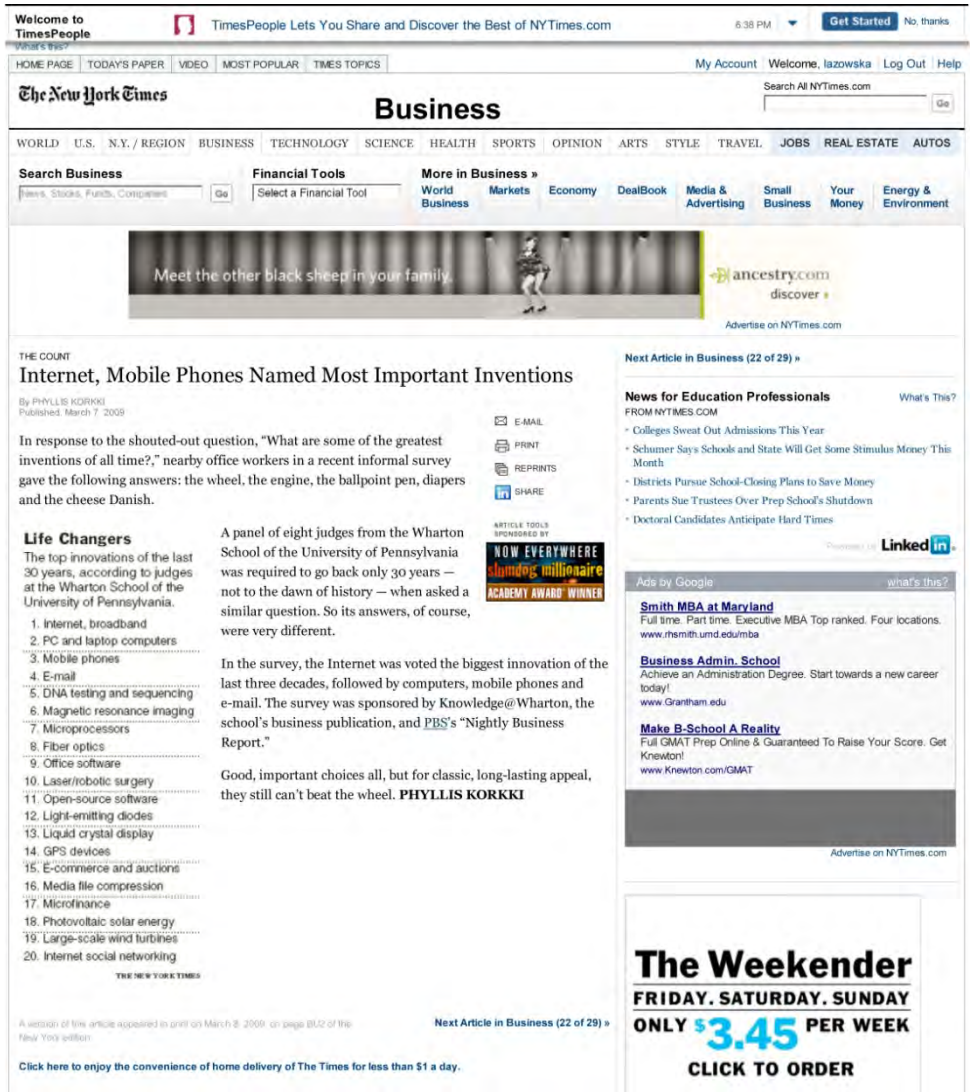


Watson, 2011

Bill Cassidy, Watson, Rush Holt



The past thirty years …



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THE COUNT

Internet, Mobile Phones Named Most Important Inventions

By PHYLLIS KORKKI
Published: March 7, 2009

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In response to the shouted-out question, "What are some of the greatest inventions of all time?," nearby office workers in a recent informal survey gave the following answers: the wheel, the engine, the ballpoint pen, diapers and the cheese Danish.

Life Changers

The top innovations of the last 30 years, according to judges at the Wharton School of the University of Pennsylvania.

1. Internet, broadband
2. PC and laptop computers
3. Mobile phones
4. E-mail
5. DNA testing and sequencing
6. Magnetic resonance imaging
7. Microprocessors
8. Fiber optics
9. Office software
10. Laser/robotic surgery
11. Open-source software
12. Light-emitting diodes
13. Liquid crystal display
14. GPS devices
15. E-commerce and auctions
16. Media file compression
17. Microfinance
18. Photovoltaic solar energy
19. Large-scale wind turbines
20. Internet social networking

THE NEW YORK TIMES

A panel of eight judges from the Wharton School of the University of Pennsylvania was required to go back only 30 years — not to the dawn of history — when asked a similar question. So its answers, of course, were very different.

In the survey, the Internet was voted the biggest innovation of the last three decades, followed by computers, mobile phones and e-mail. The survey was sponsored by Knowledge@Wharton, the school's business publication, and PBS's "Nightly Business Report."

Good, important choices all, but for classic, long-lasting appeal, they still can't beat the wheel. **PHYLLIS KORKKI**

A version of this article appeared in print on March 8, 2009, on page BU2 of the New York edition.

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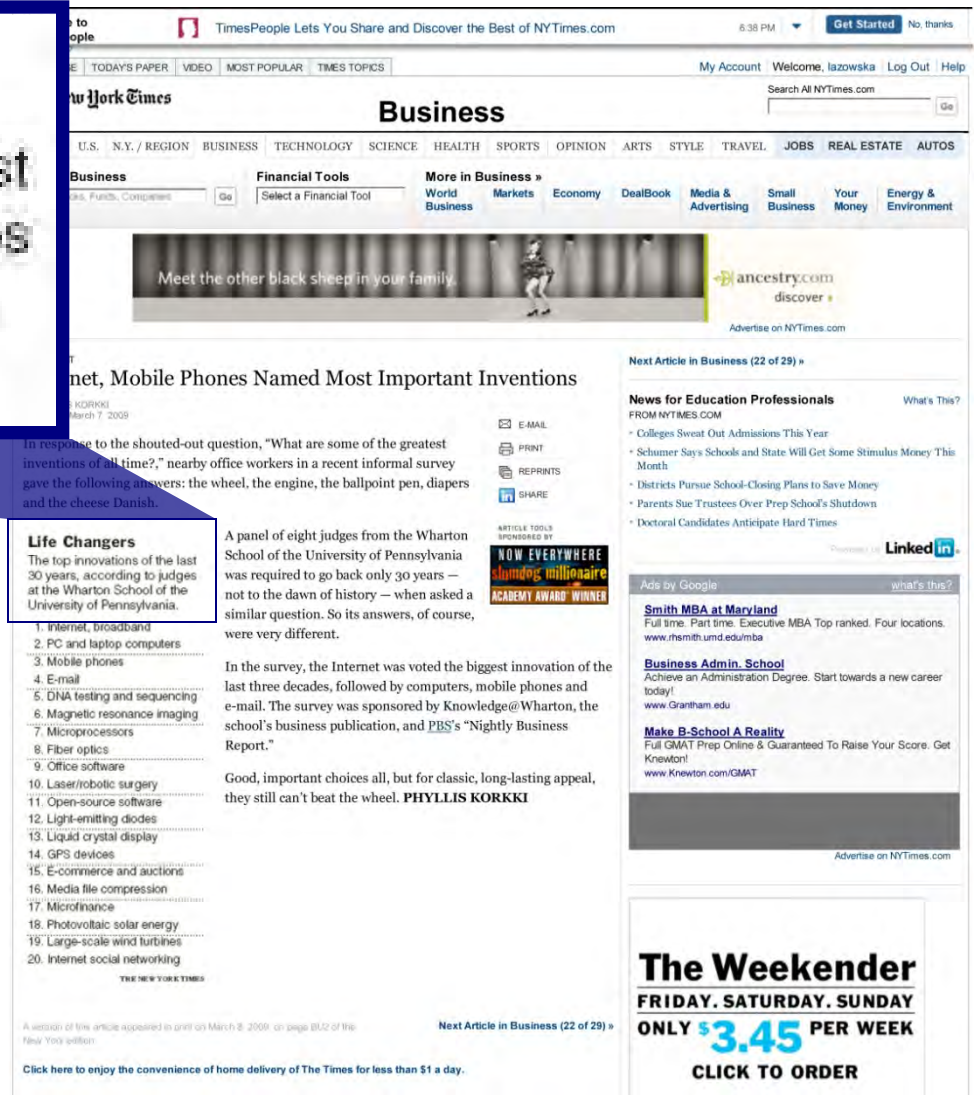

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Meet the other black sheep in your family.

…net, Mobile Phones Named Most Important Inventions

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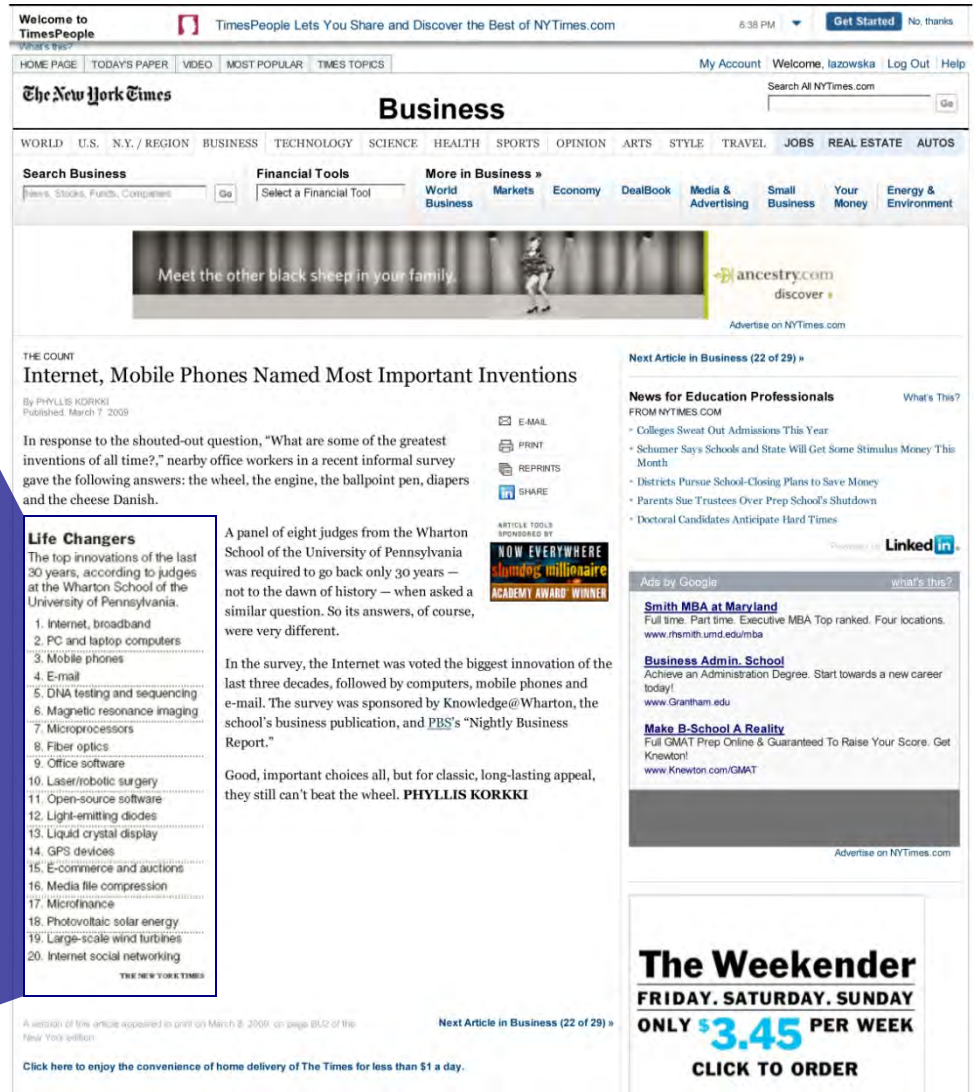

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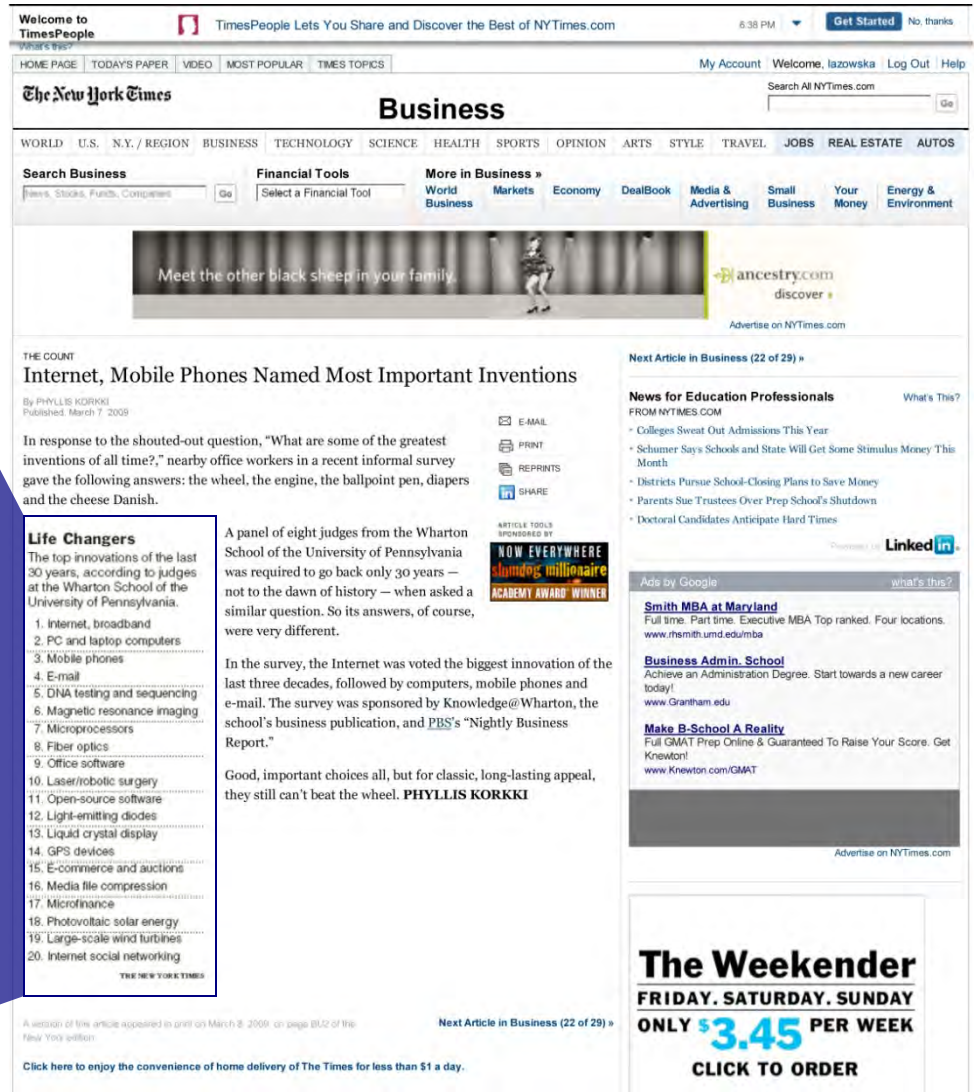
THE NEW YORK TIMES



The most recent ten years …

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

Xconomy
Business + Technology in the Exponential Economy

Scalability

AlphaServer 1200 product brief

Leadership
"To support our rapid growth, we had to find a highly upgradable and scaleable Internet server. The AlphaServer platform provides the upgrade path we need."

Jeff Bezos
CEO and Founder
Amazon.com

amazon.com

- A decade later …
  - Vastly greater scale
  - The cheapest imaginable components
  - Failures occur all the time
    - You couldn't afford to prevent or mask them in hardware
  - Software makes it
    - Fault-Tolerant
    - Highly Available
    - Recoverable
    - Consistent
    - Scalable
    - Predictable
    - Secure

