

Computer Science: Past, Present, and Future

Ed Lazowska

Bill & Melinda Gates Chair in
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University of Washington

Chair, Computing Community Consortium

Harvard University

April 2010

<http://lazowska.cs.washington.edu/harvard.pdf>



Today ...

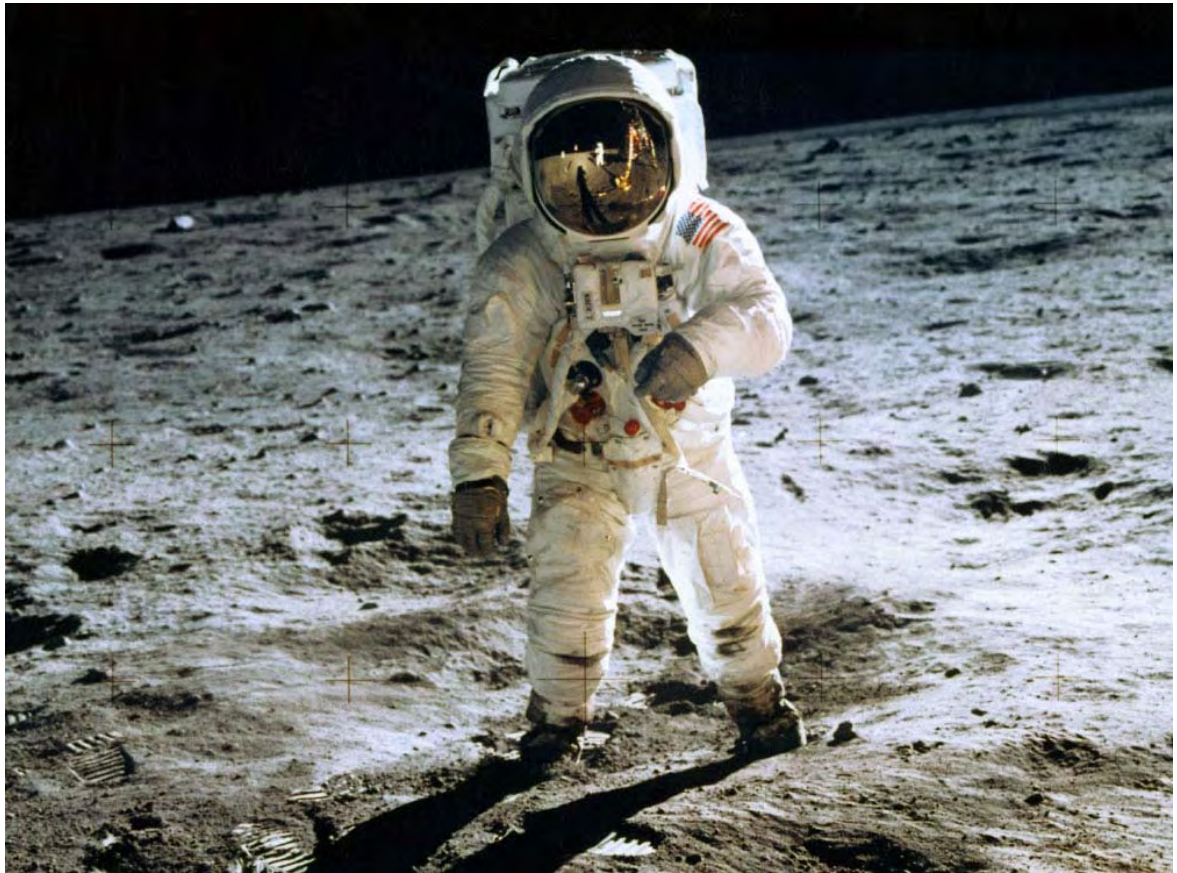


- A quick reminder of what we've accomplished as a field
- The Computing Community Consortium: origins, goals, recent activities
- Some research challenges for our field
- Be a Myth Buster!

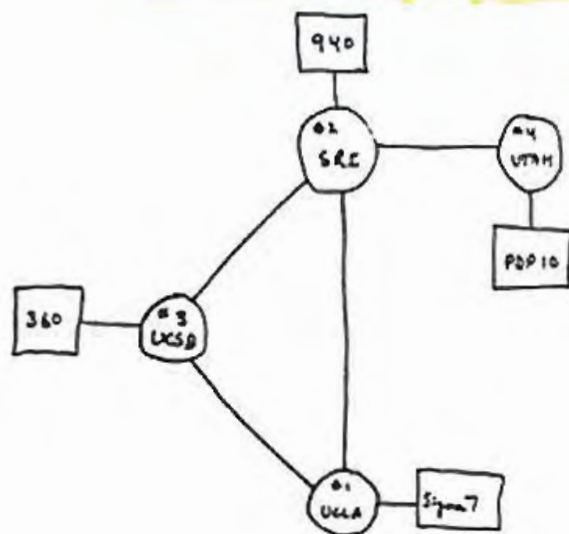
Forty years ago ...







[Peter Lee, DARPA, and Pat Lincoln, SRI]



THE ARPA NETWORK
DEC 1969
4 NODES

29 OCT 69	2100	LOADED OP. PROGRAM	SK
		EDIC BEN BARKER	
		BBV	
	22:30	Talked to SRC	SK
		Host to Host	
		Left op program	SK
		running after sending	
		a host dead message	
		to imp.	



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  US

The past thirty years ...



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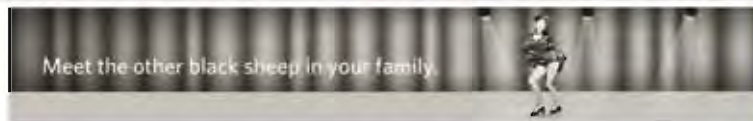


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THE COUNT

Internet, Mobile Phones Named Most Important Inventions

By PHYLLIS KORRIG Published: March 7, 2009

In response to the shouted-out question, "What are some of the greatest inventions of all time?," nearly 600 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 KORRIG

- E-MAIL
- PRINT
- REPRINTS
- SHARE

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- Parents Sue Trustees Over Prep School's Shutdown
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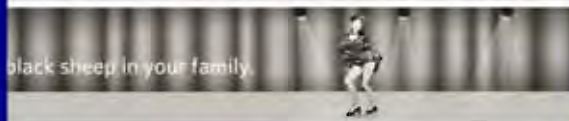
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THE NEW YORK TIMES

Named Most Important Inventions

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Landmark contributions by students



- Use of Boolean logic to model digital circuits
 - Claude Shannon, MIT, 1937
- Huffman coding
 - David Huffman, MIT, 1951
- Mathematical foundation of packet communication
 - Len Kleinrock, MIT, 1962
- Interactive computer graphics
 - Ivan Sutherland, MIT, 1963
- Computer vision
 - Larry Roberts, MIT, 1963
- Symbolic mathematics
 - William A. Martin & Joel Moses, MIT, 1967

- 
- The FLEX language and machine
 - Alan Kay, Utah, 1969
 - The Boyer-Moore theorem prover
 - Robert S. Boyer and J Strother Moore, Edinburgh, 1971
 - Efficient graph planarity testing using depth-first search
 - Bob Tarjan, Stanford, 1972
 - Ethernet
 - Bob Metcalfe, Harvard, 1973
 - BSD Unix
 - Bill Joy, Berkeley, 1977
 - VisiCalc
 - Bob Frankston & Dan Bricklin, MIT, 1979

- 
- Public key cryptography
 - Ralph Merkle, Berkeley & Stanford, 1979
 - The SUN workstation
 - Andy Bechtolsheim, Stanford, 1982
 - The Connection Machine
 - Danny Hillis, MIT, 1983
 - Sphinx (speech recognition)
 - Kai-Fu Lee, Carnegie Mellon, 1988
 - Linux
 - Linus Torvalds, Helsinki, 1991
 - BDD-based symbolic model checking
 - Ken McMillan, Carnegie Mellon, 1992



- Mosaic

- Marc Andreessen, Illinois, 1994

- The PCP theorem

- Sanjeev Arora, Berkeley, 1994

- Google

- Larry Page & Sergey Brin, Stanford, 1998

- Akamai

- Danny Lewin, MIT, 1999

- Peer-to-peer file sharing

- Shawn Fanning, Northeastern, 1999

The most recent ten years ...