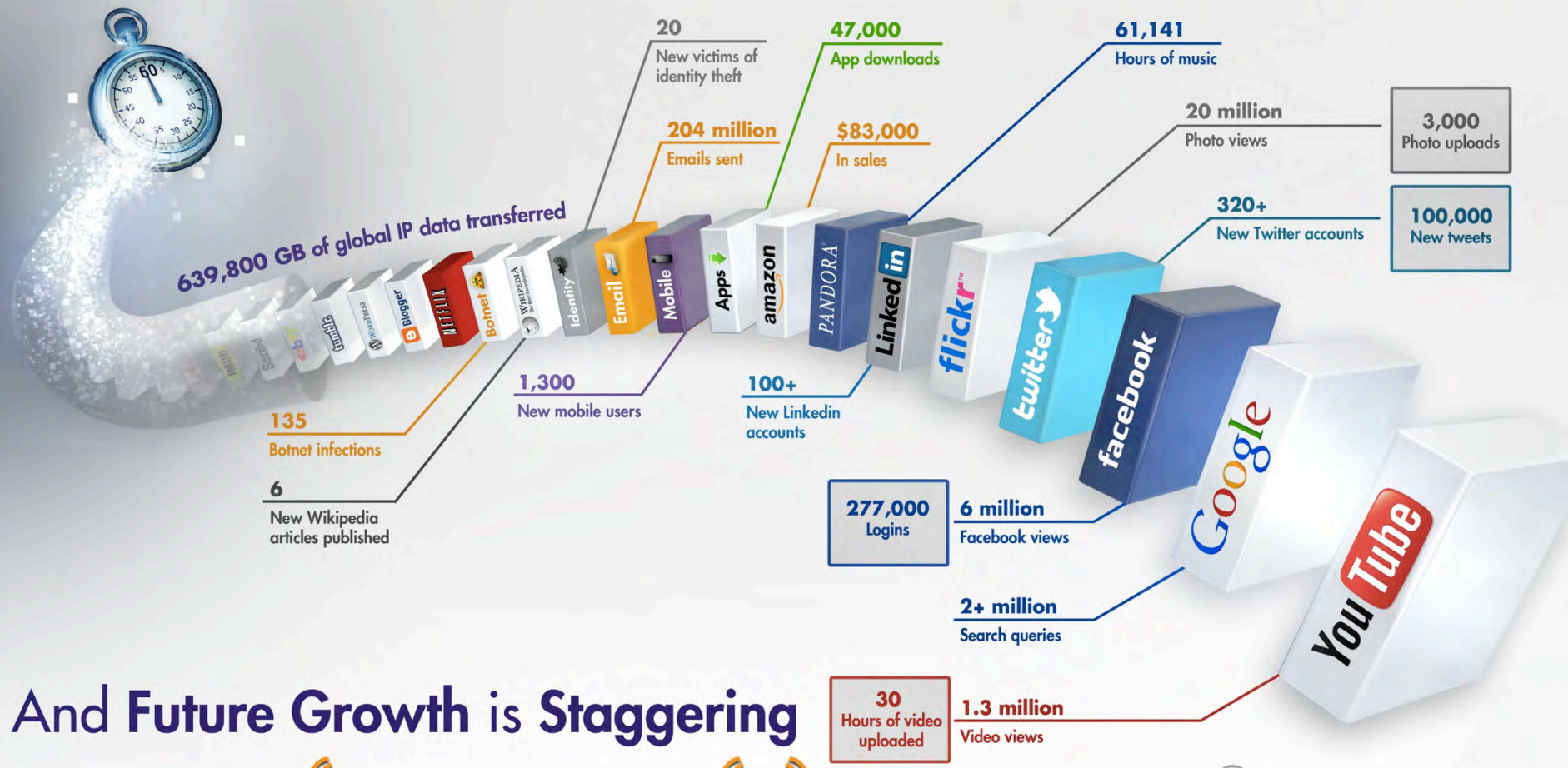
Digital media

- Text
- Audio
- Images
- Video

- Create
- Edit
- Consume

Mobility

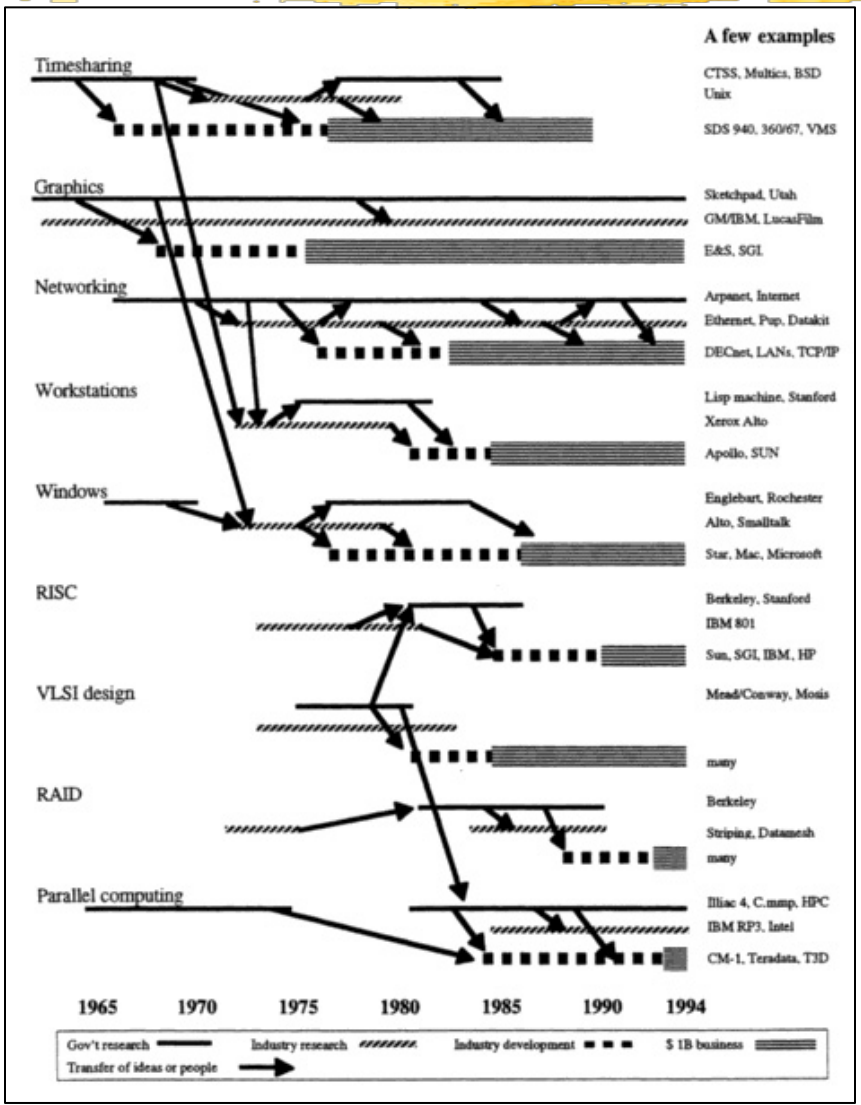
What Happens in an **Internet Minute?**



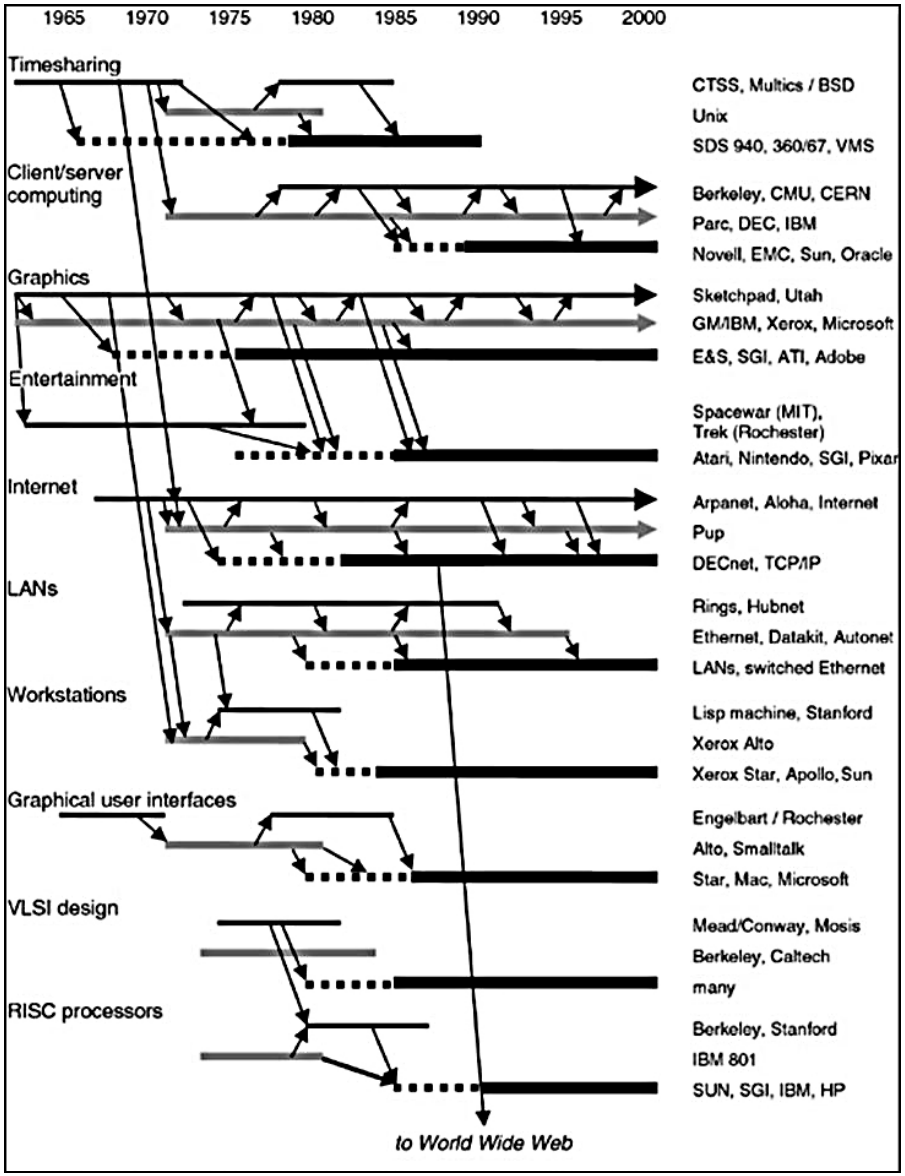
And **Future Growth** is **Staggering**

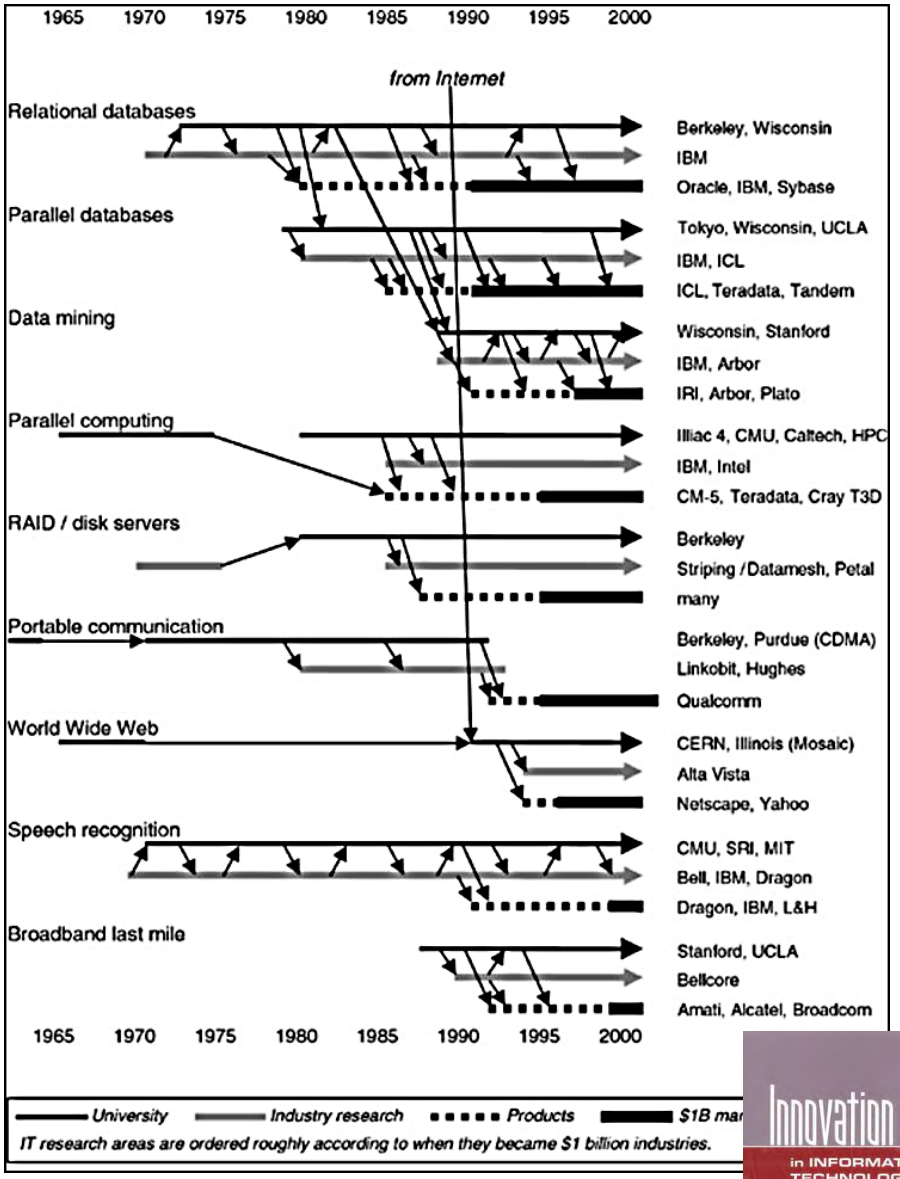
Credit: Intel Corporation

How did all this come to pass?



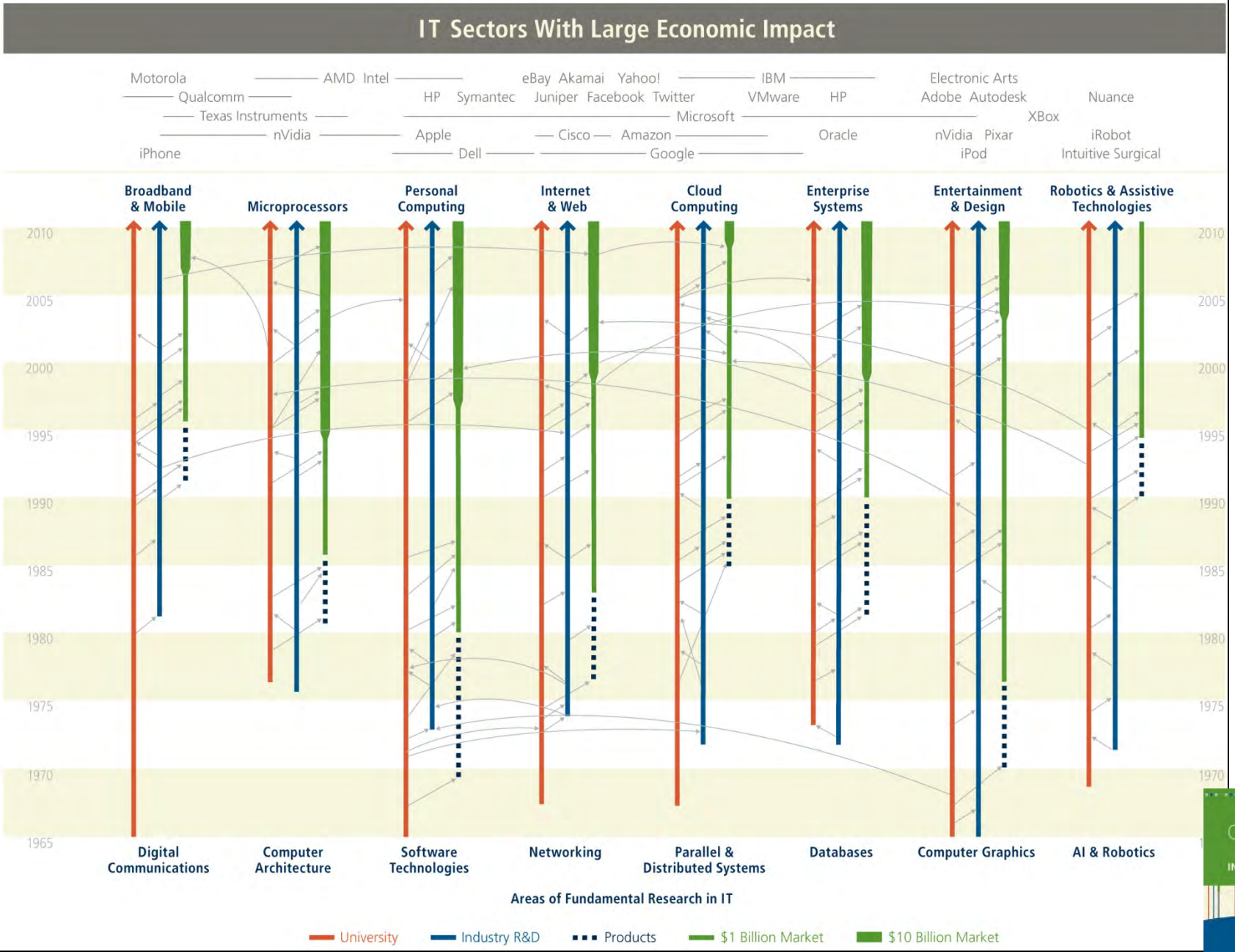
1995


1965 1970 1975 1980 1985 1990 1995 2000
Timesharing
CTSS, Multics / BSD
Unix
SDS 940, 360/67, VMS
Client/server computing
Berkeley, CMU, CERN
Parc, DEC, IBM
Novell, EMC, Sun, Oracle
Graphics
Sketchpad, Utah
GM/IBM, Xerox, Microsoft
E&S, SGI, ATI, Adobe
Entertainment
Spacewar (MIT), Trek (Rochester)
Atari, Nintendo, SGI, Pixar
Internet
Arpanet, Aloha, Internet
Pup
DECnet, TCP/IP
LANs
Rings, Hubnet
Ethernet, Datakit, Autonet
LANs, switched Ethernet
Workstations
Lisp machine, Stanford
Xerox Alto
Xerox Star, Apollo, Sun
Graphical user interfaces
Engelbart / Rochester
Alto, Smalltalk
Star, Mac, Microsoft
VLSI design
Mead/Conway, Mosis
Berkeley, Caltech
many
RISC processors
Berkeley, Stanford
IBM 801
SUN, SGI, IBM, HP
to World Wide Web


1965 1970 1975 1980 1985 1990 1995 2000
from Internet
Relational databases
Berkeley, Wisconsin
IBM
Oracle, IBM, Sybase
Parallel databases
Tokyo, Wisconsin, UCLA
IBM, ICL
ICL, Teradata, Tandem
Data mining
Wisconsin, Stanford
IBM, Arbor
IRI, Arbor, Plato
Parallel computing
Illiac 4, CMU, Caltech, HPC
IBM, Intel
CM-5, Teradata, Cray T3D
RAID / disk servers
Berkeley
Striping / Datamesh, Petal
many
Portable communication
Berkeley, Purdue (CDMA)
Linkobit, Hughes
Qualcomm
World Wide Web
CERN, Illinois (Mosaic)
Alta Vista
Netscape, Yahoo
Speech recognition
CMU, SRI, MIT
Bell, IBM, Dragon
Dragon, IBM, L&H
Broadband last mile
Stanford, UCLA
Bellcore
Amati, Alcatel, Broadcom
1965 1970 1975 1980 1985 1990 1995 2000
University
Industry research
Products
$1B ma
IT research areas are ordered roughly according to when they became $1 billion industries.


Innovation
in INFORMATION TECHNOLOGY
NATIONAL RESEARCH COUNCIL

2003


IT Sectors With Large Economic Impact
Motorola
Qualcomm
Texas Instruments
nVidia
iPhone
AMD
Intel
HP
Symantec
Apple
Dell
eBay
Akamai
Yahoo!
Juniper
Facebook
Twitter
Cisco
Amazon
Google
IBM
VMware
HP
Oracle
Microsoft
Electronic Arts
Adobe
Autodesk
nVidia
Pixar
iPod
XBox
Nuance
iRobot
Intuitive Surgical
Broadband & Mobile
Microprocessors
Personal Computing
Internet & Web
Cloud Computing
Enterprise Systems
Entertainment & Design
Robotics & Assistive Technologies
2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
Digital Communications
Computer Architecture
Software Technologies
Networking
Parallel & Distributed Systems
Databases
Computer Graphics
AI & Robotics
Areas of Fundamental Research in IT
University
Industry R&D
Products
$1 Billion Market
$10 Billion Market


Continuing
Innovation
IN INFORMATION TECHNOLOGY

2012

Lessons

- Every $1B market segment bears the clear stamp of Federal research investments
- There's nothing linear about the path from research to $1B market segment: ideas and people flow every which way
- Unanticipated results are often as important as anticipated results
- The interaction of research ideas multiplies their impact
- Entirely appropriately, corporate R&D is very heavily tilted towards D: engineering the next release of a product, vs. a 5- 10- or 15-year horizon

An Overview of the Computing Community Consortium

- A standing committee of the Computing Research Association
- Funded by NSF under a Cooperative Agreement
- Facilitates the development of a bold, multi-themed vision for computing research – and communicates this vision to stakeholders
- Led by a broad-based Council
- Chaired by Ed Lazowska and Susan Graham
- Staffed by CRA

The CCC Council

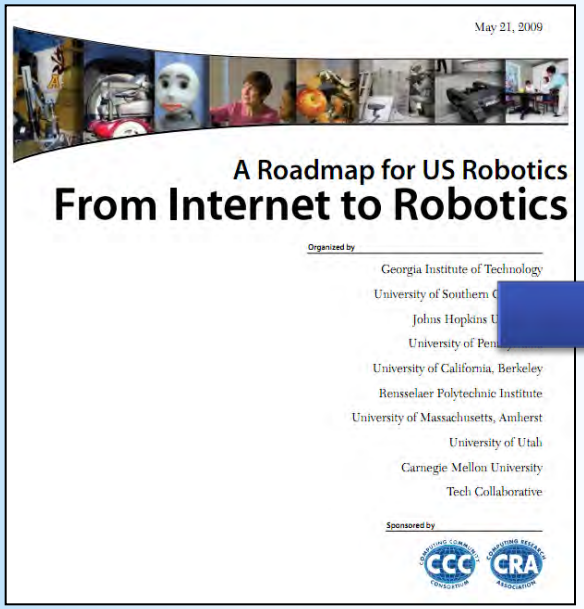
- Leadership
  - Ed Lazowska, Univ. Washington (Chair)
  - Susan Graham, UC Berkeley (Vice Chair)
  - Kenneth Hines, Program Associate
  - Andy Bernat, CRA Executive Director
- Terms ending 6/2015
  - Liz Bradley, Univ. Colorado
  - Sue Davidson, Univ. Pennsylvania
  - Joe Evans, Univ. Kansas
  - Ran Libeskind-Hadas, Harvey Mudd College
  - Shashi Shekhar, Univ. Minnesota
- Terms ending 6/2014
  - Deborah Crawford, Drexel
  - Gregory Hager, Johns Hopkins
  - Anita Jones, Univ. Virginia
  - John Mitchell, Stanford
  - Bob Sproull, Sun Labs Oracle (ret.)
  - Josep Torrellas, Univ. Illinois
- Terms ending 6/2013
  - Randy Bryant, Carnegie Mellon
  - Lance Fortnow, Northwestern -> Georgia Tech
  - Hank Korth, Lehigh
  - Eric Horvitz, Microsoft Research
  - Beth Mynatt, Georgia Tech
  - Fred Schneider, Cornell
  - Margo Seltzer, Harvard
- Former members
  - Stephanie Forrest, Univ. New Mexico, 2012
  - Chris Johnson, Univ. Utah, 2012
  - Frans Kaashoek, MIT, 2012
  - Robin Murphy, Texas A&M, 2012
  - Bill Feiereisen, LANL, 2011
  - Dave Kaeli, Northeastern, 2011
  - John King, Univ. Michigan, 2011
  - Dick Karp, UC Berkeley, 2010
  - Andrew McCallum, Univ. Massachusetts, 2010
  - Dave Waltz, Columbia, 2010
  - Greg Andrews, Univ. Arizona, 2009
  - Peter Lee, Carnegie Mellon, 2009
  - Karen Sutherland, Augsburg College, 2009

A Multitude of Activities

- **Community-initiated visioning:**
  - Workshops that bring researchers together to discuss "out-of-the-box" ideas
  - Challenges & Visions tracks at conferences
- **Outreach to the White House, Federal funding agencies:**
  - Outputs of visioning activities
  - Short reports to inform policy makers
  - Task Forces – Health IT, Sustainability IT, Data Analytics

- **Public relations efforts:**
  - Library of Congress symposia
  - Research "Highlight of the Week"
  - CCC Blog [http://cccblog.org/]
- **Nurturing the next generation of leaders:**
  - Computing Innovation Fellows Project
  - "Landmark Contributions by Students"
  - Leadership in Science Policy Institute

Example: Robotics


May 21, 2009

A Roadmap for US Robotics
From Internet to Robotics

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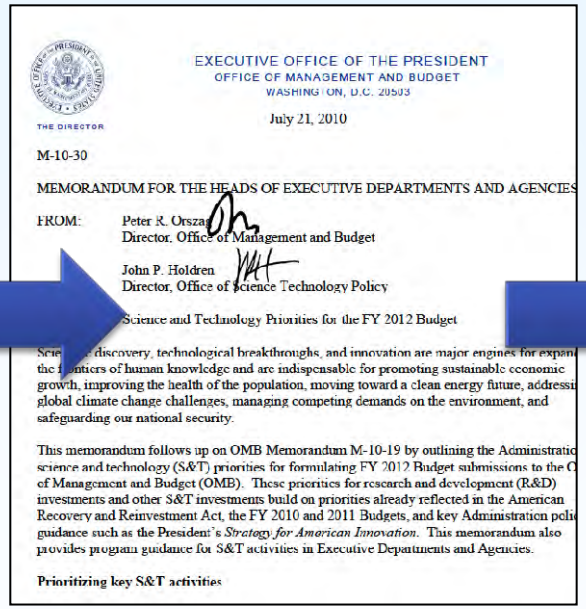
Johns Hopkins U
University of Penn
University of California, Berkeley
Rensselaer Polytechnic Institute
University of Massachusetts, Amherst
University of Utah
Carnegie Mellon University
Tech Collaborative

Sponsored by

4 meetings during summer 2008

Roadmap published May 2009

Extensive discussions between visioning leaders & agencies


EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

THE DIRECTOR

July 21, 2010

M-10-30

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Peter R. Orszag
Director, Office of Management and Budget

John P. Holdren
Director, Office of Science Technology Policy

Science and Technology Priorities for the FY 2012 Budget

Sci discovery, technological breakthroughs, and innovation are major engines for expan the frontiers of human knowledge and are indispensable for promoting sustainable economic growth, improving the health of the population, moving toward a clean energy future, addressi global climate change challenges, managing competing demands on the environment, and safeguarding our national security.

This memorandum follows up on OMB Memorandum M-10-19 by outlining the Administratic science and technology (S&T) priorities for formulating FY 2012 Budget submissions to the C of Management and Budget (OMB). These priorities for research and development (R&D) investments and other S&T investments build on priorities already reflected in the American Recovery and Reinvestment Act, the FY 2010 and 2011 Budgets, and key Administration poli guidance such as the President's *Strategy for American Innovation*. This memorandum also provides program guidance for S&T activities in Executive Departments and Agencies.

Prioritizing key S&T activities

OSTP issues directive to all agencies in summer 2010 to include robotics in FY 12 budgets


Office of Science and Technology Po

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Developing the Next Generation of Robots

Posted by Tom Kalil and Sridhar Kota on June 24, 2011 at 10:14 AM EDT

Tweet Share +

ch at Carnegie Mellon University, President Obama is launching the Advanc
esearch initiative that will promote a renaissance of American manufacturing.

One ex ting element of the President's Advanced Manufacturing Partnership is the National
Robots are working for us every day, in countless ways. At home, at work, and on the battlefie
increasingly lifting the burdens of tasks that are dull, dirty, or dangerous.

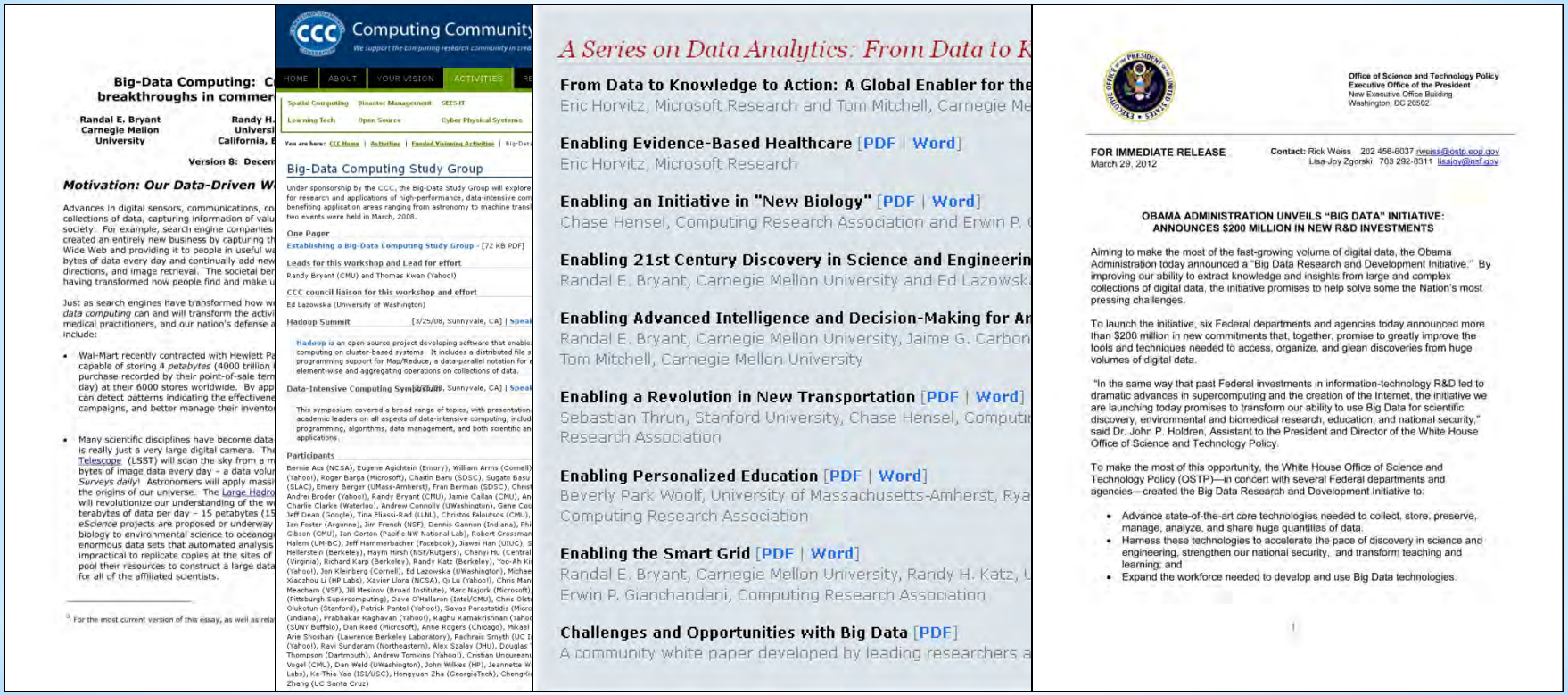
But they could do even more, and that's what the National Robotics Initiative is all about. So t
(the National Science Foundation, the National Institutes of Health, NASA, and the United Sta
Agriculture) are issuing a joint solicitation that will provide up to $70 million in research fundin
generation robotics.

The focus of this initiative is on developing robots that work with or beside people to extend o
capabilities, taking advantage of the different strengths of humans and robots. In addition to i
technology needed for next-generation robotics, the initiative will support applications such a

National Robotics Initiative announced in summer 2011

Henrik Chistensen
Georgia Tech

Example: Big Data



2008 2008 2010 2012

Example: Computer Architecture

Workshop on Advancing Computer Architecture Research (ACAR-1)

Failure is not an Option: Popular Parallel Programming

Organizers: Josep Torrellas (University of Illinois) and Mark Oskin (University of Washington).

Steering Committee: Chita Das (NSF and Pennsylvania State University), William Harrod (DARPA), Mark Hill (University of Wisconsin), James Larus (Microsoft Research), Margaret Martonosi (Princeton University), Jose Moreira (IBM Research), and Kunle Olukotun (Stanford University).

Written by: Josep Torrellas, Mark Oskin, Sarita Adve, George Almasi, Luis Ceze, Almadena Chtchelkanova, Chita Das, Bill Feiereisen, William Harrod, Mark Hill, Jon Hiller, Sampath Kannan, Krishna Kant, Christos Kozyrakis, James Larus, Richard Murphy, Onur Mutlu, Satish Narayanasamy, Kunle Olukotun, Yale Patt, Anand Sivasubramaniam, Kevin Skadron, Karin Strauss, Steven Swanson, and Dean Tullsen.

Funded by the Computing Research Association's (CRA) Computing Community Consortium (CCC) as a "visioning exercise" meant to promote forward thinking in computing research and then bring these ideas to a funded program.

Held on February 21-23, 2010 in San Diego, California
Contact: torrella@illinois.edu; oskin@cs.washington.edu
Websites: http://www.cra.org/ccc/acar.php; http://iacoma.cs.uiuc.edu/acar1

August 2010

1

Workshop on Advancing Computer Architecture Research (ACAR-II)
Laying a New Foundation for IT: Computer Architecture for 2025 and Beyond

Organizers: Mark Oskin (University of Washington) and Josep Torrellas (University of Illinois).

Steering Committee: Chita Das (Pennsylvania State University), Mark Hill (University of Wisconsin), James Larus (Microsoft Research), Margaret Martonosi (Princeton University), Jose Moreira (IBM Research), and Kunle Olukotun (Stanford University).

Written by: Mark Oskin, Josep Torrellas, Chita Das, John Davis, Sandhya Dwarkadas, Lieven Eeckhout, Bill Feiereisen, Daniel Jimenez, Mark Hill, Martha Kim, James Larus, Margaret Martonosi, Onur Mutlu, Kunle Olukotun, Andrew Putnam, Tim Sherwood, James Smith, David Wood, Craig Zilles

Funded by the Computer Research Association (CRA) Computing Community Consortium (CCC) as a "visioning exercise" meant to promote forward thinking in computer research and then bring those ideas to a funded program.

Held on September 20-21, 2010 in Seattle, Washington
Contact: oskin@cs.washington.edu; torrella@illinois.edu
Website: http://www.cra.org/acar.php

21st Century Computer Architecture

A community white paper
May 25, 2012

1. Introduction and Summary

Information and communication technology (ICT) is transforming our world, including healthcare, education, science, commerce, government, defense, and entertainment. It is hard to remember that 20 years ago the first step in information search involved a trip to the library, 10 years ago social networks were mostly physical, and 5 years ago "tweets" came from cartoon characters.

Importantly, much evidence suggests that ICT innovation is accelerating with many compelling visions moving from science fiction toward reality[1]. Appendix A both touches upon these visions and seeks to distill their attributes. Future visions include personalized medicine to target care and drugs to an individual, sophisticated social network analysis of potential terrorist threats to aid homeland security, and telepresence to reduce the greenhouse gases spent on commuting. Future applications will increasingly require processing on large, heterogeneous data sets ("Big Data"[2]), using distributed designs, working within form-factor constraints, and reconciling rapid deployment with efficient operation.

Two key—but often invisible—enablers for past ICT innovation have been semiconductor technology and computer architecture. Semiconductor innovation has repeatedly provided more transistors (Moore's Law) for roughly constant power and cost per chip (Dennard Scaling). Computer architects took these rapid transistor budget increases and discovered innovative techniques to scale processor performance and mitigate memory system losses. The combined effect of technology and architecture has provided ICT innovators with exponential performance growth at near constant cost.

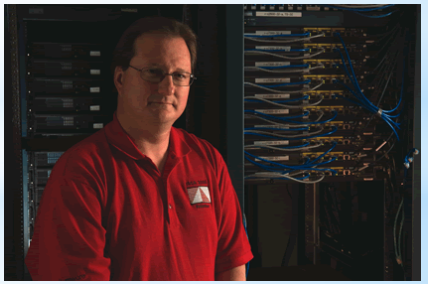
Because most technology and computer architecture innovations were (intentionally) invisible to higher layers, application and other software developers could reap the benefits of this progress without engaging in it. Higher performance has both made more computationally demanding applications feasible (e.g., virtual assistants, computer vision) and made less demanding applications easier to develop by enabling higher-level programming abstractions (e.g., scripting languages and reusable components). Improvements in computer system cost-effectiveness enabled value creation that could never have been imagined by the field's founders (e.g., distributed web search sufficiently inexpensive so as to be covered by advertising links).

[1] PCAST, "Designing a Digital Future: Federally Funded Research and Development Networking and Information Technology, Dec. 2010 (http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf).
[2] CCC, "Challenges and Opportunities with Big Data," Feb. 2012 (http://cra.org/ccc/docs/init/bigdatawhitepaper.pdf).

1

Josep Torrellas
UIUC

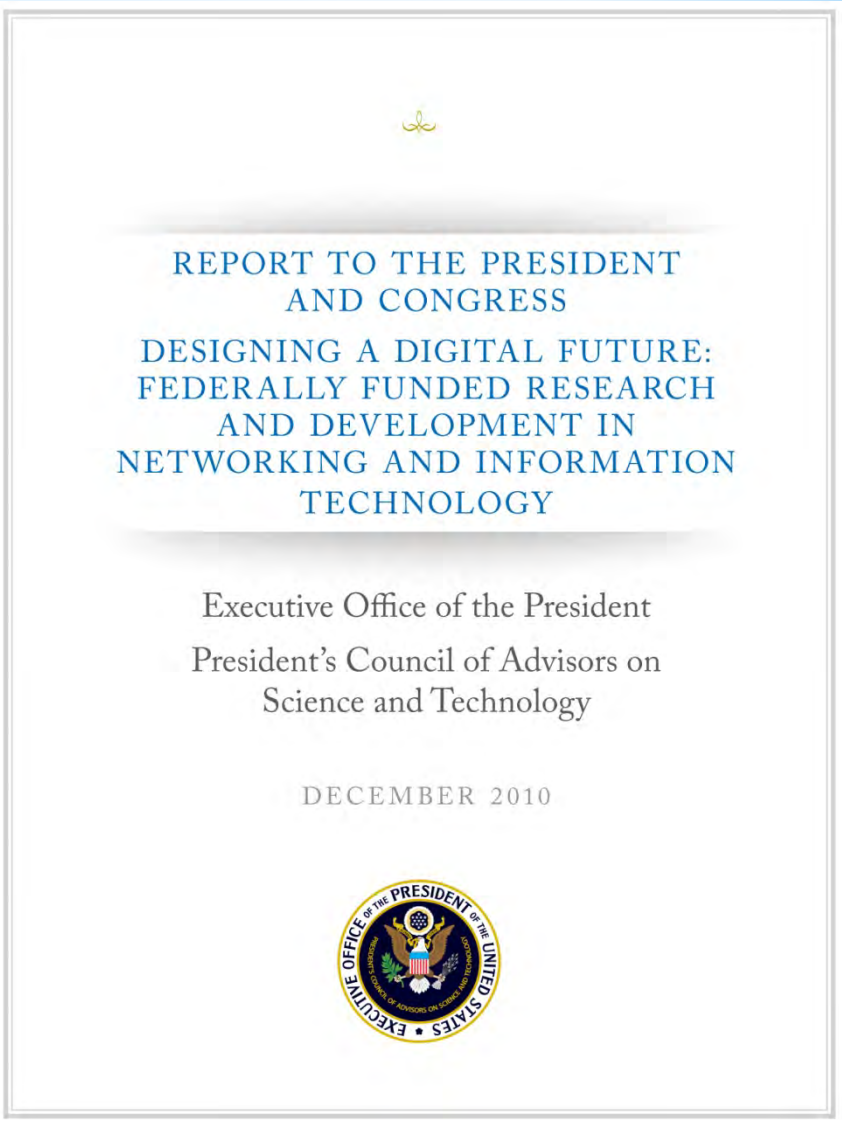
Mark Oskin
Washington



Mark Hill
Wisconsin

Example: PCAST NITRD Report

- 1/3 of the PCAST NITRD Working Group members were CCC Council members
- The report drew extensively on CCC White Papers
- An excellent roadmap for the field
- The challenge now: continuing to translate it into action



Example: Leadership in Science Policy Inst.

Computing Community Consortium

We support the computing research community in creating compelling research visions and the mechanisms to realize these visions.

HOME | ABOUT | YOUR VISION | ACTIVITIES | RESOURCES | CONTACT | GO

CCC Leadership in Science Policy Institute

Agenda

8:30 am - 9:00 am
Welcome [180 KB PDF] [Referenced videos - Lazowska | Bartlett | Brooks]
(Fred Schneider, Cornell, Workshop Chair)

Lay out the goals of the workshop: to provide a crash-course in relevant science policy issues and the mechanics of policymaking, including a sense of how federal science policy is crafted, how it's implemented, and where are the opportunities for members of the community to participate in the policy-making process.

9:00 am - 10:30 am
Interacting with Agencies/Creating New Initiatives
(Jeannette Wing, CMU [434 KB PDF]; Milt Corn, NIH [242 KB PDF]; Henry Kelly, DOE)

The agencies are where the science-policy rubber hits the road, where decisions made in both the Administrative and Legislative branches get implemented, and the most common avenue for individuals in the science community to interact with the federal government. Influencing policy decisions at the agency level can require a somewhat different skill set and somewhat different approach than influencing your faculty peers, the Congress, or the White House. Agencies also provide opportunities for individuals in the community to directly shape federal policy in their field, by serving on an agency advisory committee, or by taking a rotation as a program manager, division director, or office director. This session will cover the agency budget process and will discuss opportunities for scientists to advise and engage federal science agencies like NSF, DOE, and NIH. The speakers will discuss the mechanics of how agency new initiatives get started, focusing on the culture and traditions that constitute the lens through which agencies view themselves and are viewed by others. In practical terms, how is success measured? To what extent is outside advice sought and in support of what kinds of activities? What kinds of advice and modes of engagement are unlikely to be effective?

Back to Main Page

Content is still being added to this site. Please check back periodically. The last change was made on: **December 13, 2011**.

Logistics

Date: November 7, 2011
Location: Hyatt Regency Capitol Hill, Washinton, DC

Participation in the workshop will include breakfast and lunch at the workshop, as well as a reception with workshop speakers and other interested guests at the conclusion of the meeting. Hotel accommodations for two nights (before and after the workshop) as well as reimbursement for airfare and other travel expenses will be provided by the workshop (through funding from CCC).

Agenda

List of Sessions and Speakers and Slides

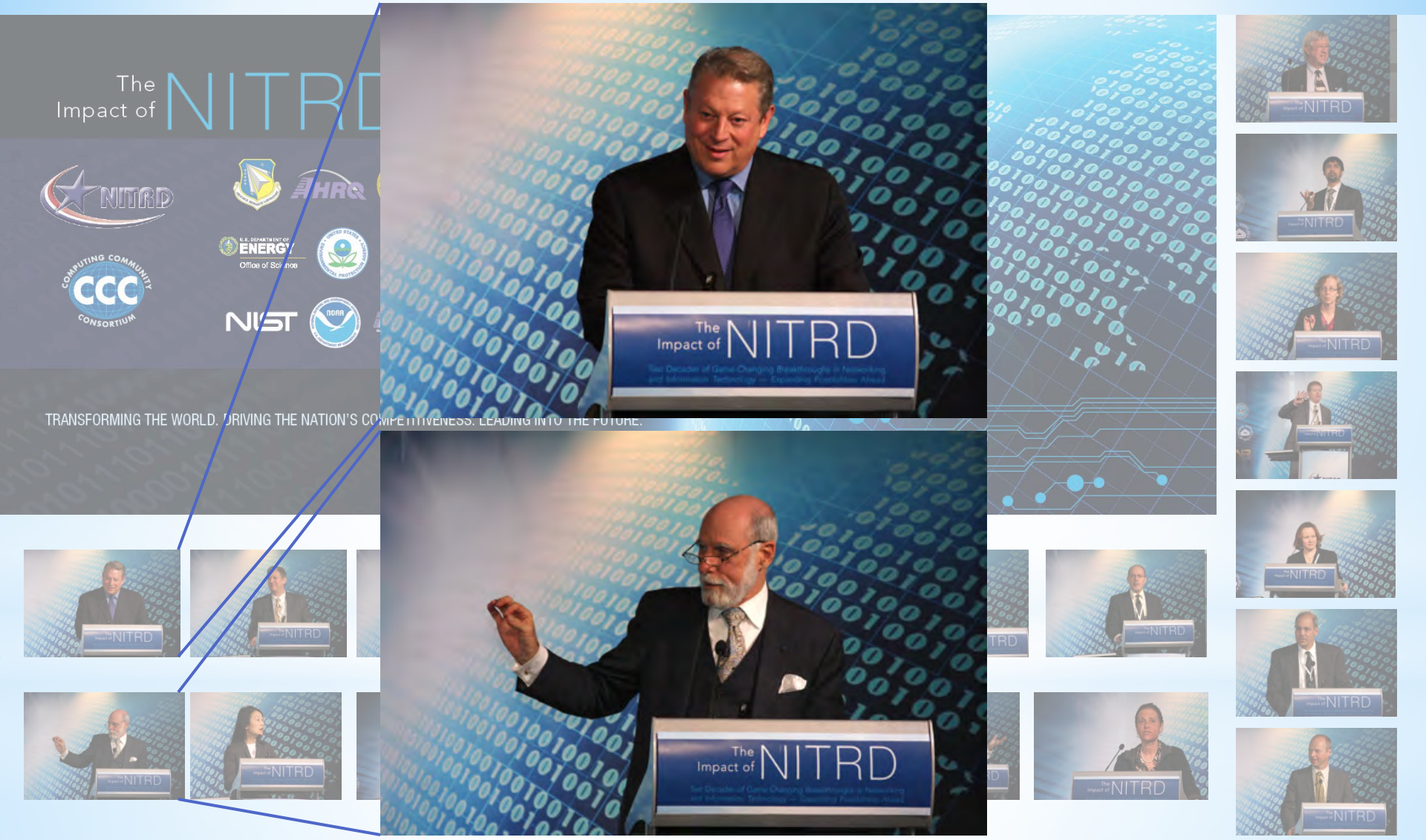

Milt Corn, NIH


Henry Kelly, DoE


Attendees

Example: NITRD Symposium (2/16/2012)

Example: NITRD Symposium (2/16/2012)



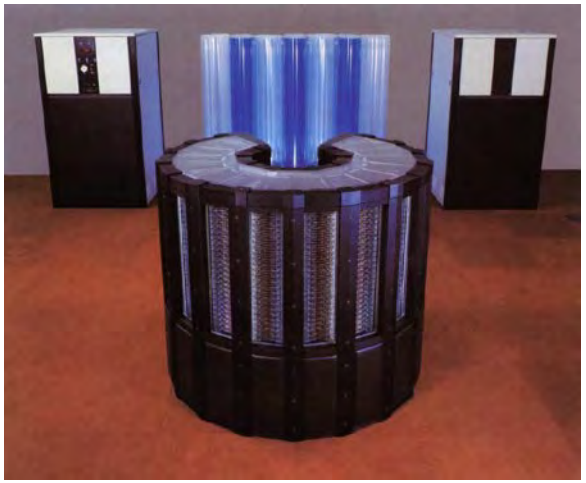
A Community Effort – We Need You!