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



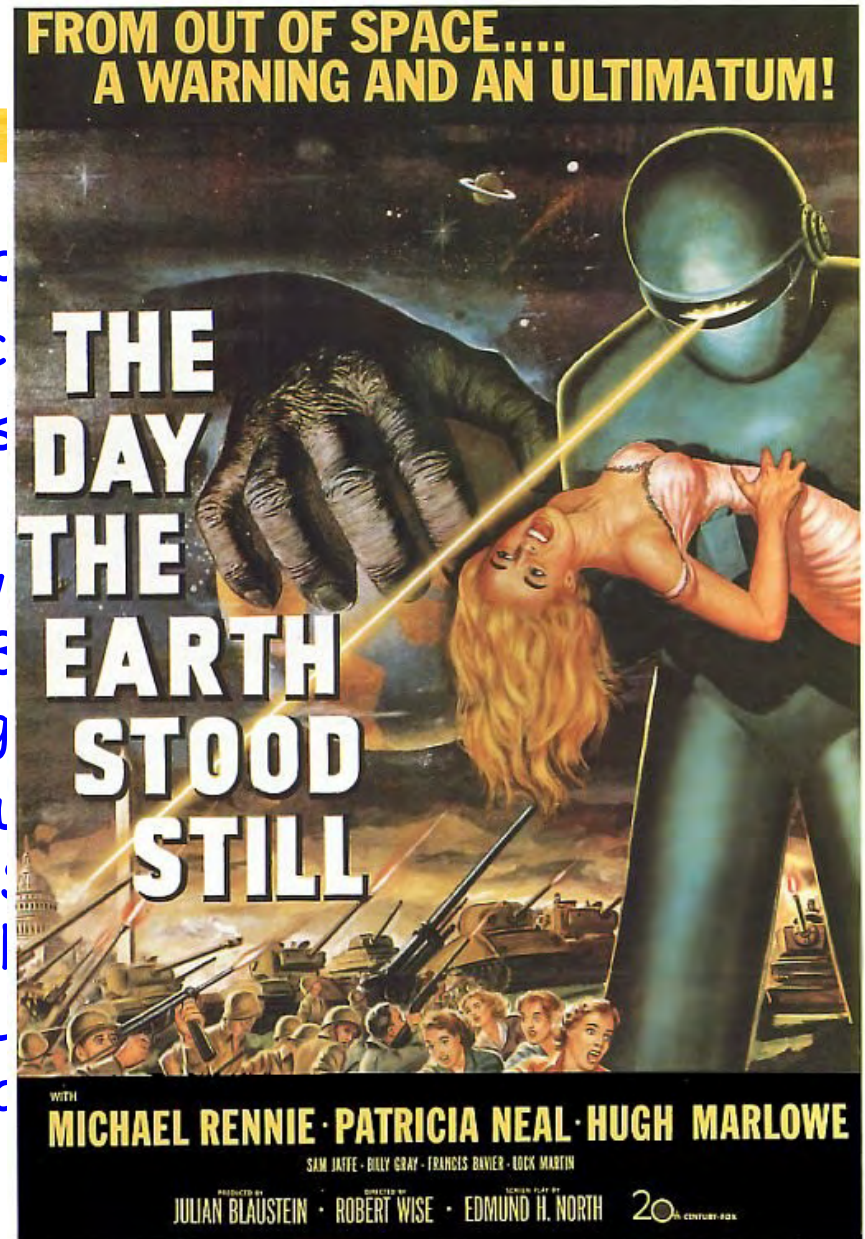
Imagine spending a day without information technology



- A day without the Internet and all that it enables
- A day without diagnostic medical imaging
- A day during which automobiles lacked electronic ignition, antilock brakes, and electronic stability control
- A day without digital media - without wireless telephones, high-definition televisions, MP3 audio, DVD video, computer animation, and videogames
- A day during which aircraft couldn't fly, travelers had to navigate without benefit of GPS, weather forecasters had no models, banks and merchants couldn't transfer funds electronically, factory automation ceased to function, and the US military lacked technological supremacy

Imagine spending a day without information technology

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- A day without diagnostic medic
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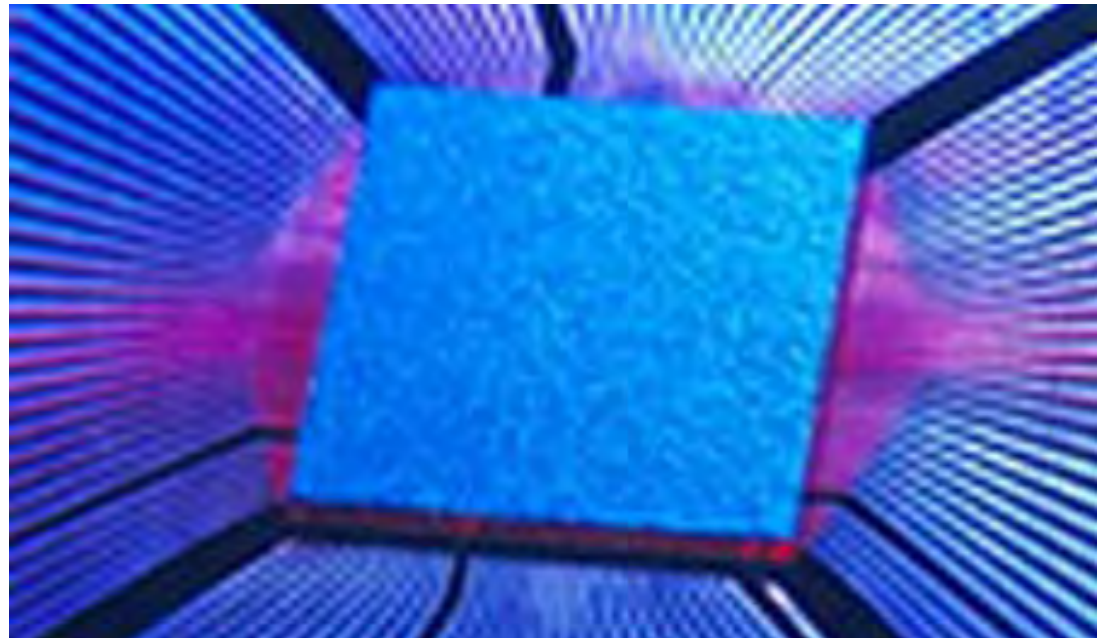
10,000,000,000,000,000,000
grains of rice

- Ten quintillion: $10 \cdot 10^{18}$
 - The number of grains of rice harvested in 2004



10,000,000,000,000,000,000 transistors

- Ten quintillion: 10^{18}
 - The number of grains of rice harvested in 2004
 - The number of transistors fabricated in 2004