- Propose visioning activities, white papers, Challenges & Visions tracks at research conferences
- Put together short research videos for undergraduates
- Contribute to the CCC Blog
- Send us a research highlight for the Highlight of the Week

Get involved:
khines@cra.org
http://cra.org/ccc or http://cccblog.org/

The next ten years …

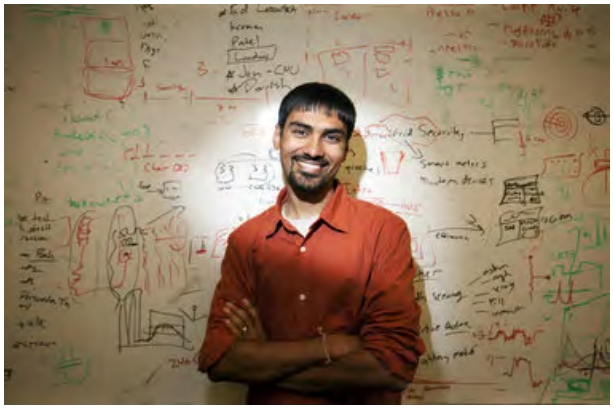
Simulation -> Communication -> Embodiment



My own (consistent) version: In the next ten years, we will put the "smarts" in …

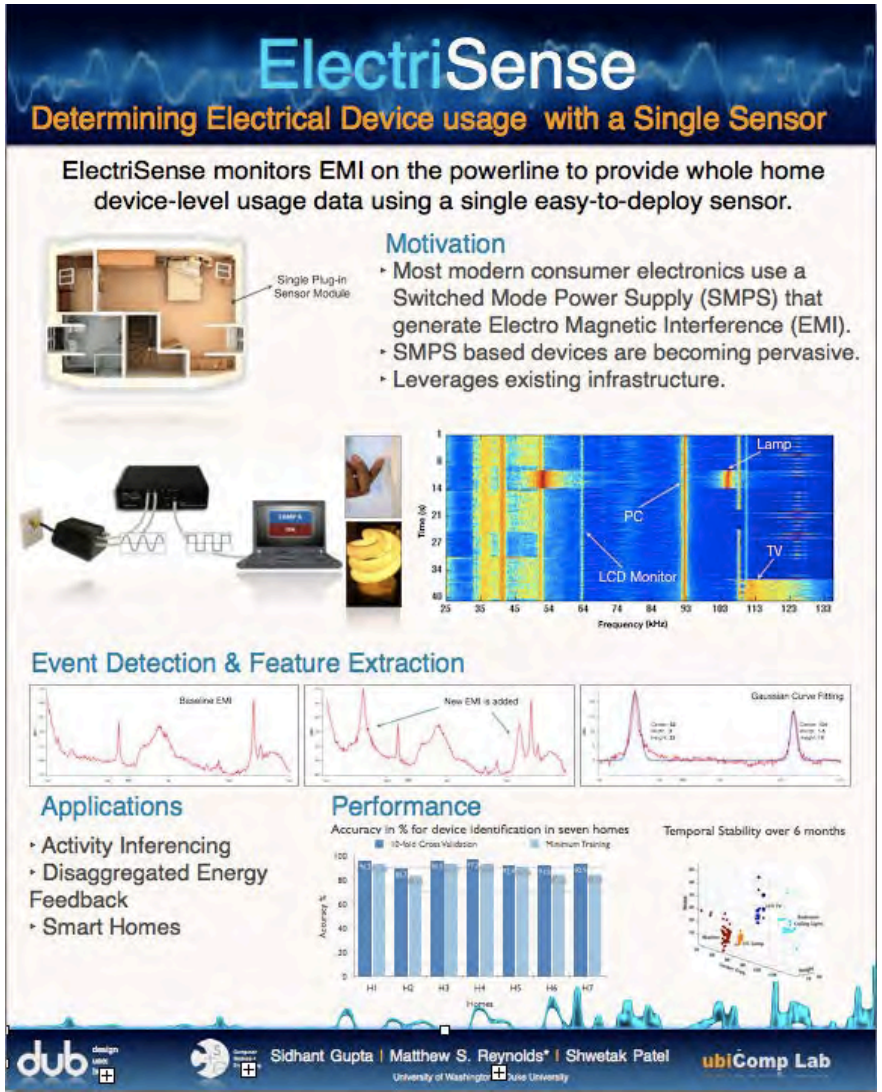
- Smart homes
- Smart cars
- Smart health
- Smart robots
- Smart science (confronting the data deluge)
- Smart crowds and human-computer systems
- Smart interaction (virtual and augmented reality)

Smart homes



Shwetak Patel,
University of Washington
2011 MacArthur Fellow

MACARTHUR
The John D. and Catherine T. MacArthur Foundation

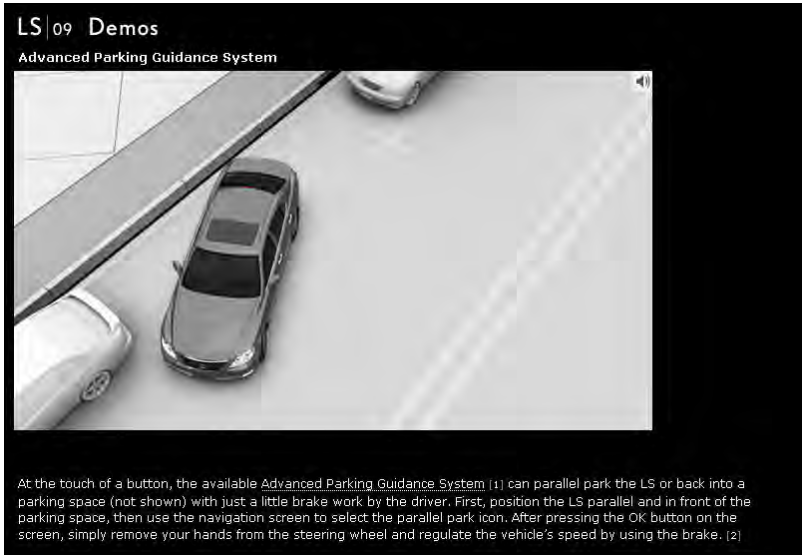


Smart cars

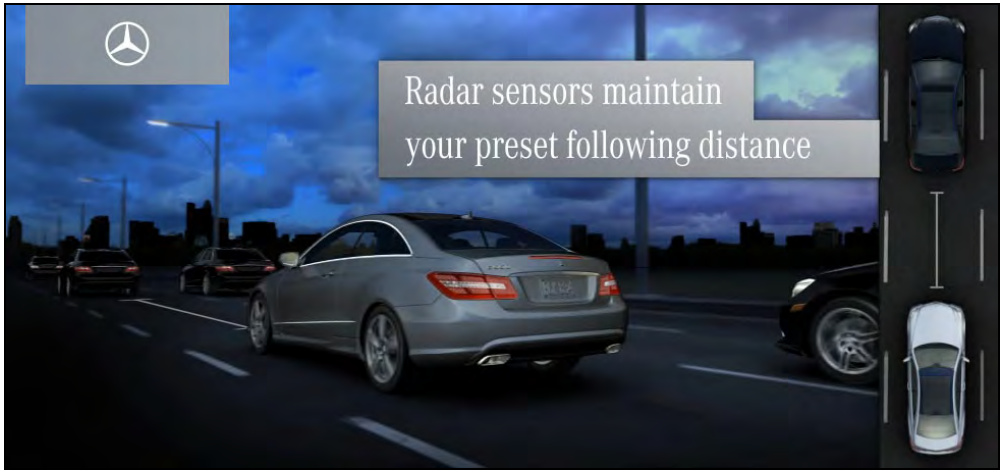
DARPA Grand Challenge

DARPA Urban Challenge

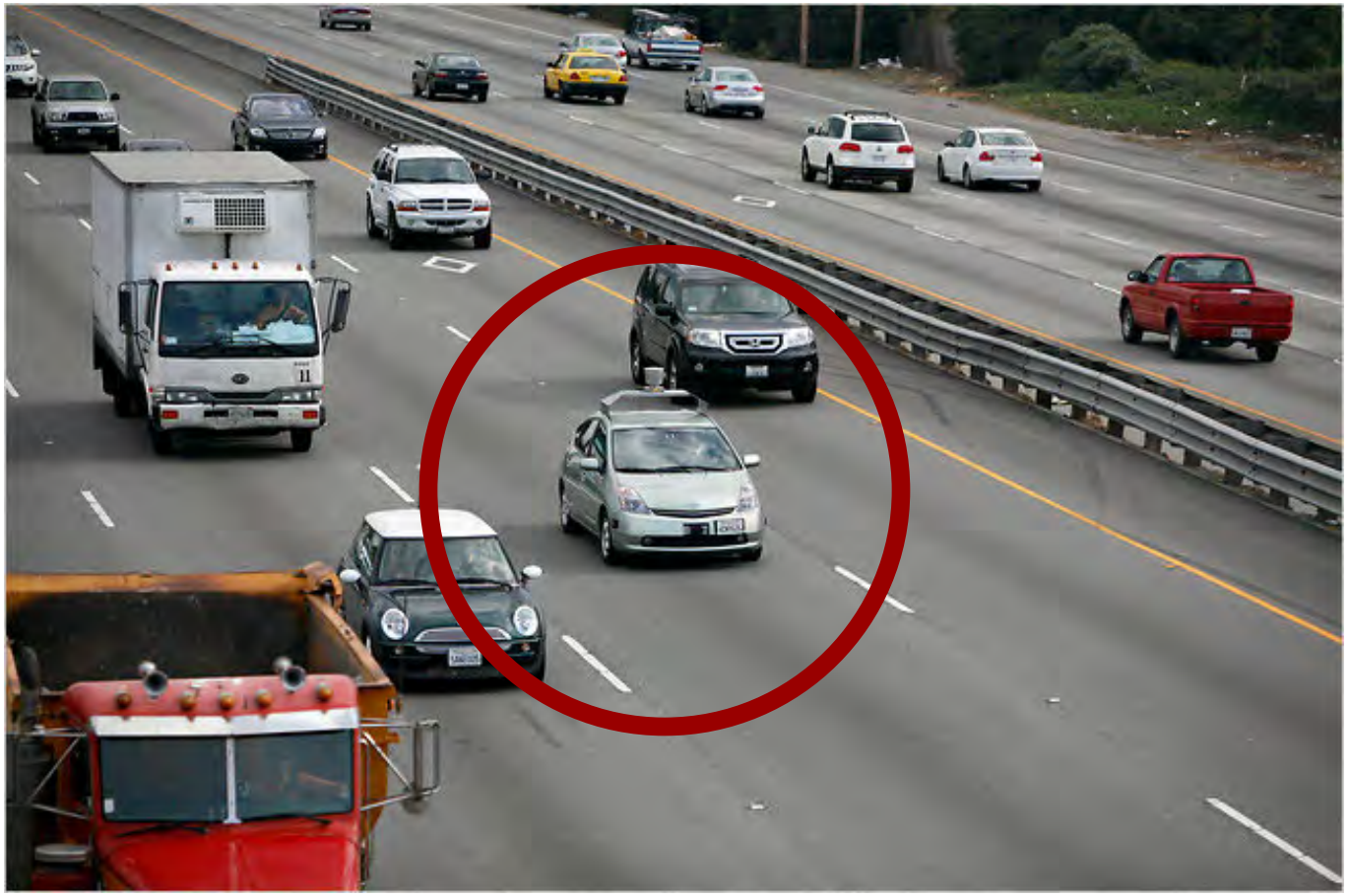
← Lane departure warning



← Self-parking



← Adaptive cruise control



Google autonomous car on US 101 near Mountain View CA

Autonomous Driving

Google's modified Toyota Prius uses an array of sensors to navigate public roads without a human driver. Other components, not shown, include a GPS receiver and an inertial motion sensor.

LIDAR
A rotating sensor on the roof scans more than 200 feet in all directions to generate a precise three-dimensional map of the car's surroundings.

POSITION ESTIMATOR
A sensor mounted on the left rear wheel measures small movements made by the car and helps to accurately locate its position on the map.

VIDEO CAMERA
A camera mounted near the rear-view mirror detects traffic lights and helps the car's onboard computers recognize moving obstacles like pedestrians and bicyclists.

RADAR
Four standard automotive radar sensors, three in front and one in the rear, help determine the positions of distant objects.

Source: Google

THE NEW YORK TIMES; PHOTOGRAPHS BY RAMIN RAHIMIAN FOR THE NEW YORK TIMES

- In 2004, in just the United States:
  - 6,181,000 police-reported traffic accidents
    - 42,636 people killed
    - 2,788,000 people injured
    - 4,281,000 had property damage only
  - ~ $250 billion (that's *one quarter of a trillion dollars* …) in *annual* economic cost
    - 100 times greater than even an extravagant estimate of the nation's annual investment in computing research
  - 

ENDNOTES

1 Availability of E 350 BlueTEC and 4MATIC models is delayed. See dealer for details.

2 DISTRONIC PLUS adaptive cruise control is no substitute for active driving involvement. It does not react to stationary objects, nor recognize or predict the curvature and lane layout of the road or the movement of vehicles ahead. It is the driver's responsibility at all times to be attentive to traffic and road conditions, and to provide the steering, braking and other driving inputs necessary to retain control of the vehicle. Drivers are cautioned not to wait for the DISTRONIC Proximity Warning System before braking, as that may not afford sufficient time and distance to brake safely. After braking the car for stopped traffic ahead, system resumes automatically only if traffic pauses for less than 3 seconds.

3 Driving while drowsy or distracted is dangerous and should be avoided. ATTENTION ASSIST may be insufficient to alert a fatigued or distracted driver of lane drift and cannot be relied on to avoid an accident or serious injury.

4 PRE-SAFE® closes the side windows and sunroof when the system's sensors detect side movement that suggests a possible accident.

But there's more at stake than safety …

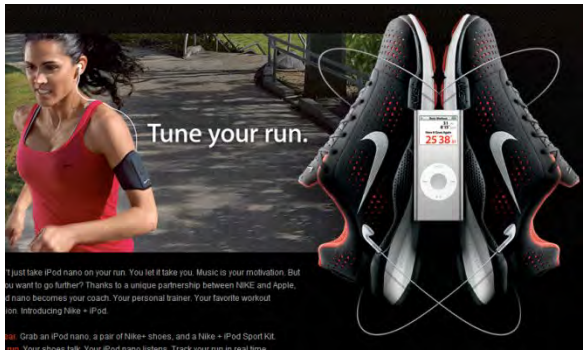
- Energy and the environment
  - Highway transportation uses 22% of all US energy
- Efficiency and productivity
  - Traffic congestion in the US is responsible for 3.6 billion vehicle hours of delay annually
- Equity
  - The elderly, and low-income individuals forced to the exurbs, are disadvantaged
- The economic and environmental costs of manufacturing automobiles

And computing research is central to the solutions

- Real-time sensor information for transit location
- Personalized, real-time information for choosing travel options
- Zipcar on steroids 
- Routing around congestion, for transit and personal vehicles
- Greater vehicle density through semi-automated control

Smart health: Personalized health monitoring

Omron pedometer



Nike + iPod

Bodymedia multi-function

Biozoom: body fat, hydration, blood oxygen, etc.

Glucowatch: measuring body chemistry

Larry Smarr

Smart health: Evidence-based medicine

- Machine learning for clinical care
- Predictive models
- Cognitive assistance for physicians

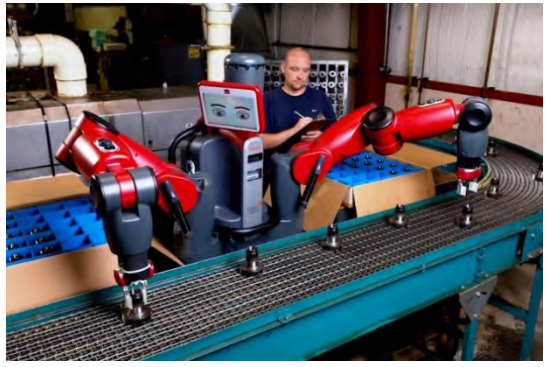
Smart health: P4 medicine

INSTITUTE FOR Systems Biology

Smart robots

iRobot

rethink robotics



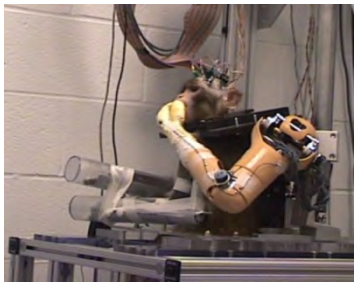
Smart health + smart robots

Yoky Matsuoka
University of Washington
-> Google -> Nest
2007 MacArthur Fellow

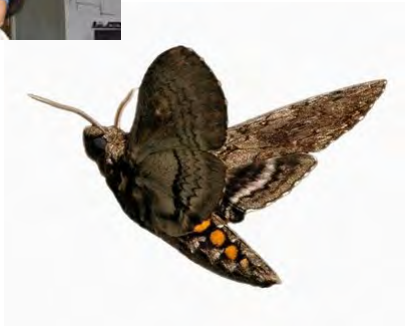
MACARTHUR
The John D. and Catherine T. MacArthur Foundation

Tom Daniel
University of Washington
1996 MacArthur Fellow

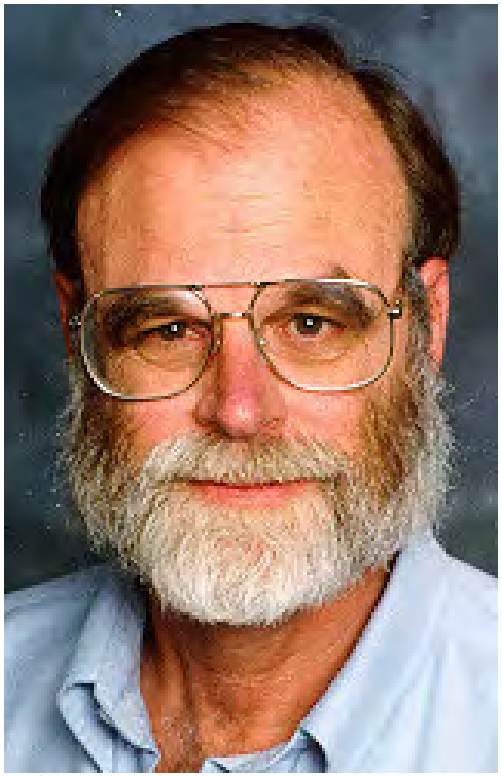
MACARTHUR
The John D. and Catherine T. MacArthur Foundation



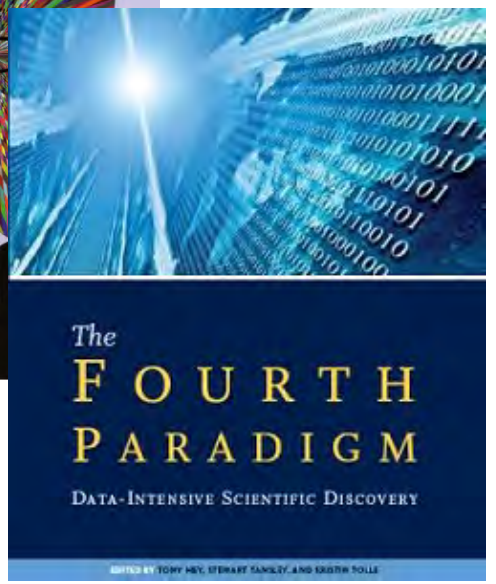
NSF Engineering Research Center for
Sensorimotor Neural Engineering



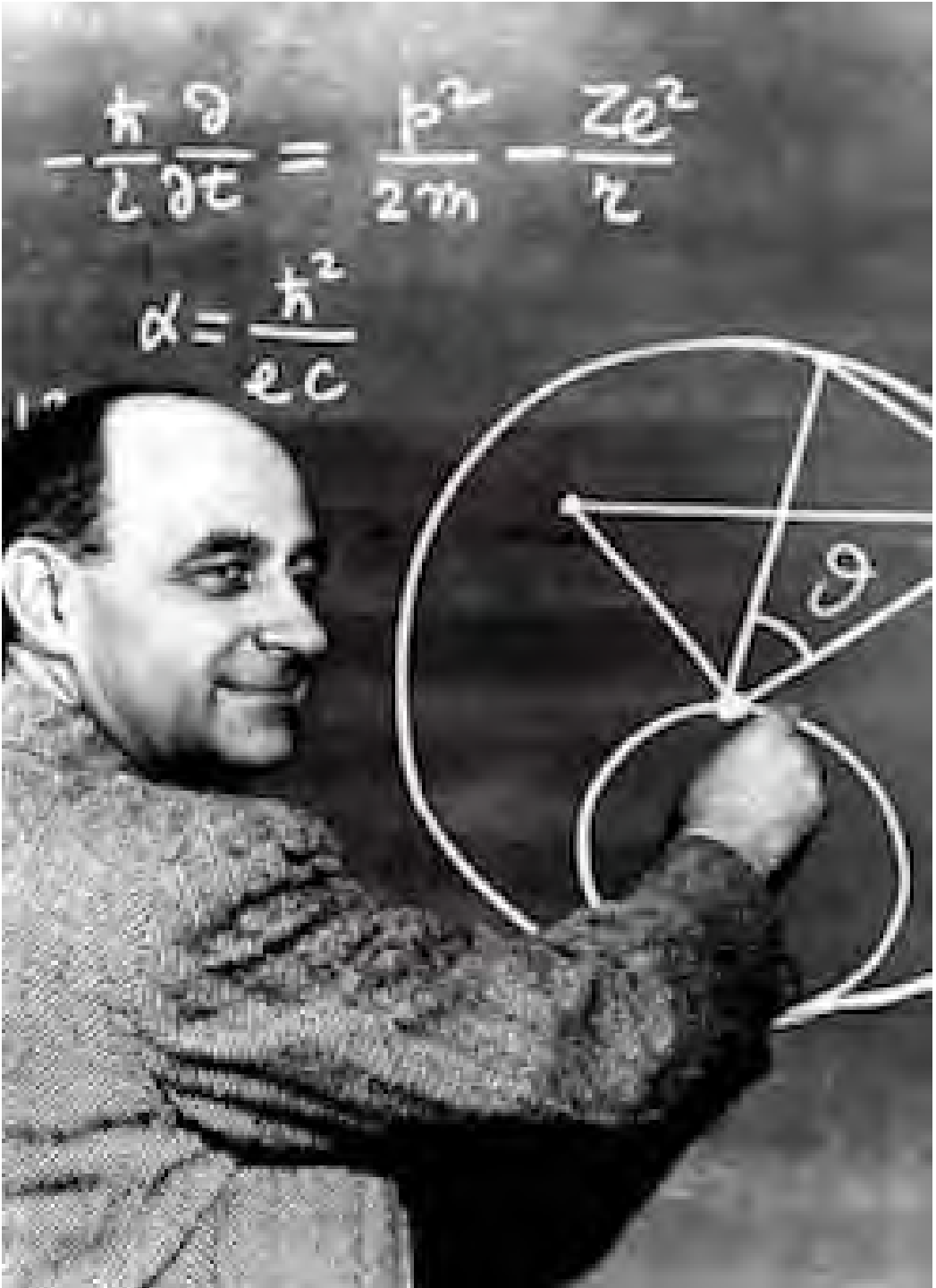
Smart science: eScience (data-driven discovery)



Jim Gray,
Microsoft Research



Transforming science (again!)



Theory

Experiment

Observation

Theory

Experiment

Observation

Credit: John Delaney, University of Washington

Theory

Experiment

Observation

Computational Science

SLOAN DIGITAL SKY SURVEY

Theory

Experiment

Observation

Computational Science

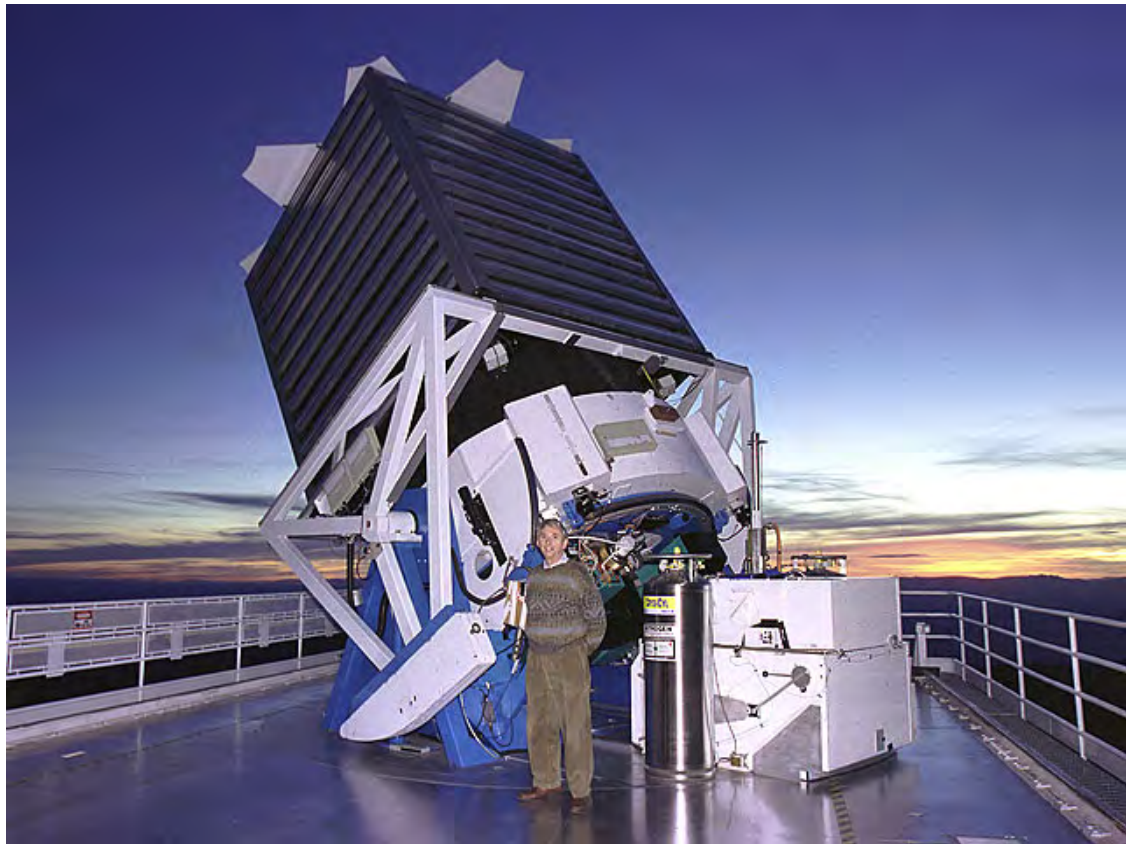
eScience

eScience is driven by *data* more than by cycles

- Massive volumes of data from sensors and networks of sensors

Apache Point telescope, SDSS

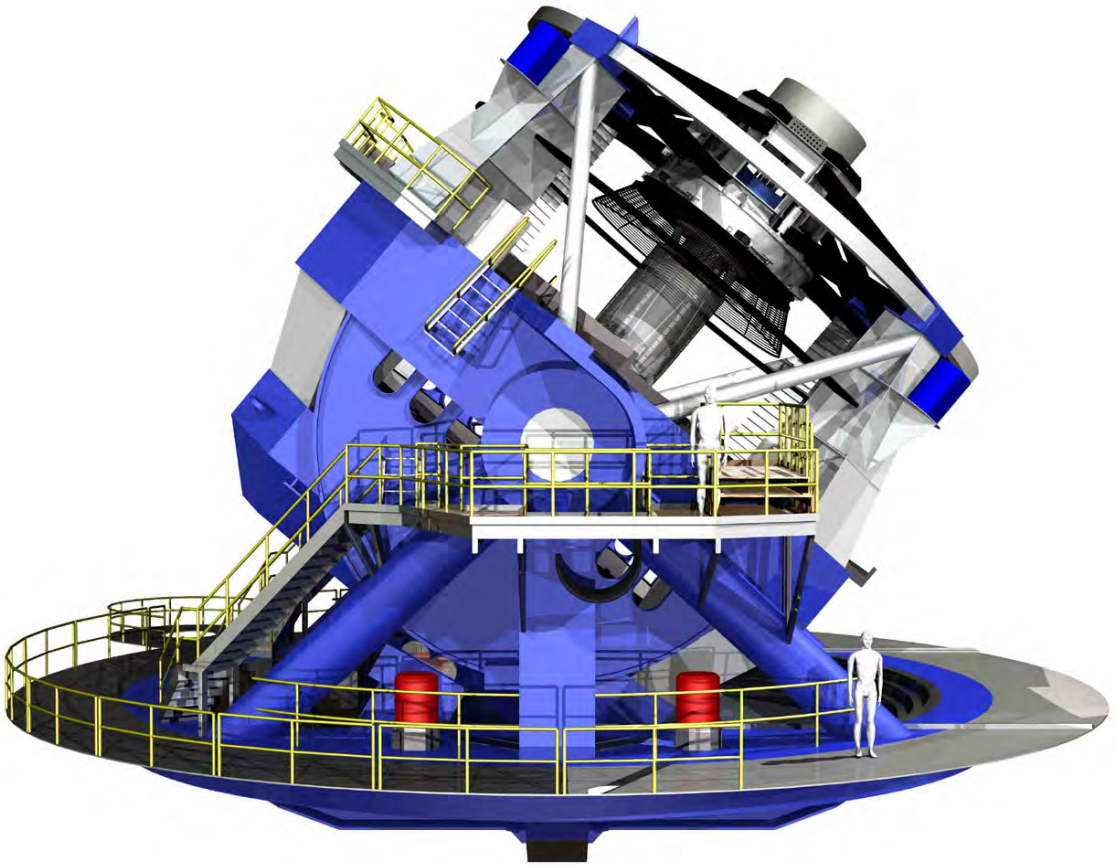
80TB of raw image data (80,000,000,000,000 bytes) over a 7 year period



Large Synoptic Survey Telescope (LSST)

40TB/day (an SDSS every two days), 100+PB in its 10-year lifetime

400mbps sustained data rate between Chile and NCSA



Large Hadron Collider

700MB of data per second, 60TB/day, 20PB/year

Illumina HiSeq 2000 Sequencer

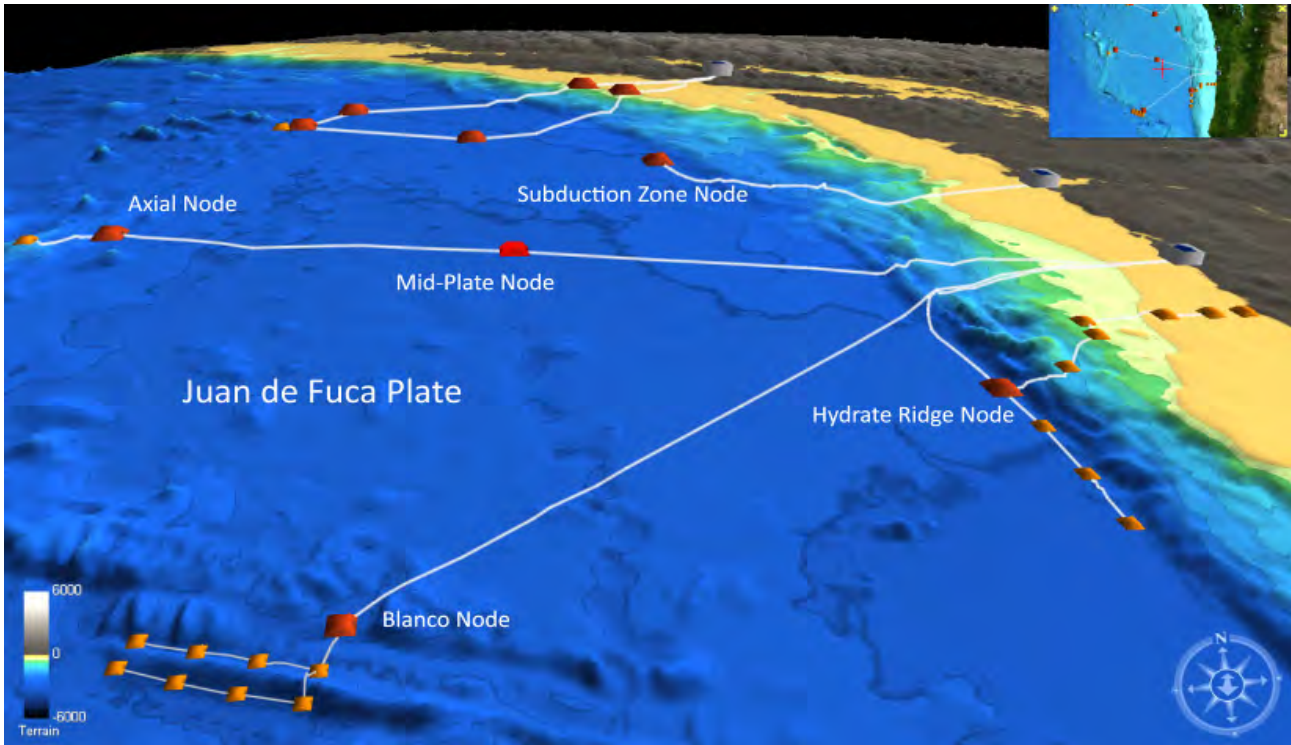
~1TB/day

Major labs have 25-100 of these machines

OCEAN OBSERVATORIES INITIATIVE

Regional Scale Nodes of the NSF Ocean Observatories Initiative

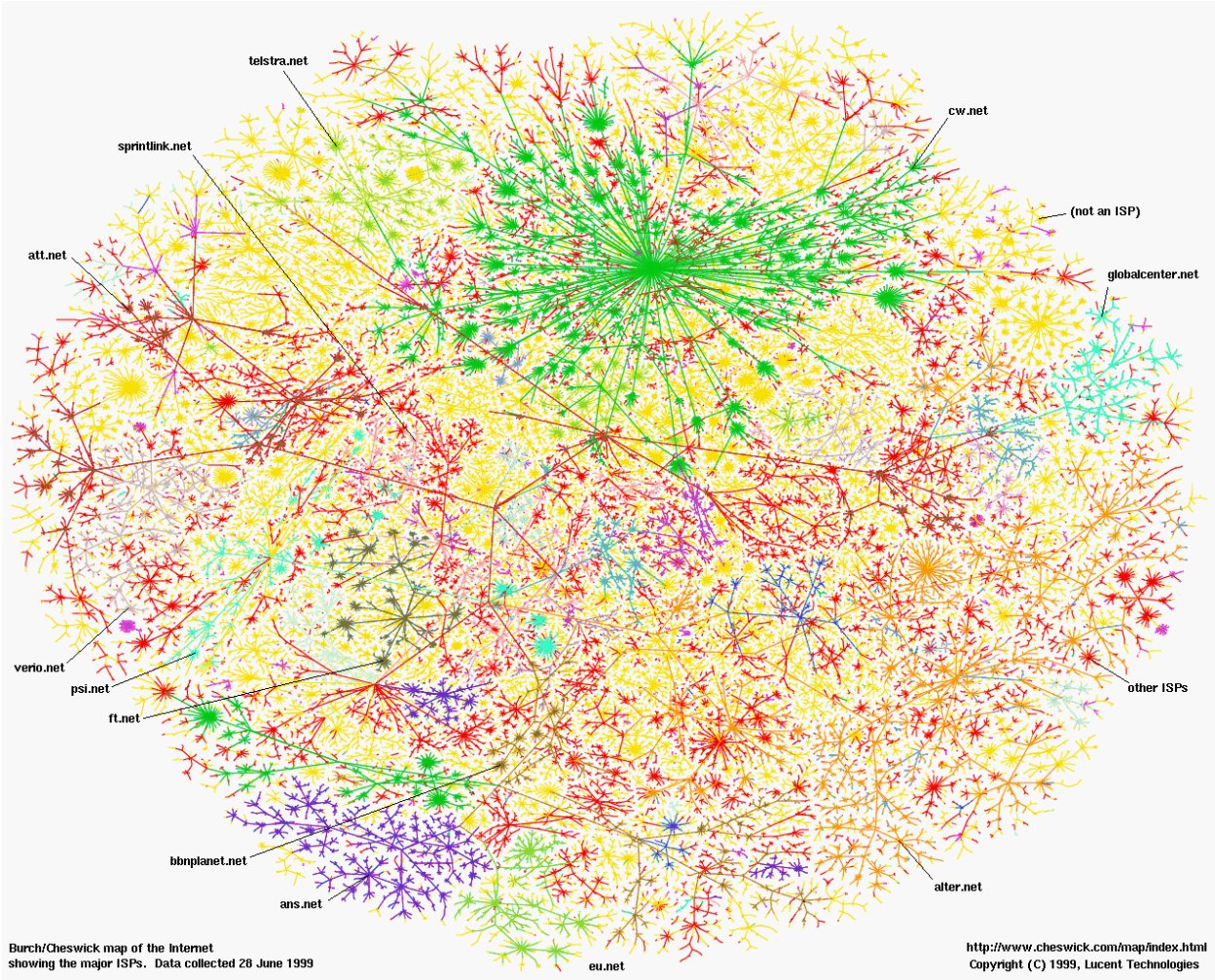
1000 km of fiber optic cable on the seafloor, connecting thousands of chemical, physical, and biological sensors



The Web

20+ billion web pages x 20KB = 400+TB

One computer can read 30-35 MB/sec from disk => 4 months just to read the web



Point-of-sale terminals

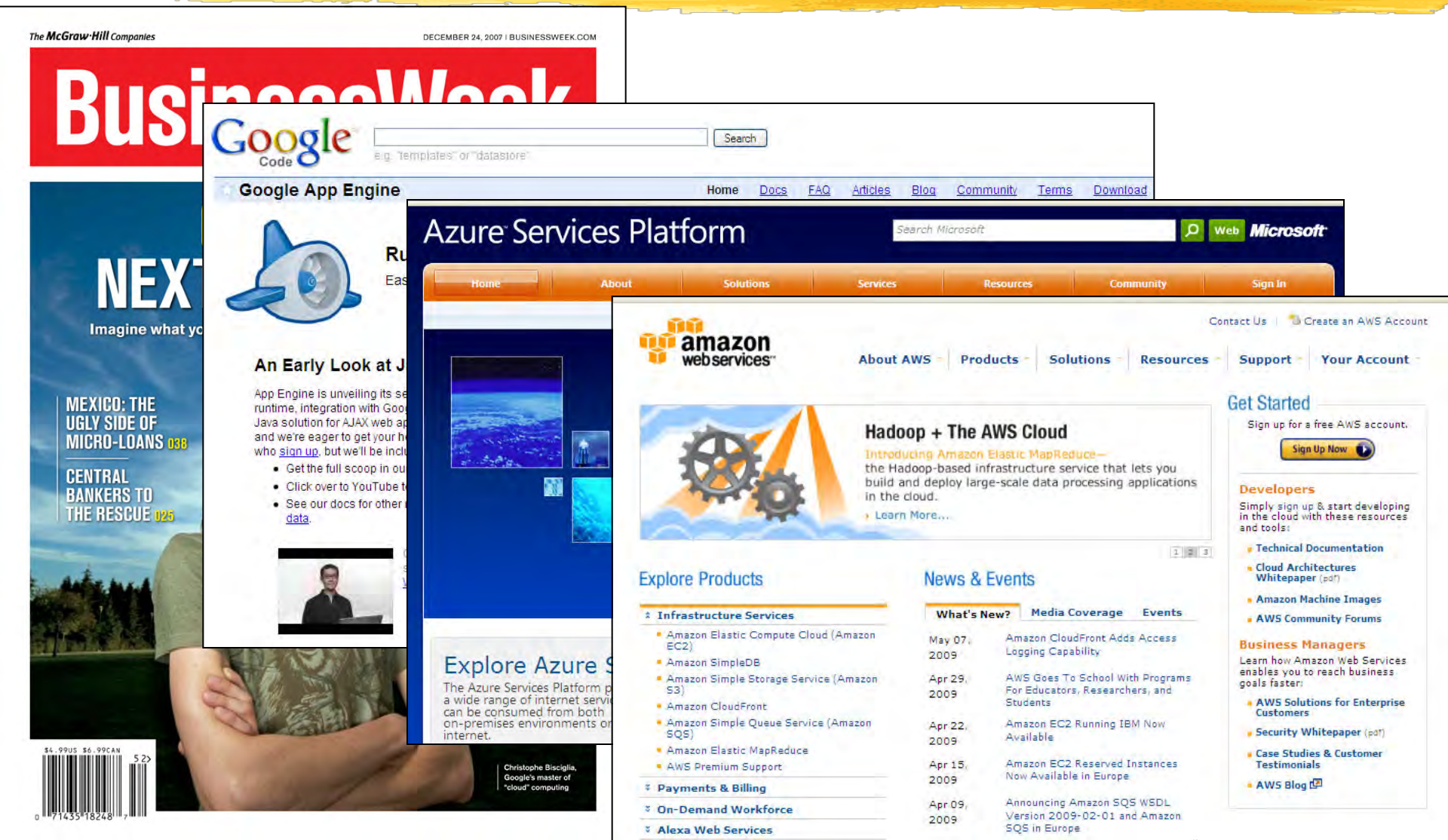
eScience is about the *analysis* of data

- The automated or semi-automated extraction of knowledge from massive volumes of data
  - There's simply too much of it to look at
- It's not just a matter of volume
  - Volume
  - Rate
  - Complexity / dimensionality

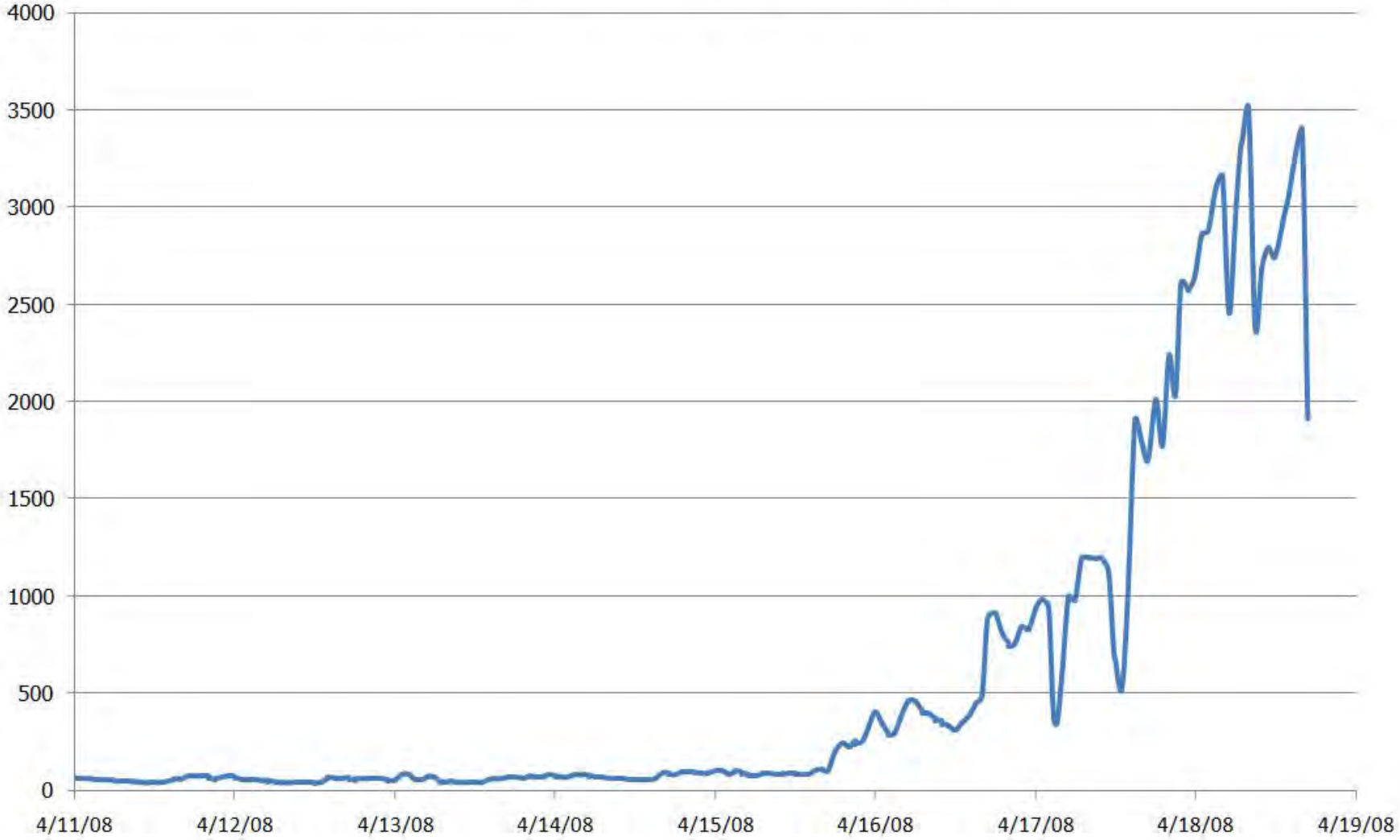
eScience utilizes a spectrum of computer science techniques and technologies

- Sensors and sensor networks
- Backbone networks
- Databases
- Data mining
- Machine learning
- Data visualization
- Cluster computing at enormous scale (the cloud)