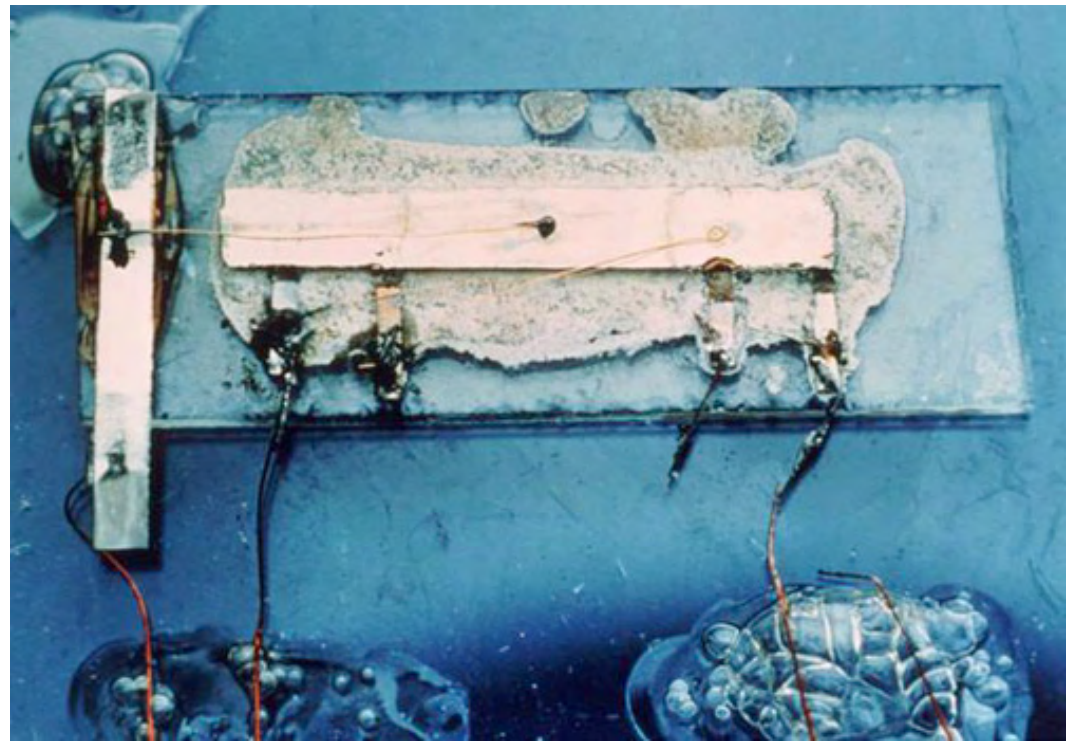
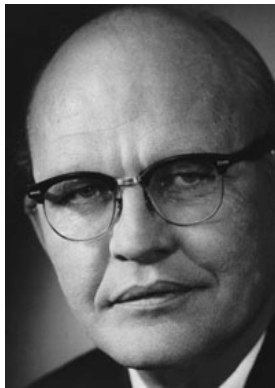
The transistor

- William Shockley, Walter Brattain and John Bardeen, Bell Labs, 1947



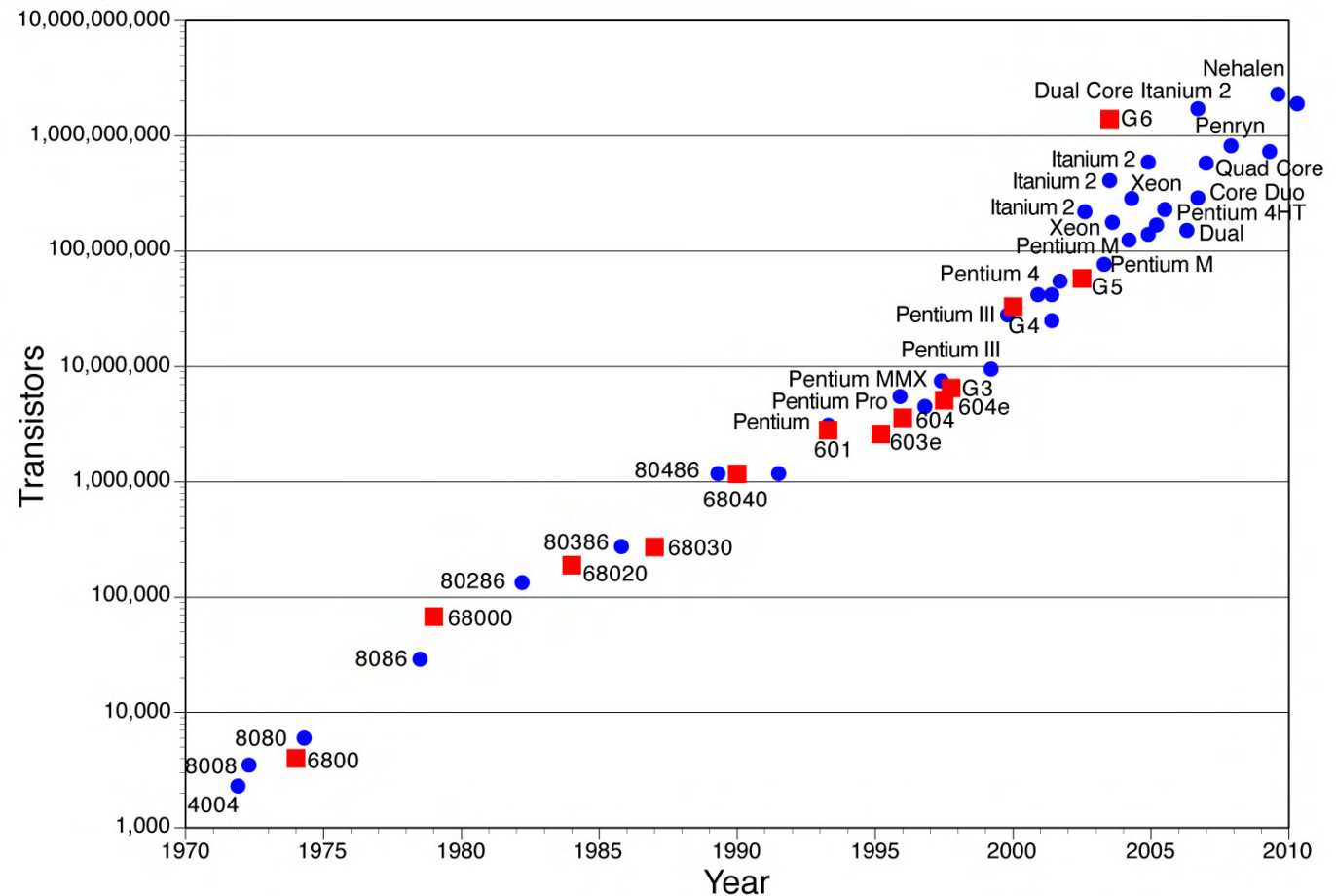
The integrated circuit

- Jack Kilby, Texas Instruments, and Bob Noyce, Fairchild Semiconductor Corporation, 1958



Exponential progress

Gordon Moore, 1965





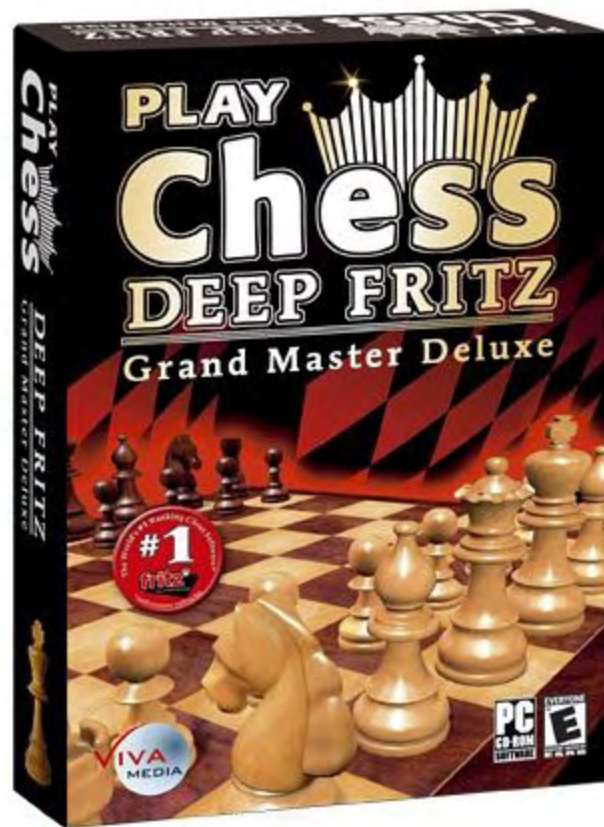


Software makes equal progress



Deep Blue, 1997





Price: **\$19.99** & eligible for free shipping
with **Amazon Prime**

Deep Fritz, 2002



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[®]

Web commerce back-end, 1997

■ Contrast ...

- The cheapest imaginable components
 - | Failures occur all the time
 - | You couldn't afford to prevent this in hardware
- Software makes it
 - | Fault-Tolerant
 - | Highly Available
 - | Recoverable
 - | Consistent
 - | Scalable
 - | Predictable
 - | Secure



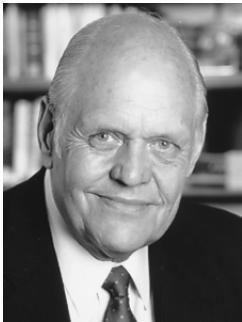
Web commerce back-end, 2007

This sort of progress makes it dicey to predict the future



"I think there is a world market for maybe five computers" - Thomas J. Watson, founder and Chairman of IBM, 1943

"Computers in the future may weigh no more than 1.5 tons" - *Popular Science*, 1949

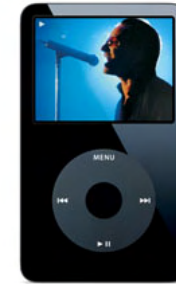


"There is no reason anyone would want a computer in their home" - Ken Olsen, founder and President of Digital Equipment Corporation, 1977

Today: More than 1 billion PCs in use ...

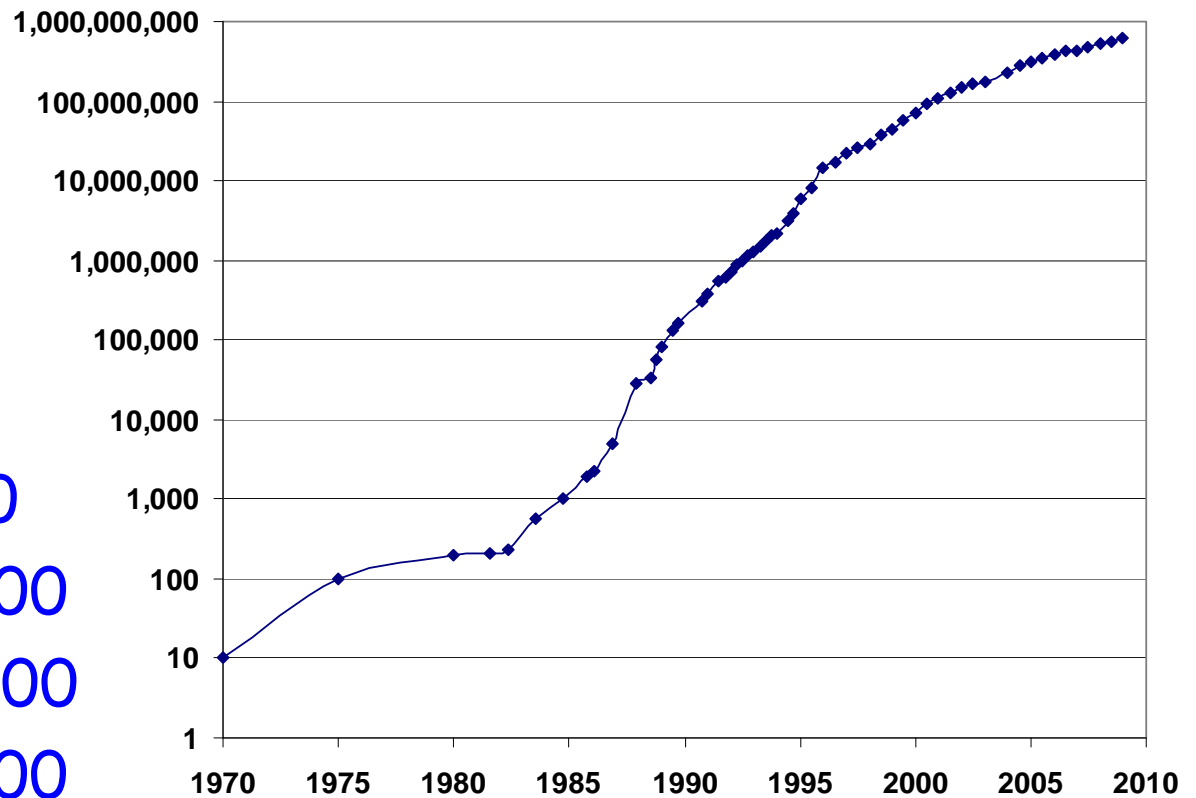


Representing less than 2% of all processors!



Number of Internet hosts

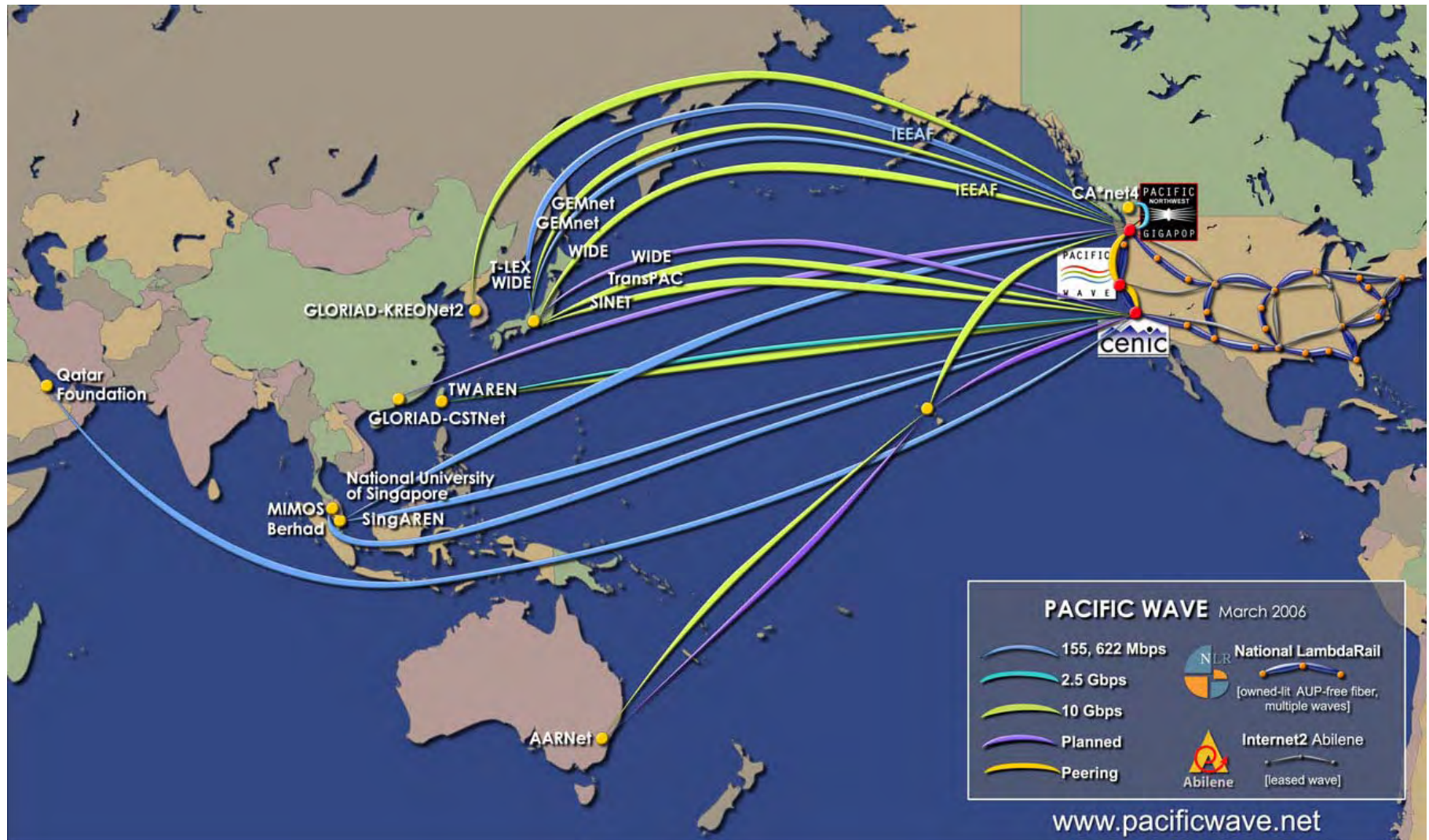
- 1970: 10
- 1975: 100
- 1980: 200
- 1985: 2,000
- 1990: 350,000
- 1995: 10,000,000
- 2000: 100,000,000
- 2005: 375,000,000
- 2010: 700,000,000