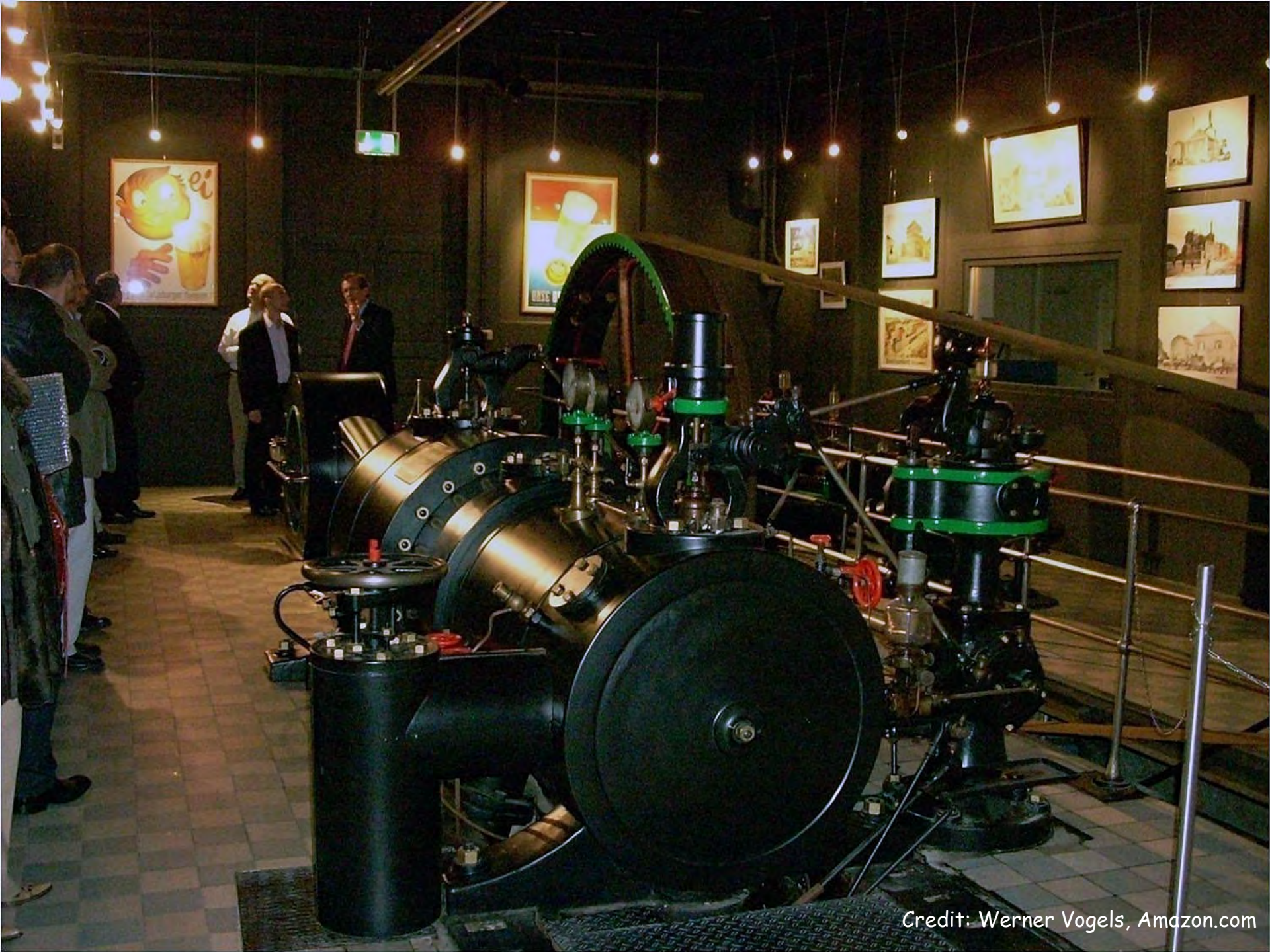
eScience is married to the cloud: Scalable computing and storage for everyone



Animoto: EC2 Instance Usage



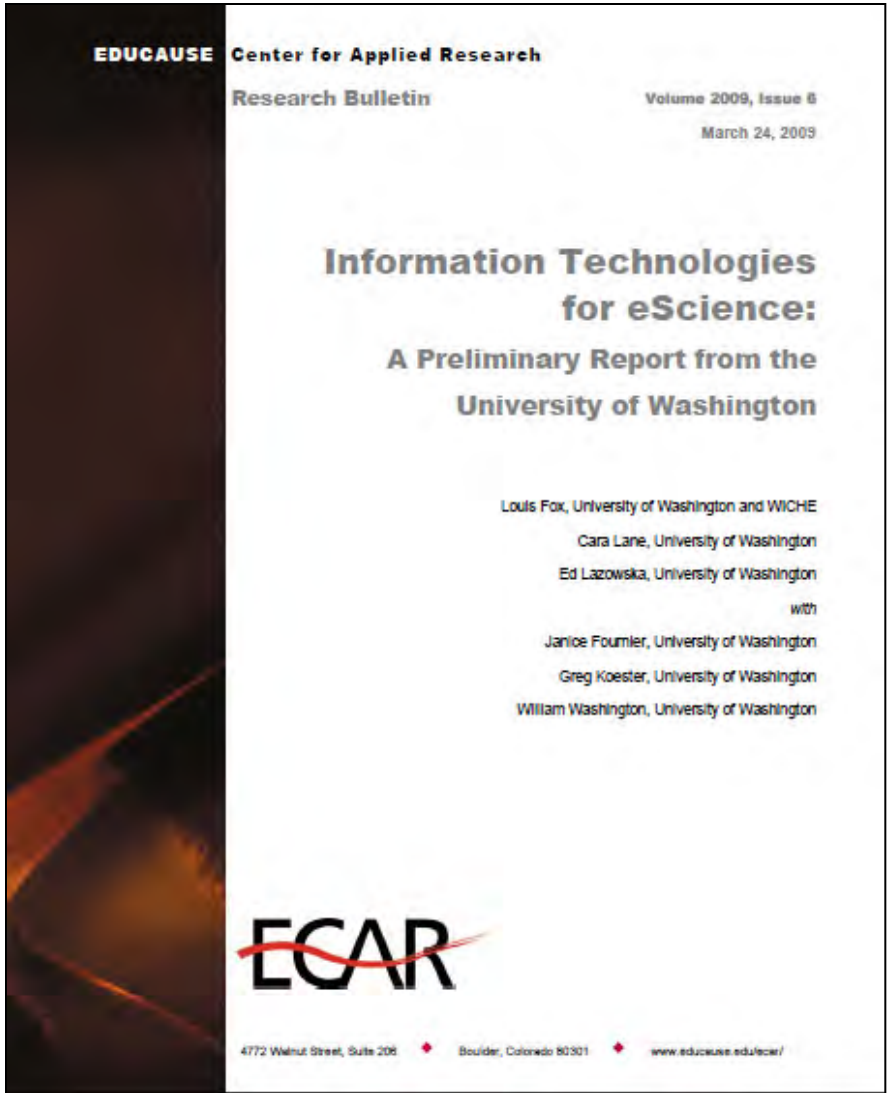
Credit: Werner Vogels, Amazon.com


Credit: Werner Vogels, Amazon.com

eScience will be pervasive

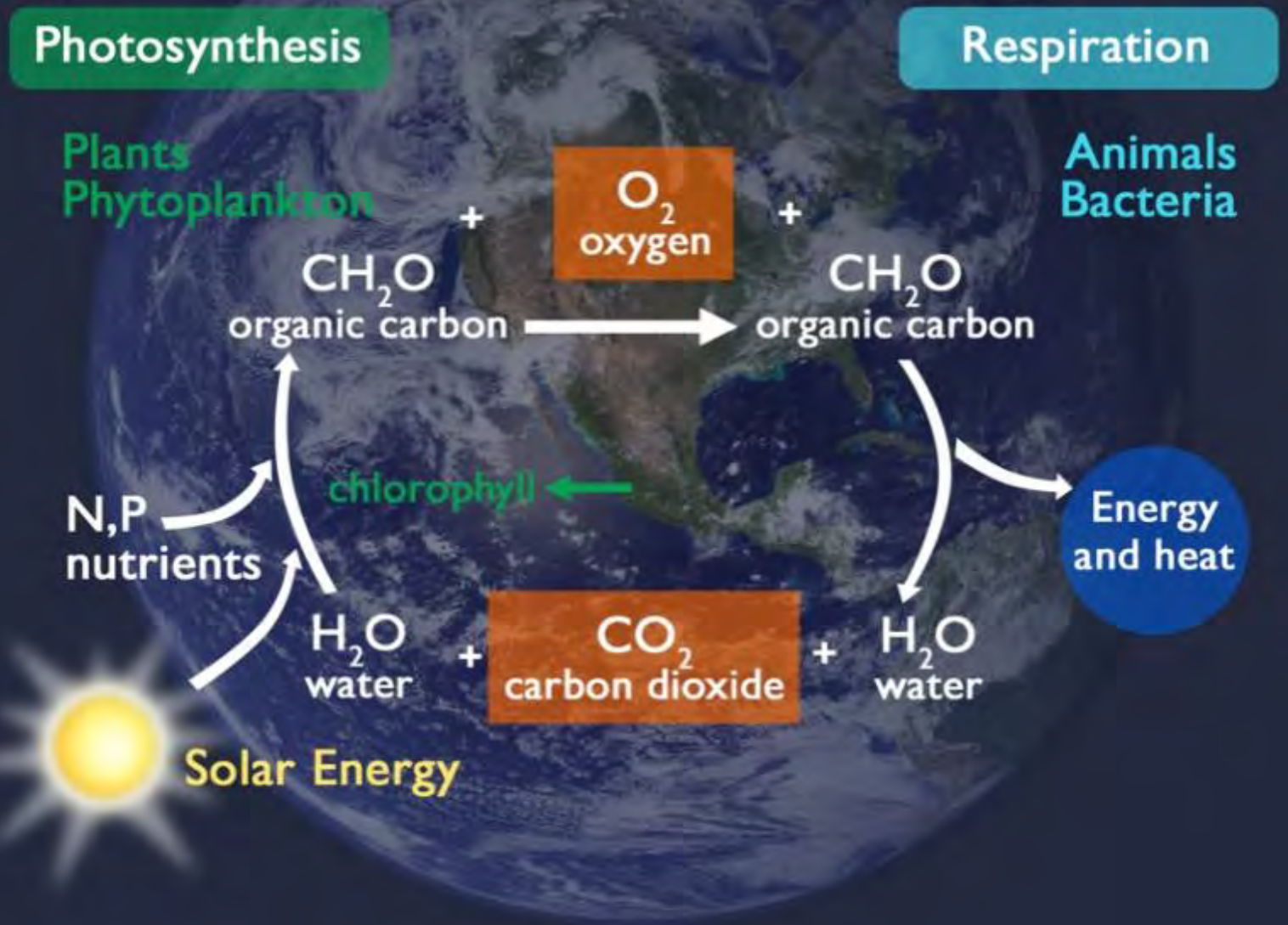
- Simulation-oriented computational science has been transformational, but it has been a niche
  - As an institution (e.g., a university), you didn't need to excel in order to be competitive
- eScience capabilities must be broadly available in any institution
  - If not, the institution will simply cease to be competitive

Top scientists across all fields grasp the implications of the looming data tsunami



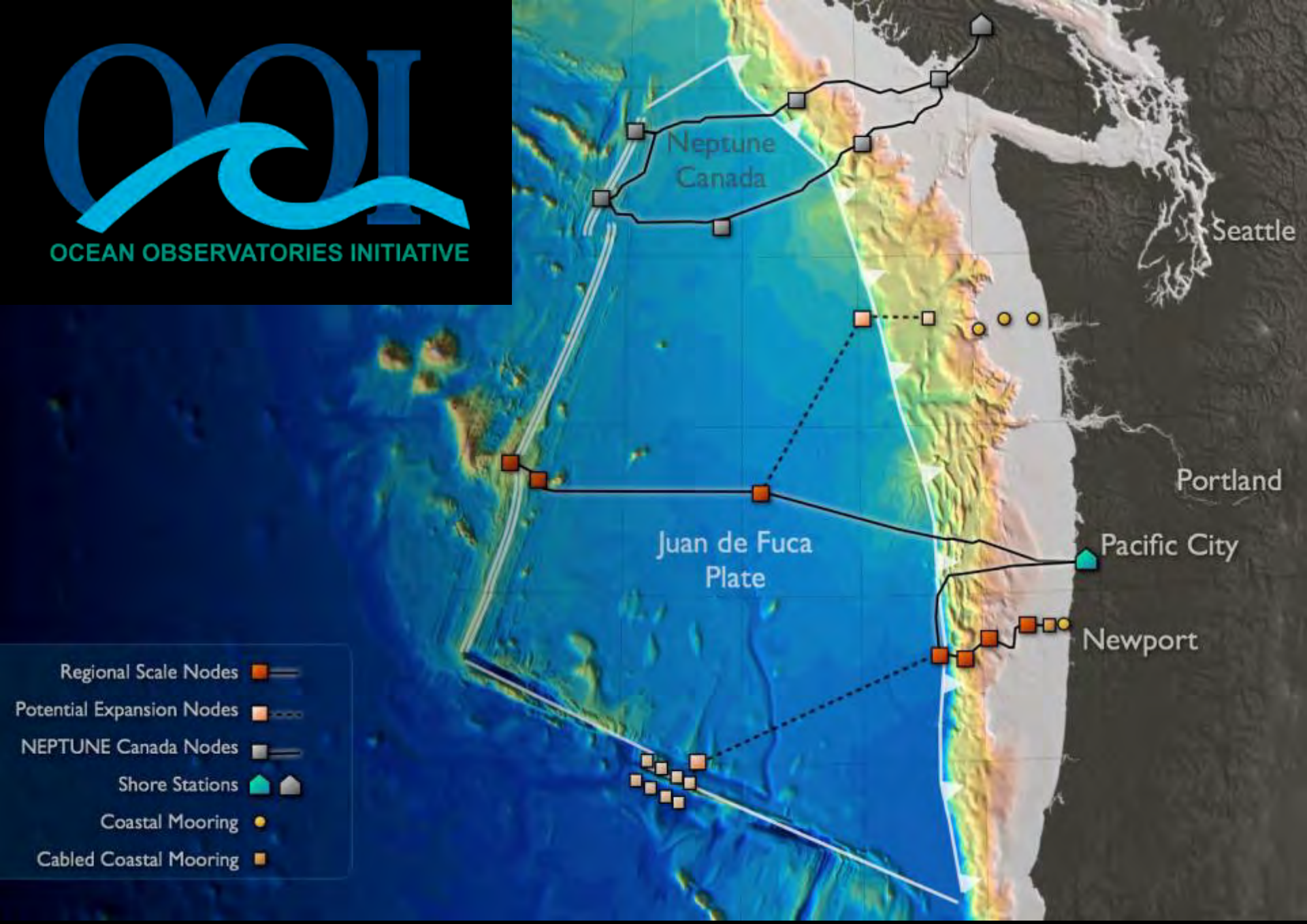
- Survey of 125 top investigators
  - "Data, data, data"
- Flat files and Excel are the most common data management tools
  - Great for Microsoft … lousy for science!
- Typical science workflow:
  - 2 years ago: 1/2 day/week
  - Now: 1 FTE
  - In 2 years: 10 FTE
- Need tools!

Life on Planet Earth



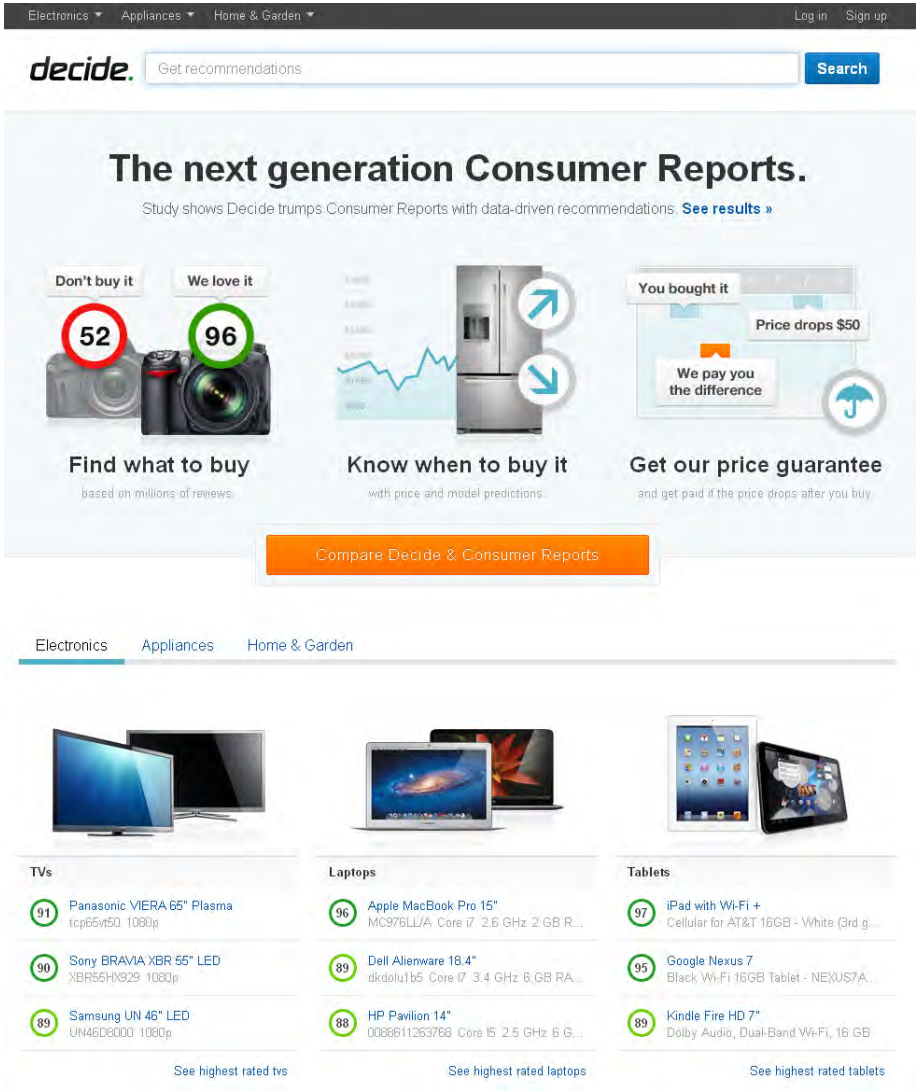
Credit: John Delaney, University of Washington

Credit: John Delaney, University of Washington



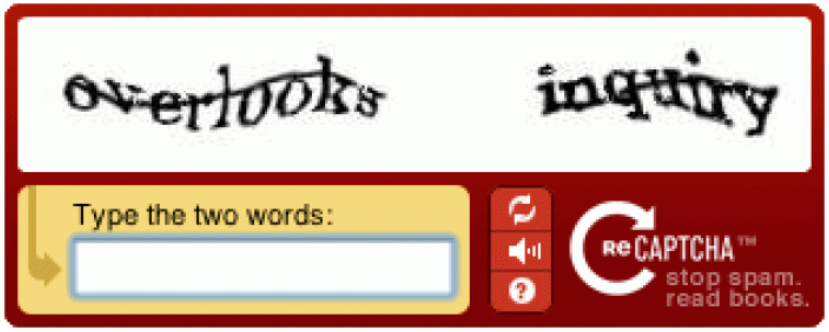
Credit: John Delaney, University of Washington

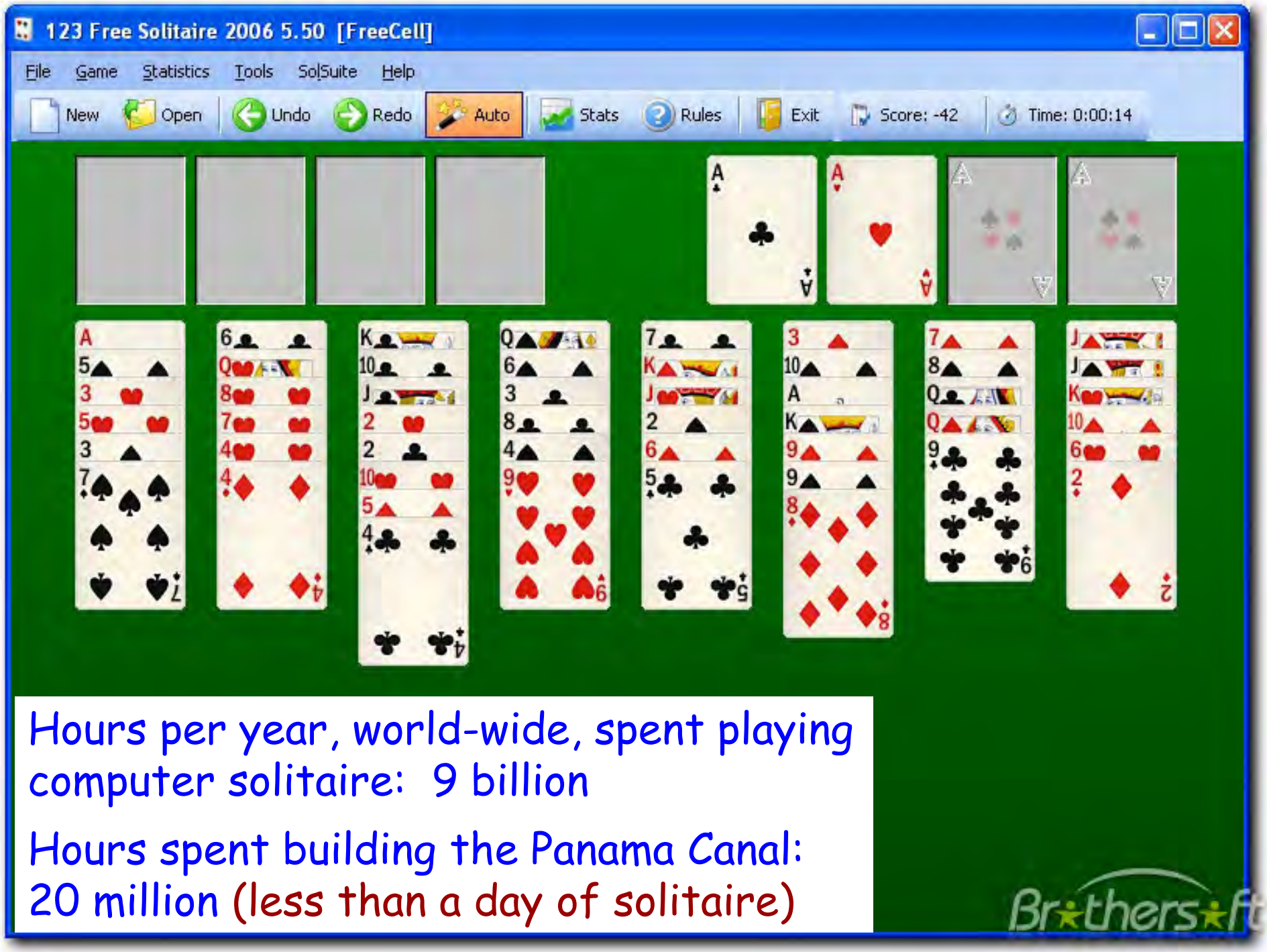
Of course, "big data" is about much more than science