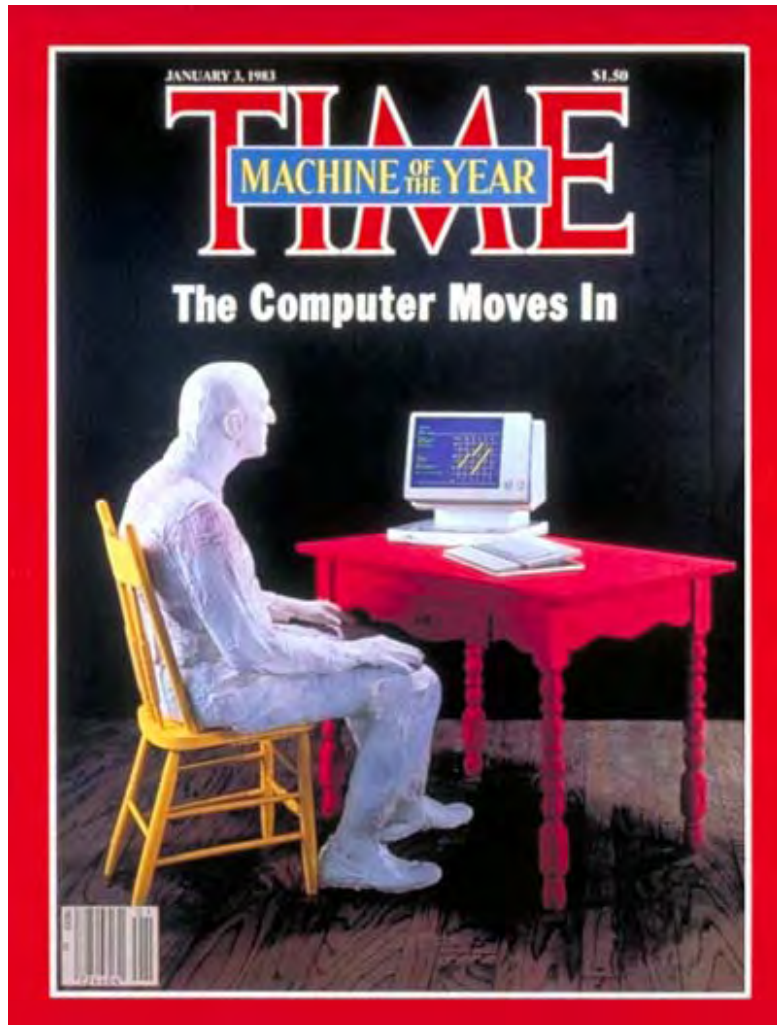
A connected region - then



A connected region - now




The Computer: *Time Magazine's* 1982 "Machine of the Year"



- "In medicine, the computer, which started by keeping records and sending bills, now suggests diagnoses. The process may sound dehumanized, but in one hospital ... a survey of patients showed that they found the machine 'more friendly, polite, relaxing and comprehensible' than the average physician."



- 
- "When the citizen of tomorrow wants a new suit, one futurist scenario suggests, his personal computer will take his measurements and pass them on to a robot that will cut his choice of cloth with a laser beam and provide him with a perfectly tailored garment."

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- 
- "In the home, computer enthusiasts delight in imagining machines performing domestic chores."

- “In the home, computer enthusiasts delight in imagining machines performing domestic chores.”

vacuum your carpet



iRobot®

- “In the home, computer enthusiasts delight in imagining machines performing domestic chores.”

wash your floor



iRobot®

- “In the home, computer enthusiasts delight in *imagining* machines performing domestic chores.”

scrub your pool



iRobot®

- "In the home, computer enthusiasts delight in imagining machines performing domestic chores."

clean your gutters



iRobot®

- "In the home, computer enthusiasts delight in imagining machines performing domestic chores."

amuse your pet



iRobot®

- "In the home, computer enthusiasts delight in imagining machines performing domestic chores."

detonate your IED's



iRobot®

The Computing Community Consortium



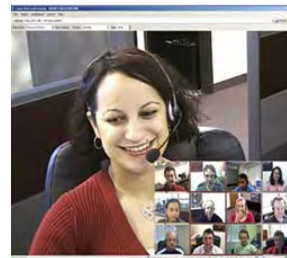
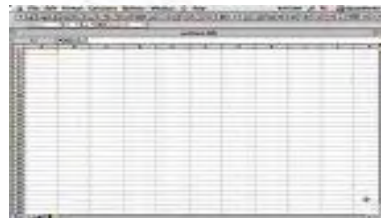
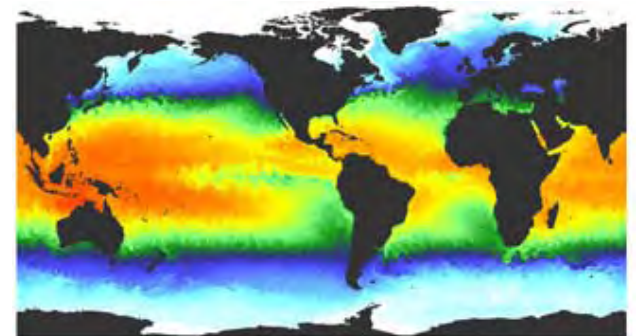
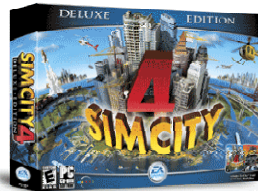
Computing Community Consortium

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

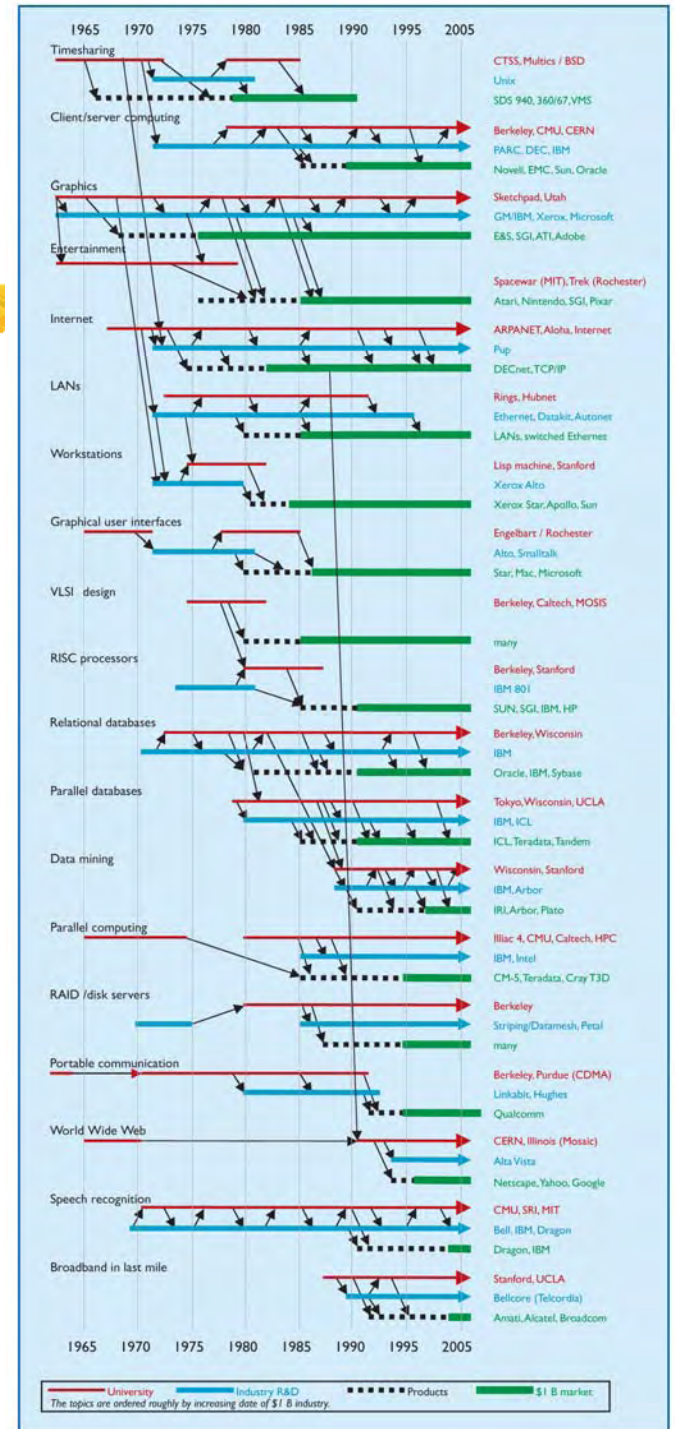
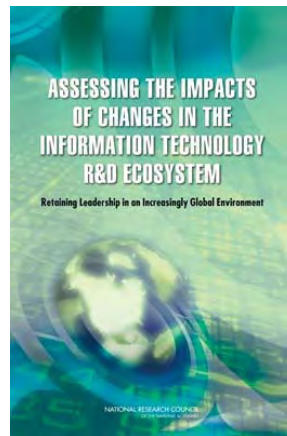
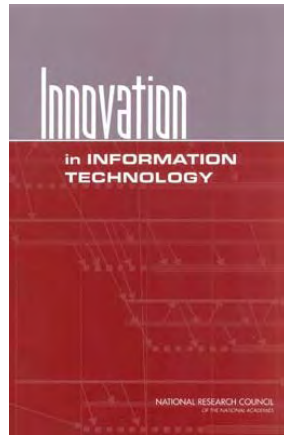
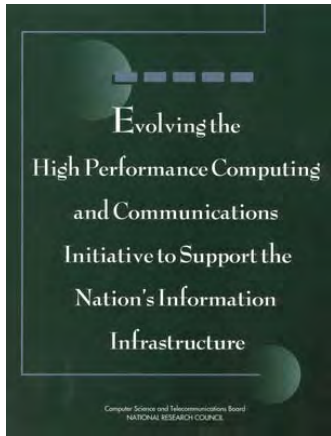


Computing has changed the world

- Advances in computing change the way we live, work, learn, and communicate
- Advances in computing drive advances in nearly all other fields
- Advances in computing power our economy
 - Not just through the growth of the IT industry - through productivity growth across the entire economy

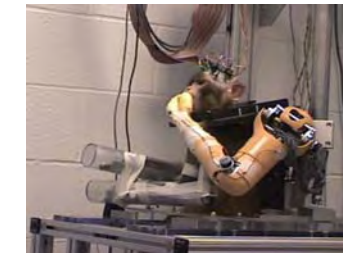
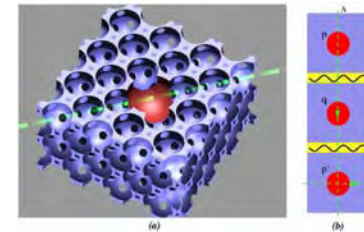
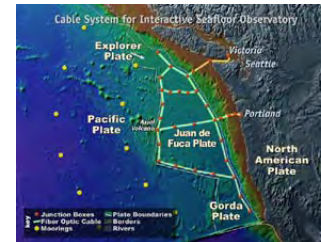
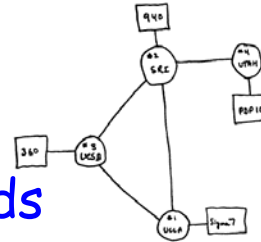


Research has built the foundation



The future is full of opportunity

- Creating the future of networking
- Driving advances in all fields of science and engineering
- Revolutionizing transportation
- Personalized education
- The smart grid
- Predictive, preventive, personalized medicine
- Quantum computing
- Empowerment for the developing world
- Personalized health monitoring => quality of life
- Harnessing parallelism
- Neurobotics
- Synthetic biology



We must work together to establish, articulate, and pursue visions for the field

- The challenges that will shape the intellectual future of the field
- The challenges that will catalyze research investment and public support
- The challenges that will attract the best and brightest minds of a new generation



To this end, NSF asked CRA to create the Computing Community Consortium

- To catalyze the computing research community to consider such questions
 - To envision long-range, more audacious research challenges
 - To build momentum around such visions
 - To state them in compelling ways
 - To move them towards funded initiatives
 - To ensure "science oversight" of large-scale initiatives
- A "cooperative agreement" with NSF
 - Close coordination



The CCC Council - broad representation

■ Chair

- Ed Lazowska

■ Terms ending 2013

- Randy Bryant
- Lance Fortnow
- Hank Korth
- Eric Horvitz
- Beth Mynatt
- Fred Schneider
- Margo Seltzer

■ Terms ending 2012

- Stephanie Forrest
- Chris Johnson
- Anita Jones
- Frans Kaashoek
- Ran Libeskind-Hadas
- Robin Murphy

■ Terms ending 2011

- Bill Feiereisen
- Susan Graham (v ch)
- Dave Kaeli
- John King
- Bob Sproull

■ Ex Officio

- Andy Bernat
- Erwin Gianchandani

■ Rotated off

- Dick Karp, 2010
- Andrew McCallum, 2010
- Dave Waltz, 2010
- Greg Andrews, 2009
- Peter Lee, 2009
- Karen Sutherland, 2009

Major continuing activities

■ Countless talks

The Computing Community Consortium: Stimulating Bigger Thinking

Ed Lazowska

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

Chair, Computing Community Consortium

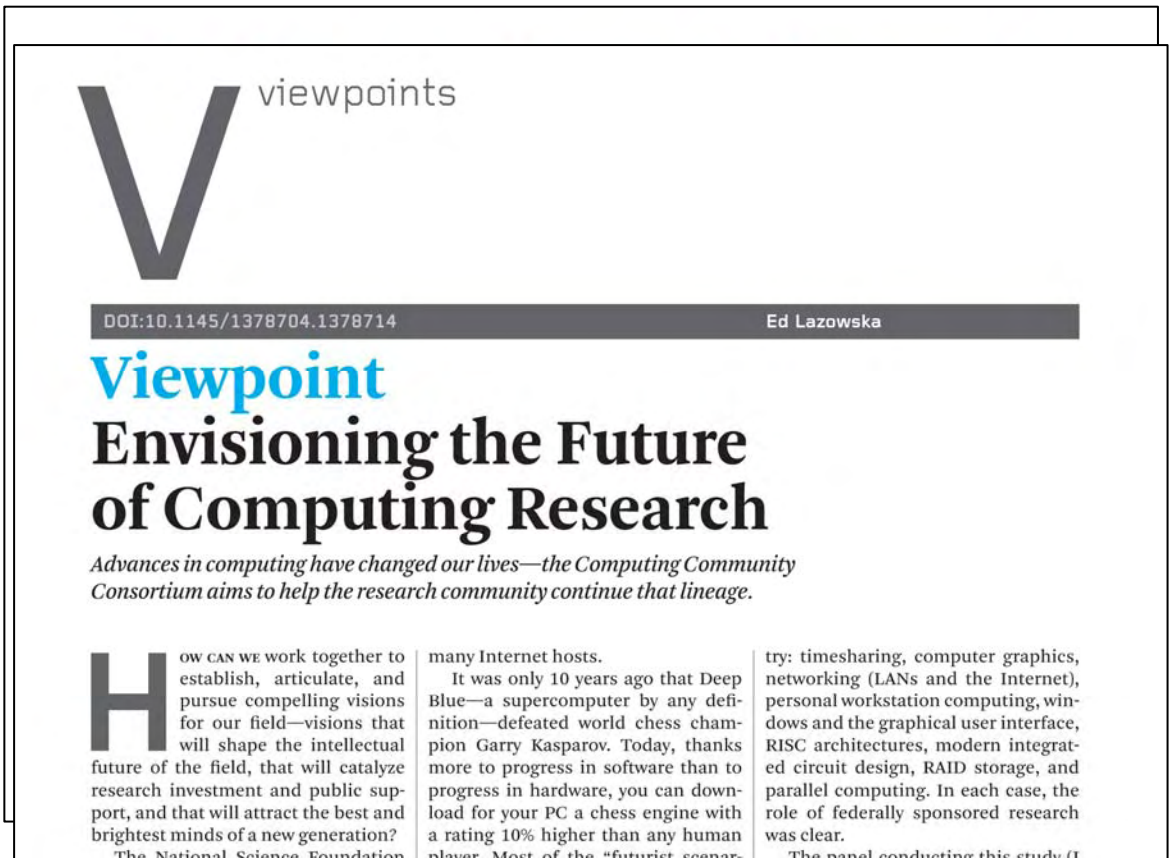
Tapia Conference Career Workshop
April 2009

<http://www.cra.org/ccc/>



Major continuing activities

- Countless talks
- Countless articles



Viewpoints

DOI:10.1145/1378704.1378714 Ed Lazowska

Viewpoint

Envisioning the Future of Computing Research

Advances in computing have changed our lives—the Computing Community Consortium aims to help the research community continue that lineage.