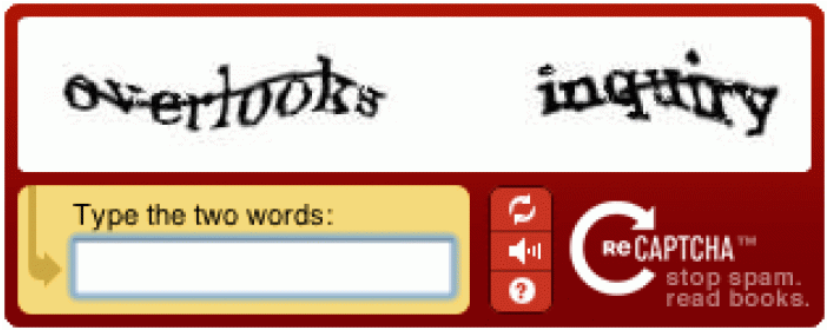


Smart crowds and human-computer systems

Luis von Ahn, CMU



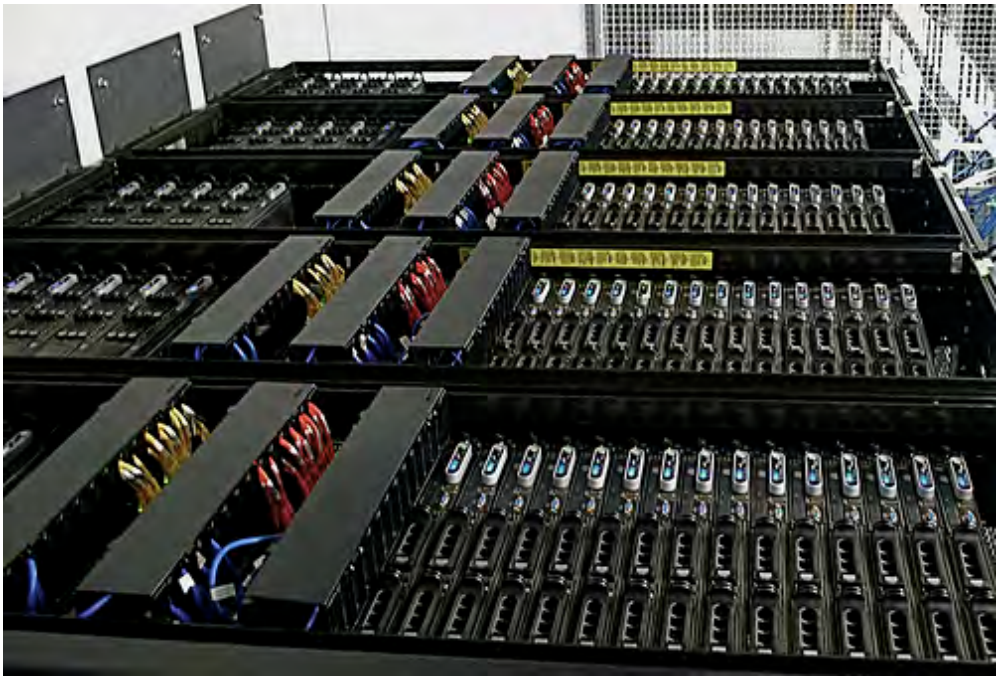

123 Free Solitaire 2006 5.50 [FreeCell]
File Game Statistics Tools SolSuite Help
New Open Undo Redo Auto Stats Rules Exit Score: -42 Time: 0:00:14
Hours per year, world-wide, spent playing computer solitaire: 9 billion
Hours spent building the Panama Canal: 20 million (less than a day of solitaire)
Brothersoft



The New York Times

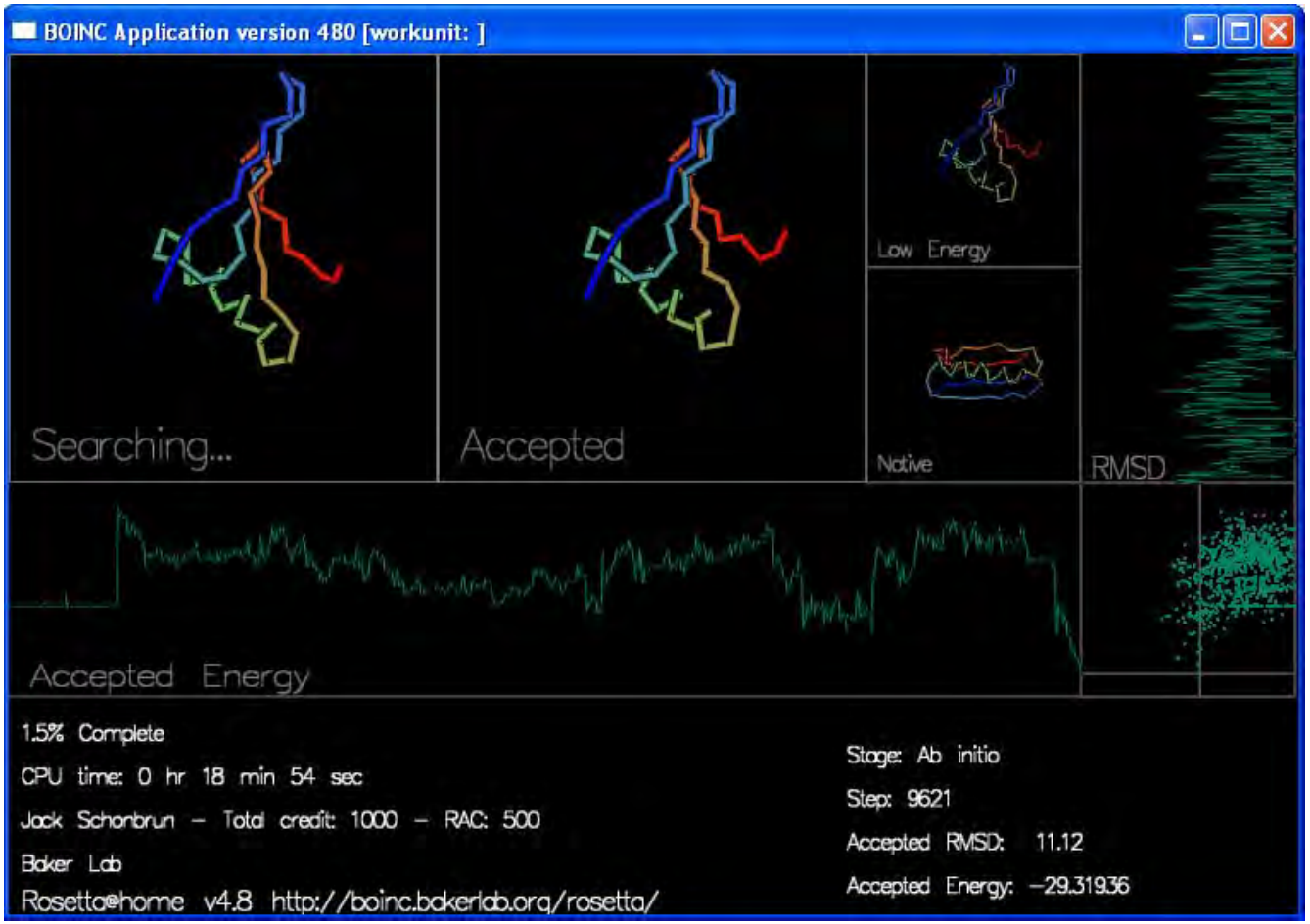
Years 1851-1980 were fully digitized, start to finish, in 2009!

David Baker,
University of Washington



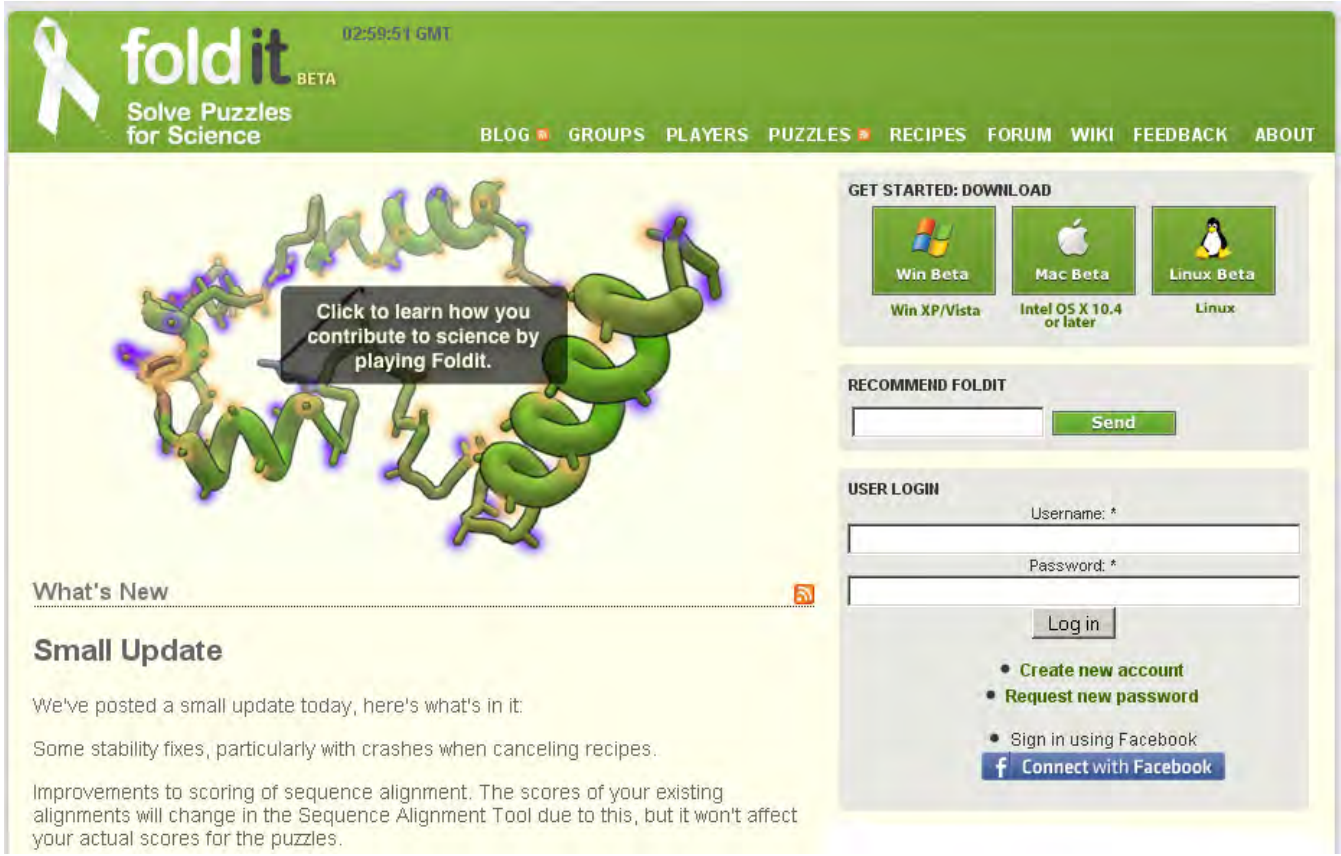
Rosetta@home

Protein Folding, Design, and Docking



Zoran Popovic,
University of Washington

Center for Game Science



fold it BETA

20:46:49 GMT

Solve Puzzles for Science

BLOG GROUPS PLAYERS PUZZLE

BootsMcGraw

Global Soloist Rank: #6

Global Soloist Score: 3784

Cases

Profile

Name: BootsMcGraw

Location: Dallas, Texas USA

Started Folding: 12/06/08

About me: An educated redneck here, from Dallas, Texas.

When I was in grad school in 1985 at the State University of New York at Buffalo, my master's thesis was to construct and present a computer program that predicted the secondary structures (helix, sheet, loop) of proteins based on their amino acid sequences. Tertiary structure (i.e. folding) prediction was a pie-in-the-sky fantasy.

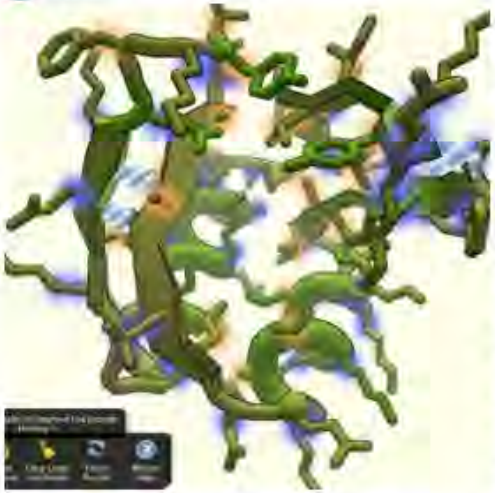
Imagine my delight, a quarter century later, to find out that not only are people determining tertiary structures of proteins, but they've made a *game* of it.

Hobbies: Licensed Massage Therapist; also a photographer, videographer, and webmaster. I have studied health and nutrition for over twenty years. Ask me my opinions about the subject.

Group: Contenders

Gamers Unlock Protein Mystery That Baffled AIDS Researchers For Years

By Leslie Horn | September 19, 2011 10:42am EST | 51 Comments | Email | Print



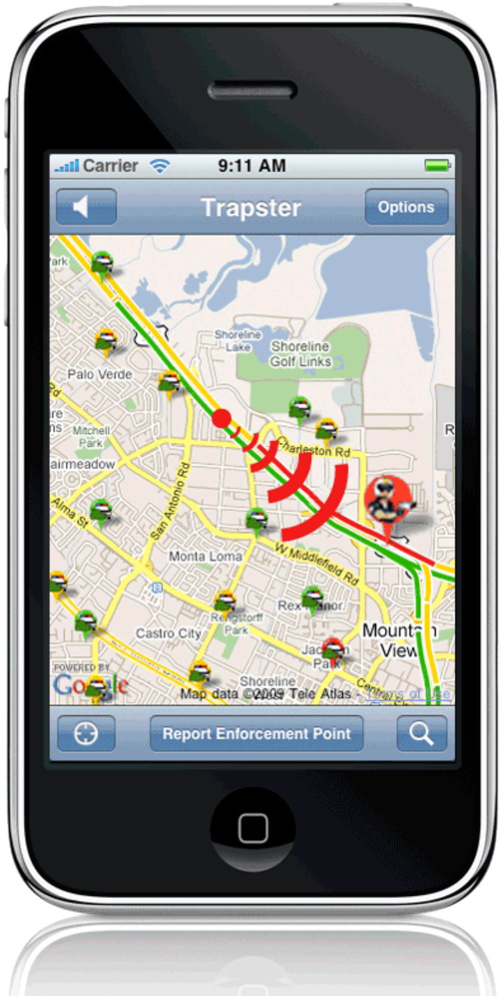
In just three weeks, gamers deciphered the structure of a key protein in the development of AIDS that has stumped scientists for years. According to a study published Sunday in the journal *Nature Structural & Molecular Biology*, the findings could present a significant breakthrough for AIDS and HIV research.

Using an online game called Foldit, players were able to predict the structure of a protein called retroviral protease, an enzyme that plays a critical role in the way HIV multiplies. Unlocking the build of the protein could theoretically aid scientists in developing drugs that would stop protease from spreading.

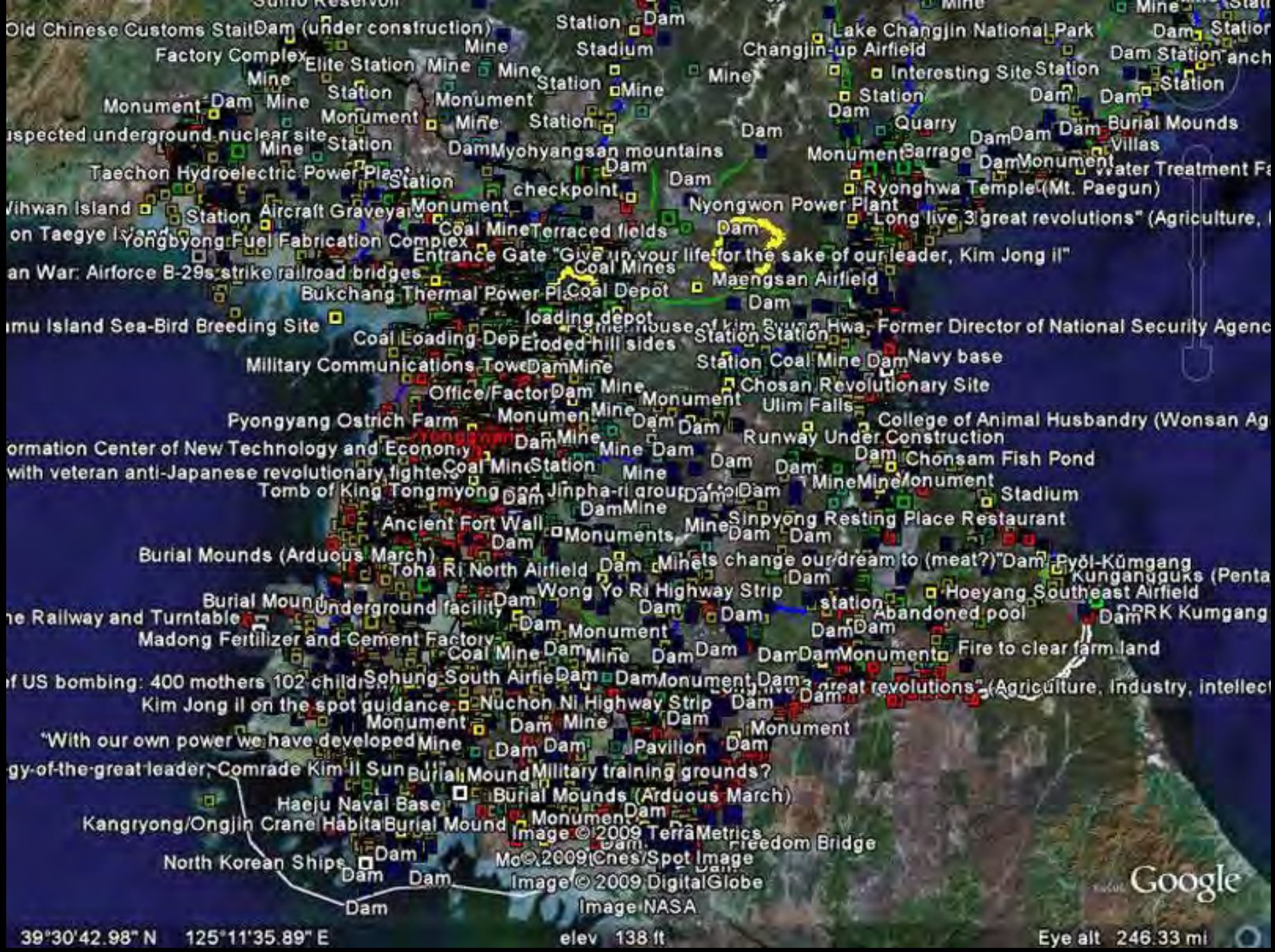
"Following the failure of a wide range of attempts to solve the crystal structure of M-PMV retroviral protease by molecular replacement, we challenged players of the protein folding game Foldit to produce accurate models of the protein," the study reads. "Remarkably, Foldit players were able to generate models of sufficient quality for successful molecular replacement and subsequent structure determination. The refined structure provides new insights for the design of antiretroviral drugs."