HOW CAN WE work together to establish, articulate, and pursue compelling visions for our field—visions that will shape the intellectual future of the field, that will catalyze research investment and public support, and that will attract the best and brightest minds of a new generation?

The National Science Foundation

many Internet hosts.

It was only 10 years ago that Deep Blue—a supercomputer by any definition—defeated world chess champion Garry Kasparov. Today, thanks more to progress in software than to progress in hardware, you can download for your PC a chess engine with a rating 10% higher than any human player. Most of the “futurist scenar-

try: timesharing, computer graphics, networking (LANs and the Internet), personal workstation computing, windows and the graphical user interface, RISC architectures, modern integrated circuit design, RAID storage, and parallel computing. In each case, the role of federally sponsored research was clear.

The panel conducting this study (I

Major continuing activities

- Countless talks
- Countless articles
- CCC blog

The screenshot shows the CCC Blog homepage. The main header includes the CCC logo and the title 'CCC BLOG THE COMPUTING COMMUNITY CONSORTIUM'. Navigation links for 'HOME', 'ABOUT THE CCC', and 'ABOUT THIS BLOG' are present. A sidebar on the left offers a 'Subscribe in a reader' link, a 'Subscribe to this Blog' email form, and a 'Recent Posts' section. The main content area features a post titled 'Where the jobs are ...' dated January 4th, categorized under 'Uncategorized, pipeline, resources'. The post includes two bar charts: 'Employment growth within the 10 BLS major occupational groups, 2008-18' and 'Employment growth within the 8 BLS "Professional and related" occupations, 2008-2018'. The first chart shows growth rates for various groups, with 'Professional and related' at 18.8%. The second chart shows growth for a subset of these groups, with 'Professional and related' at 22.2%.

CCC BLOG
THE COMPUTING COMMUNITY CONSORTIUM

HOME ABOUT THE CCC ABOUT THIS BLOG

Subscribe in a reader

Subscribe to this Blog
Your email:

Subscribe Unsubscribe

Recent Posts
Computing Research that Changed the World: Reflections and Perspectives
Computer Engineer Barbie!
Where the jobs are ...
"Exponentials R Us" – Seven Computer Science Game-Changers from the 2000's, and Seven More to Come
A Report on the Cross-layer Reliability Visioning Study Group
A Report on the Discovery and Innovation in Health IT Worksho...

JAN 4 Where the jobs are ...
Filed Under Uncategorized, pipeline, resources

Employment growth within the 10 BLS major occupational groups, 2008-18

Occupational Group	Employment Growth (2008-18)
Total all occupations	10.1%
Management, business, and finance	10.8%
Professional and related	18.8%
Service	11.8%
Sales and related	6.2%
Office and administrative support	7.8%
Food, drinking water, and lodging	0.1%
Construction and extraction	13.0%
Transportation, equipment, and maintenance	7.4%
Production and transportation	0.3%
Installation and maintenance	4.0%

Every second year, the US Bureau of Labor Statistics provides a ten-year forecast of job growth in all fields of employment. The most recent forecast, released in November 2009 and covering the period 2008-2018, may be found [here \(pdf\)](#). Among the highlights:

■ Among the 10 major BLS occupational groups, the "Professional and related" category (which includes computer science occupations) is projected to grow by the largest percentage between now and 2018.

Employment growth within the 8 BLS "Professional and related" occupations, 2008-2018

Occupational Group	Employment Growth (2008-2018)
Professional and related	22.2%
Management, business, and finance	18.8%
Service	11.8%
Sales and related	6.2%
Office and administrative support	7.8%
Food, drinking water, and lodging	0.1%
Construction and extraction	13.0%
Transportation, equipment, and maintenance	7.4%
Production and transportation	0.3%
Installation and maintenance	4.0%

Major continuing activities

- Countless talks
- Countless articles
- CCC blog
- Computing research highlight of the week

The screenshot displays the homepage of the Computing Community Consortium (CCC). The header features the CCC logo and the text "Computing Community Consortium" with the tagline "We support the computing research community in creating compelling research visions and the mechanisms to realize these visions." Below the header is a navigation menu with links for HOME, YOUR VISION, PLANS, ACTIVITIES (highlighted in green), RESOURCES, ABOUT, CRA, and a GO button. The main content area is titled "COMPUTING RESEARCH HIGHLIGHT OF THE WEEK [January 14 - 21, 2010]" and features an article titled "'One Keypad per Child' Lets School Children Share Screen to Learn Math". The article text describes a system developed by University of Washington computer science undergraduates that allows up to four students to share a single computer for interactive math problems. It includes a quote from Joyojeet Pal, a lecturer in UW Computer Science & Engineering, and mentions that the system, called MultiLearn, will be tested with 180 students in rural India. There are two images: one showing children using a shared computer and another showing a man with a play button overlay. On the right side, there are sections for "Relevant Links" (Press Release, Project Web Page, Research Papers, Media Contact), "Keywords" (educational technology, information technology for development, University of Washington), and "Buzz" (RSS SUBSCRIBE, EMAIL NOTIFY, EMBED CODE, SHARE).

Major continuing activities

- Countless talks
- Countless articles
- CCC blog
- Computing research highlight of the week
- Community visioning exercises

The screenshot shows the homepage of the Computing Community Consortium (CCC). The header features the CCC logo and the text "Computing Community Consortium" with the tagline "We support the computing research community in creating compelling research visions and the mechanisms to realize these visions." Below the header is a navigation menu with tabs for HOME, YOUR VISION, PLANS, ACTIVITIES, RESOURCES, ABOUT, CRA, and GO. The main content area has a large heading "What questions shape our intellectual future?" followed by a paragraph of text and a call to action: "Click on the tabs below to see some of these activities." Below this is a row of tabs for various research areas: NetSE, Cyber Physical Systems, Robotics, Big Data Computing, Theoretical CS, FOSS, Online Education, XLayer, Global Development, ACAR, and HealthIT. The page also features two highlighted sections: "Computing Research that Changed the World" and "Highlight of the Week" with a sub-heading "New Search Technique for Images and Videos".

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

HOME YOUR VISION PLANS ACTIVITIES RESOURCES ABOUT CRA GO

What questions shape our intellectual future?

What attracts the best and brightest minds of a new generation? What are the next big computing ideas, the ones that will define the future of computing, galvanize the very best students, and catalyze research investment and public support? The Computing Community Consortium (CCC) seeks to mobilize the computing research community to answer these questions by identifying major research opportunities for the field.

Click on the tabs below to see some of these activities.

»» NetSE Cyber Physical Systems Robotics Big Data Computing Theoretical CS
FOSS Online Education XLayer Global Development ACAR HealthIT

Computing Research that Changed the World

This invitation only symposium, "Computing Research that Changed the World: Reflections and Perspectives," was organized by the Computing Community Consortium in collaboration with Congressman Bart Gordon (D-TN), Congressman Ralph Hall (R-TX), Congressman Daniel Lipinski (D-IL), Congressman Vern Ehlers (R-MI), Congressman Rush Holt (D-NJ) and Sen. Jay Rockefeller (D-WV). It was held in the Library of Congress on March 25, 2009.