Regina Dugan

Peter Lee



Credit: Peter Lee, Microsoft Research



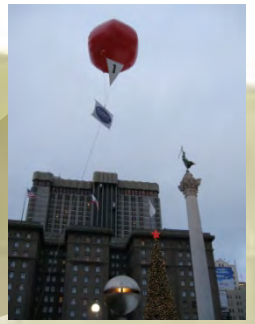
Credit: Peter Lee, Microsoft Research

DARPA NETWORK CHALLENGE

40th Anniversary of the Internet

29 Oct – Announced
5 Dec – Balloons Up

$40k Prize



Waterfront Park
Portland, OR

Union Square
San Francisco, CA

Chase Palm Park
Santa Barbara, CA

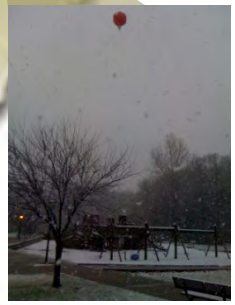
Chaparral Park
Scottsdale, AZ

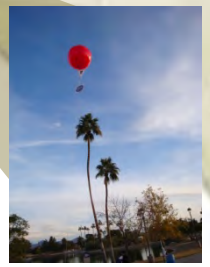
Glasgow Park
Christiana, DE

Tonsler Park
Charlottesville, VA

Lee Park
Memphis, TN

Centennial Park
Atlanta, GA





Katy Park
Katy, TX

Collins Avenue
Miami, FL

4367 registrants
39 countries
922 submissions
370 correct locations

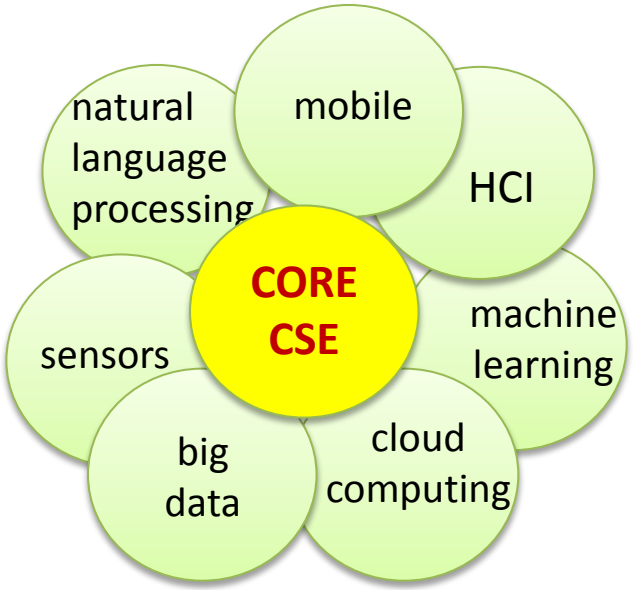
Credit: Peter Lee, Microsoft Research

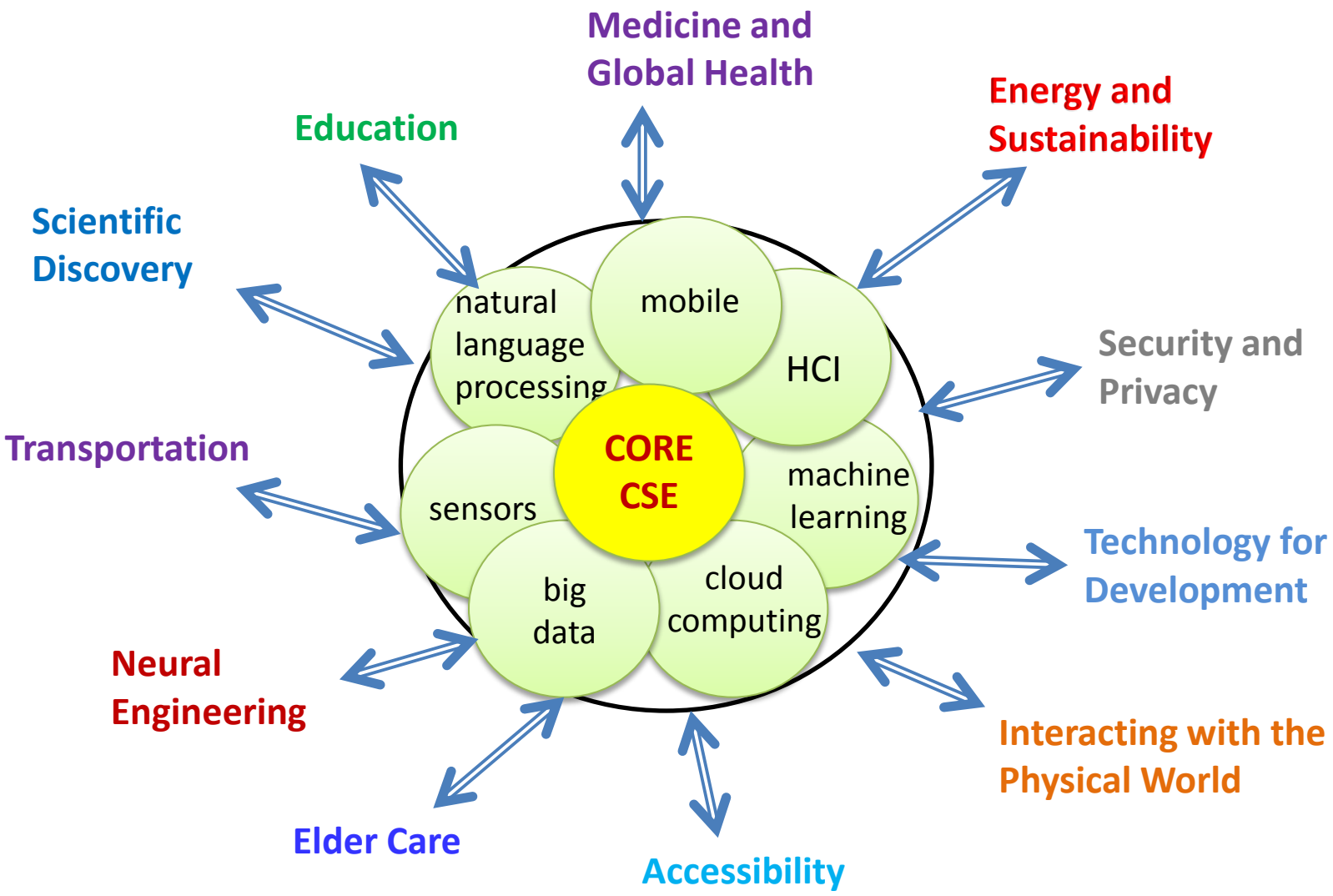
Smart interaction

KINECT™
for XBOX 360

- Speech recognition (MSR Redmond)
  - No push-to-talk
  - 4-meter distance, no headset
  - 80db ambient noise
  - Microphone array costs 30 cents
- Identity recognition (MSR Asia)
  - VGA camera
  - 4-meter distance
  - Varying ambient light
  - Sibling differentiation
- Tracking (MSR Cambridge)
  - Real-time
  - 100% on – deal with compounding errors
  - All body types, all numbers of bodies
  - People are jumping like monkeys
- System performance (MSR Silicon Valley)
  - Machine learning training utilized massive parallelism
  - Xbox GPU implementation of key functions yielded several-thousand-fold performance gains

All of those "smarts" lead to a particular view of the field


natural language processing
mobile
HCI
CORE CSE
sensors
machine learning
big data
cloud computing



Credit: Hank Levy, University of Washington

Computer Science & Engineering

UNIVERSITY of WASHINGTON

JEFF HEER

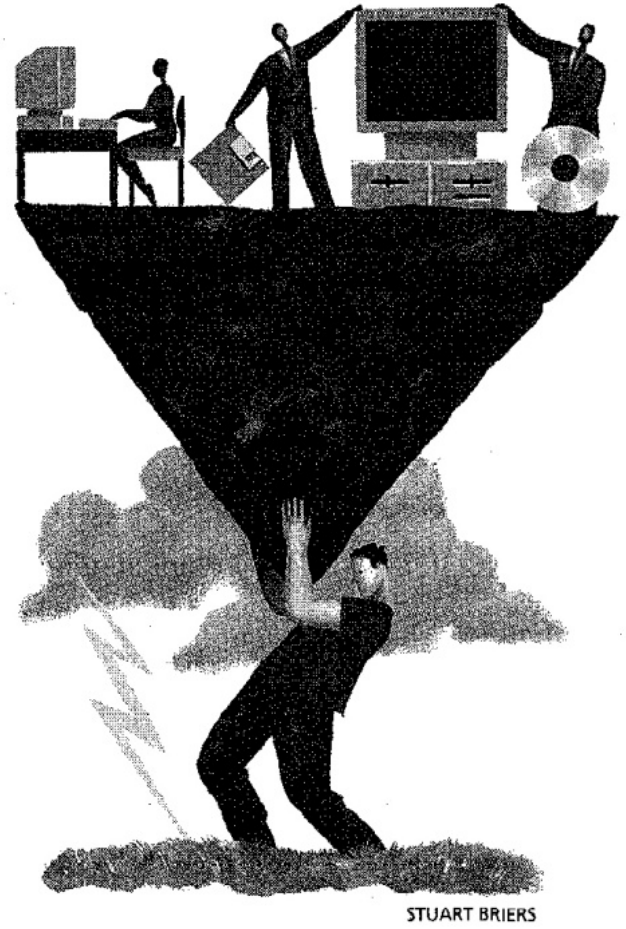
CARLOS GUESTRIN

EMILY FOX

BEN TASKAR

Senior hires catapult the University of Washington in machine learning and "big data"

Exhortation #1: Embrace "applications" as part of our field!



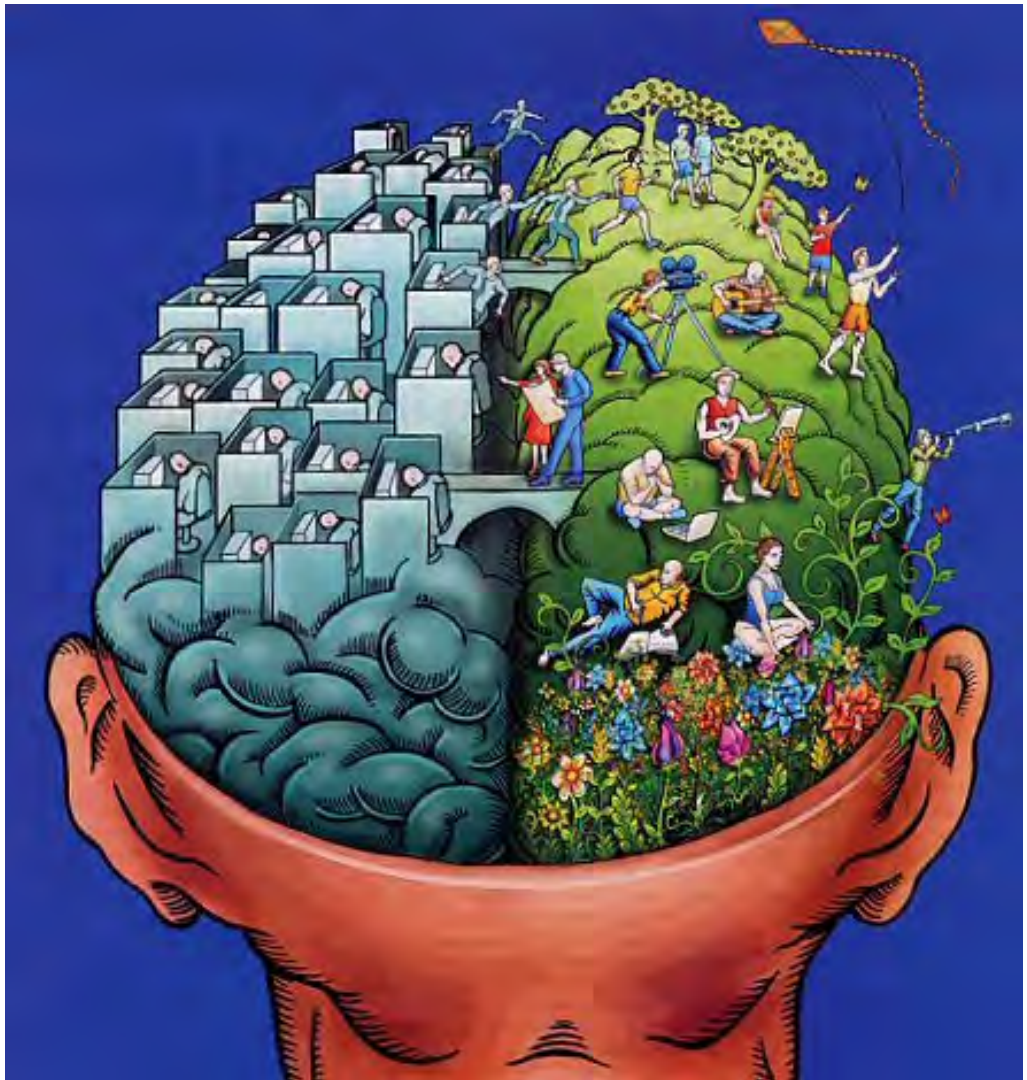
STUART BRIERS

"The last electrical engineer"

If current trends endure, future computers will consist of a single chip. No one will have the foggiest idea what is on it. Somewhere in the basement of Intel or its successor will be a huge computer file with the chip's listing. The last electrical engineer will sit nearby, handcuffed to the disk drive in a scene out of *Ben Hur*. That engineer will be extremely well paid, and his or her every demand will be immediately satisfied. That engineer will be the last keeper of the secret of the universe: E = IR.

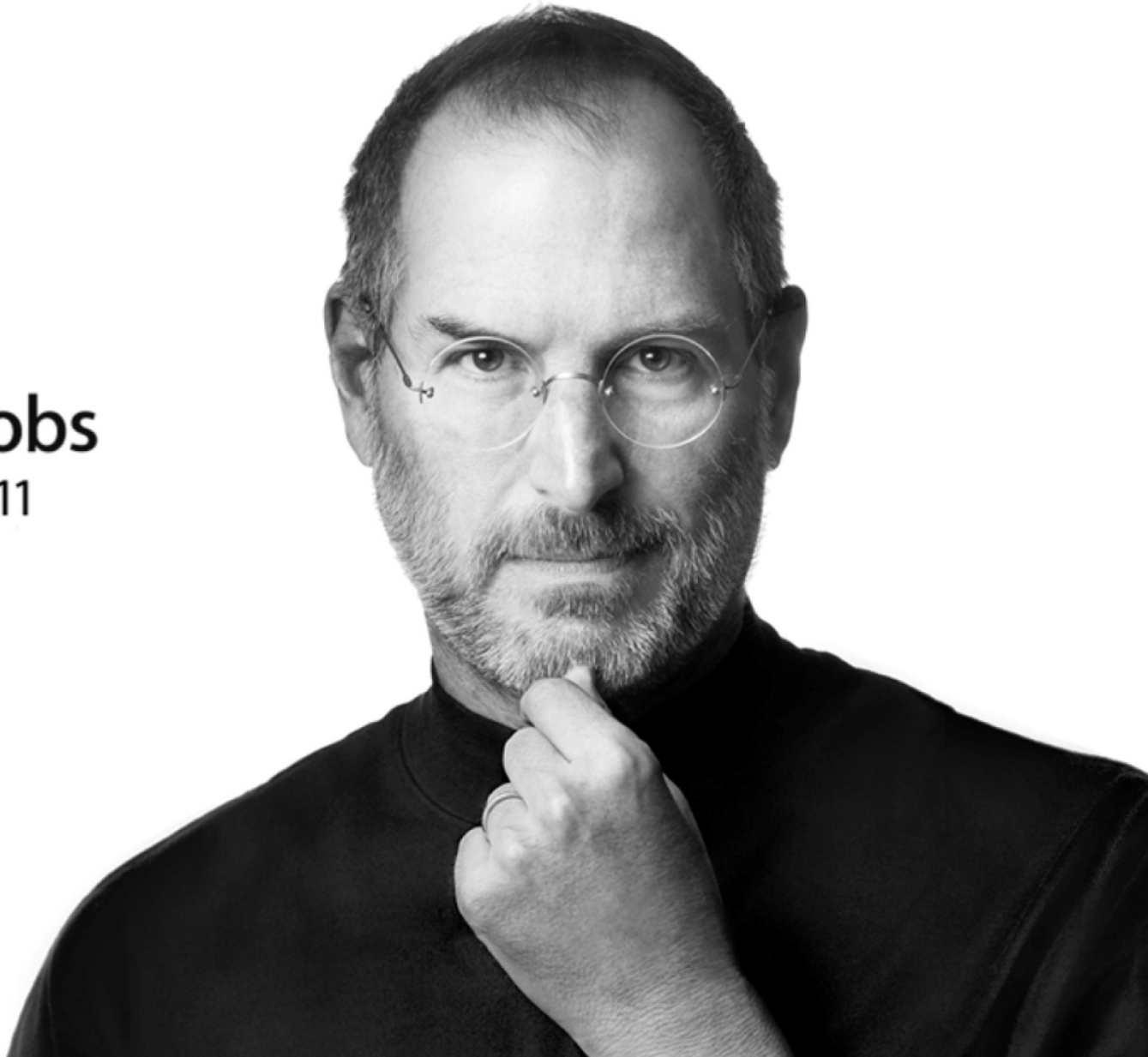
ROBERT W. LUCKY
Rlucky@bellcore.com

Exhortation #2: Use both sides of your brain!



Steve Jobs

1955-2011



the ONION
America's Finest News Source

Last American Who Knew What The Fuck He Was Doing Dies

OCTOBER 6, 2011 | ISSUE 47•40

Exhortation #3: Be a Mythbuster!

VIEWER Q&A >>

Get the truth on how the team really feels about the show.

MUSIC MYTHS >>

Can that high note really shatter glass? Bust it now.

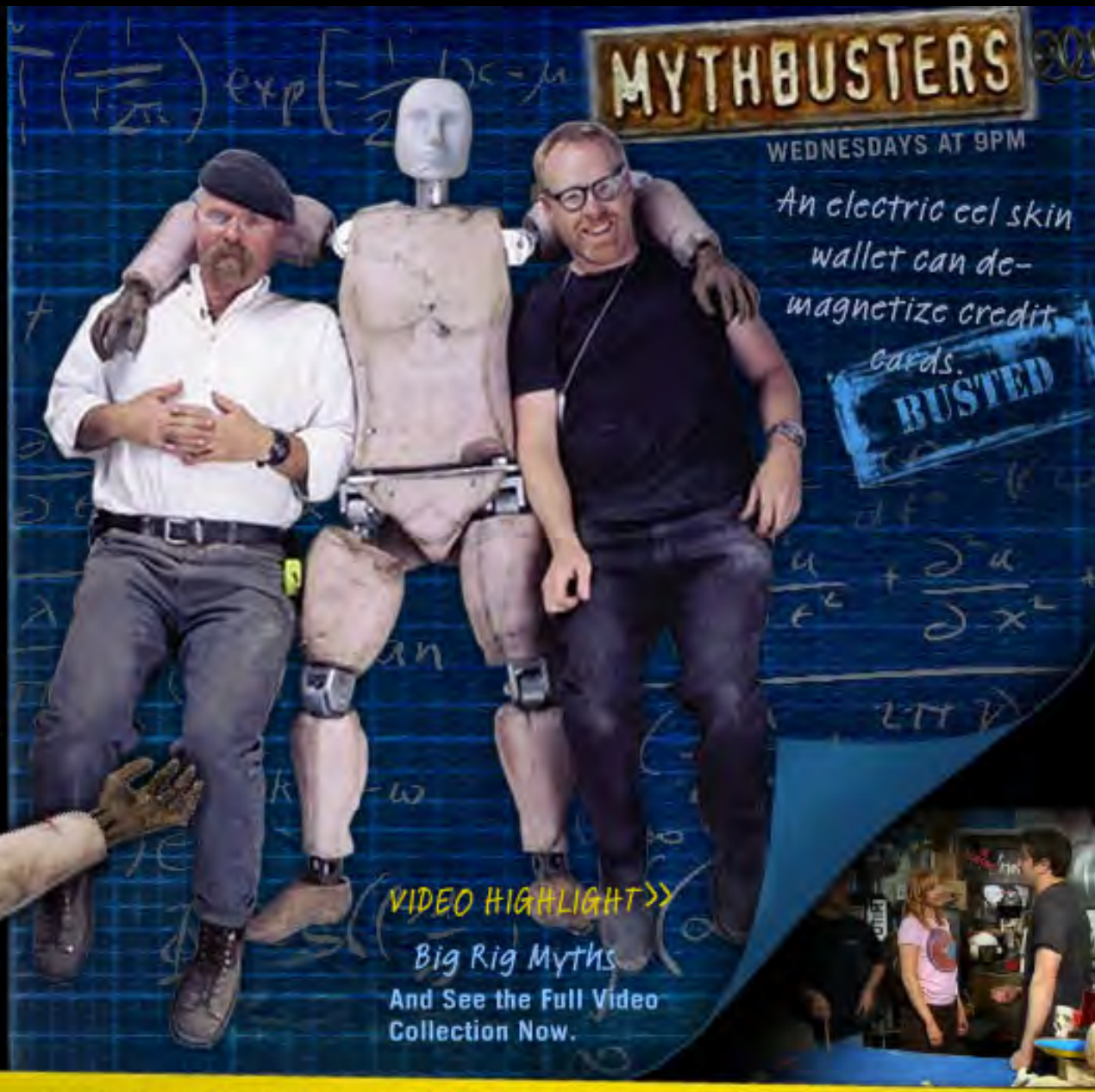
JOIN THE MESSAGE BOARD

"Baby snakes do not have control of how much venom they use and will shoot it all into you while a full grown snake conserves their venom. Is this true?" -- jeredweaver56

SUBMIT A MYTH >>

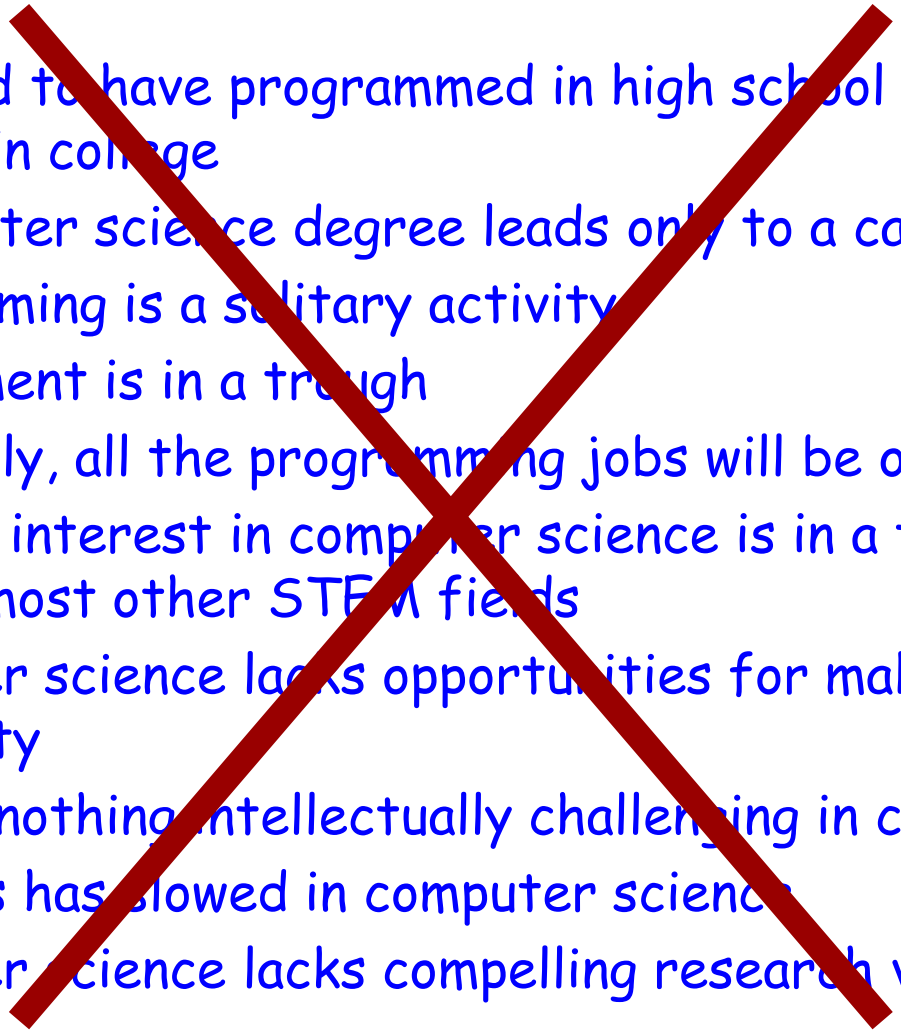
BE A MYTHBUSTER >>

Debunk a few classic myths. Give this interactive a whirl.



How's Your Brain Function? Watch Video and Take a Memory Exam.

Dispel these myths!



- You need to have programmed in high school to pursue computer science in college
- A computer science degree leads only to a career as a programmer
- Programming is a solitary activity
- Employment is in a trough
- Eventually, all the programming jobs will be overseas
- Student interest in computer science is in a trough, and is lower than in most other STEM fields
- Computer science lacks opportunities for making a positive impact on society
- There's nothing intellectually challenging in computer science
- Progress has slowed in computer science
- Computer science lacks compelling research visions

Is this a great time, or what?!?!

http://lazowska.cs.washington.edu/michigan.pdf
http://www.cra.org/ccc/
http://www.cs.washington.edu/WhyCSE/