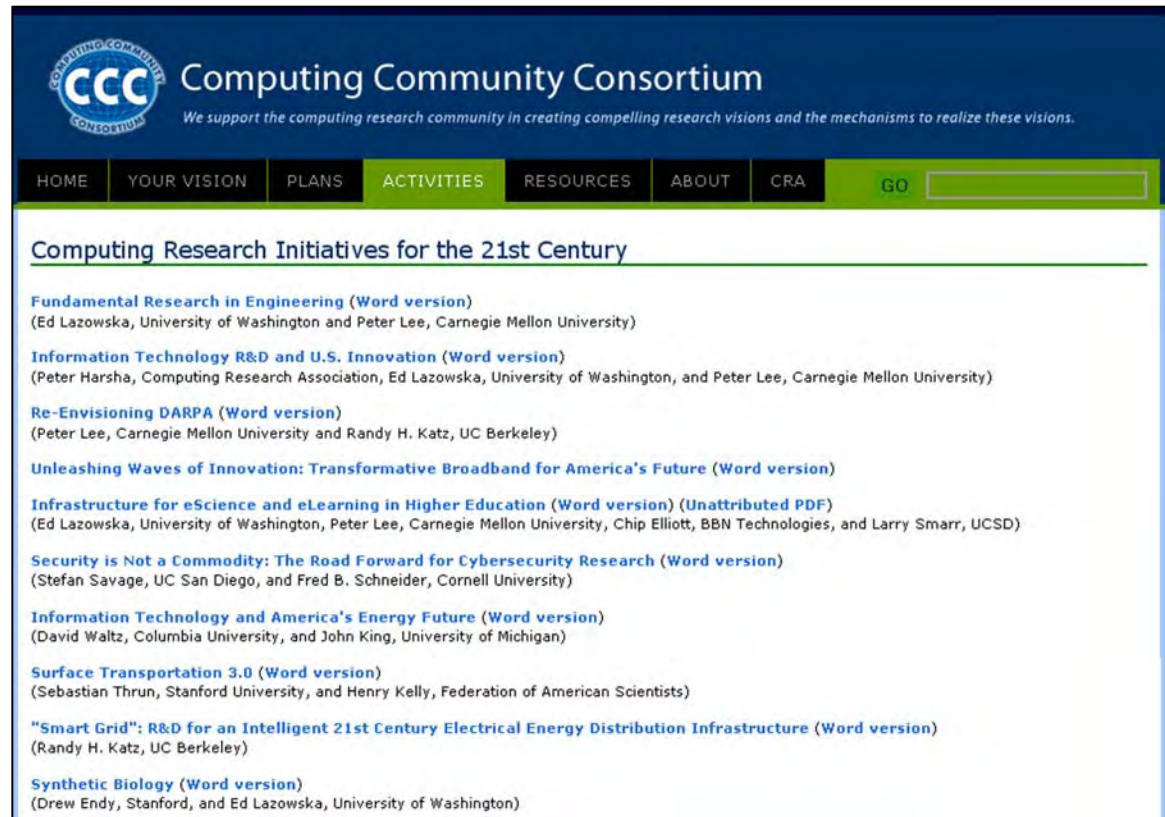
Highlight of the Week

New Search Technique for Images and Videos

University of Washington computer science undergraduates have developed a system that lets up to four students share a single computer to do interactive math problems. Early tests show that students using

Major special initiatives

■ Transition Team white papers



The screenshot shows the homepage of the Computing Community Consortium (CCC). The header features the CCC logo and the text "Computing Community Consortium" with the tagline "We support the computing research community in creating compelling research visions and the mechanisms to realize these visions." Below the header is a navigation menu with links for HOME, YOUR VISION, PLANS, ACTIVITIES, RESOURCES, ABOUT, and CRA. A search bar with a "GO" button is also present. The main content area is titled "Computing Research Initiatives for the 21st Century" and lists several white papers with their authors and affiliations.

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

HOME YOUR VISION PLANS **ACTIVITIES** RESOURCES ABOUT CRA GO

Computing Research Initiatives for the 21st Century

- [Fundamental Research in Engineering \(Word version\)](#)
(Ed Lazowska, University of Washington and Peter Lee, Carnegie Mellon University)
- [Information Technology R&D and U.S. Innovation \(Word version\)](#)
(Peter Harsha, Computing Research Association, Ed Lazowska, University of Washington, and Peter Lee, Carnegie Mellon University)
- [Re-Envisioning DARPA \(Word version\)](#)
(Peter Lee, Carnegie Mellon University and Randy H. Katz, UC Berkeley)
- [Unleashing Waves of Innovation: Transformative Broadband for America's Future \(Word version\)](#)
- [Infrastructure for eScience and eLearning in Higher Education \(Word version\) \(Unattributed PDF\)](#)
(Ed Lazowska, University of Washington, Peter Lee, Carnegie Mellon University, Chip Elliott, BBN Technologies, and Larry Smarr, UCSD)
- [Security is Not a Commodity: The Road Forward for Cybersecurity Research \(Word version\)](#)
(Stefan Savage, UC San Diego, and Fred B. Schneider, Cornell University)
- [Information Technology and America's Energy Future \(Word version\)](#)
(David Waltz, Columbia University, and John King, University of Michigan)
- [Surface Transportation 3.0 \(Word version\)](#)
(Sebastian Thrun, Stanford University, and Henry Kelly, Federation of American Scientists)
- ["Smart Grid": R&D for an Intelligent 21st Century Electrical Energy Distribution Infrastructure \(Word version\)](#)
(Randy H. Katz, UC Berkeley)
- [Synthetic Biology \(Word version\)](#)
(Drew Endy, Stanford, and Ed Lazowska, University of Washington)

Major special initiatives

- Transition Team white papers
- Library of Congress Symposium



Major special initiatives

- Transition Team white papers
- Library of Congress Symposium
- Computing Innovation Fellows project
 - 1209 mentors
 - 526 applicants
 - Mariah Meyer (Utah) -> Hanspeter Pfister
 - Jennifer Wortman
 - Vaughan (Penn) -> Yiling Chen
 - Benjamin Lee -> Stanford (Mark Horowitz)

COMPUTING RESEARCH ASSOCIATION (CRA) | NATIONAL SCIENCE FOUNDATION (NSF) | COMPUTING COMMUNITY CONSORTIUM (CCC)

Computing Innovation Fellows Project

Home | CRA | CCC | CISE

The 2009 Computing Innovation Fellows have been selected!

[View the press release with the names of the 2009 Fellows and their Mentors.](#)

Congratulations to everyone who was selected for a CIFellow award!
Thank you for your interest in CIFellows. The response has been tremendous!
[For up-to-the-minute news on the progress of the selection process, check out the forum.](#)

In the light of the response that the CIFellows has received, we have set up a courtesy website where employers can post available positions suitable for new computing PhD's. This site is available at <http://cifellows.org/opportunities>.

An additional courtesy site has been set up for computing PhD's to post their profiles and availability. This website is available at <http://cifellows.org/profiles>. We encourage employers and candidates to make use of these complimentary services.

The Computing Community Consortium (CCC) and the Computing Research Association (CRA), with funding from the National Science Foundation, announce a program for new PhD graduates to obtain one-to-two year postdoctoral positions

Major special initiatives

- Transition Team white papers
- Library of Congress Symposium
- Computing Innovation Fellows project
- Landmark Contributions by Students

Landmark Contributions by Students in Computer Science

Version 11: September 15, 2009

There are many reasons for research funding agencies (DARPA, NSF, etc.) to invest in the education of students. Producing the next generation of innovators is the most obvious one. In addition, though, there are an impressive number of instances in our field in which undergraduate and graduate students have made truly game-changing contributions in the course of their studies.

The inspiring list below was compiled by the following individuals and their colleagues: Bill Bonvillian (MIT), Susan Graham (Berkeley), Anita Jones (University of Virginia), Ed Lazowska (University of Washington), Pat Lincoln (SRI), Fred Schneider (Cornell), and Victor Zue (MIT).

We solicit your suggestions for additional student contributions of comparable impact – post them on the Computing Community Consortium blog, <http://www.cccb.org/2009/08/28/landmark-contributions-by-students-in-computer-science/>, or send them to Ed Lazowska, lazowska@cs.washington.edu.

Major special initiatives

- Transition Team white papers
- Library of Congress Symposium
- Computing Innovation Fellows project
- Landmark Contributions by Students
- NetSE Research Agenda

NetSE Research Agenda: Executive Summary and Recommendations

Over the past forty years, computer networks, and especially the Internet, have gone from research curiosity to fundamental infrastructure. In terms of societal impact, the Internet has changed the way we live, work and play, and altered our notions of democracy, education, healthcare, entertainment and commerce. In terms of its design, the Internet has shown a remarkable ability to adapt to, even inspire, changes in technologies and applications. In short, the Internet has been a powerful engine for technological innovation and societal evolution.

However, this is no time to rest on the successes of the past. To meet society's future requirements and expectations, networks in general, and the Internet in particular, will need to be better: more secure, more accessible, more predictable, and more reliable.

In 2008, the Computing Community Consortium (CCC) charged the Network Science and Engineering (NetSE) Council with developing a comprehensive research agenda that would support the development of better networks. The NetSE Council was to consider previous reports such as those produced by the Global Environment for Network Innovation (GENI) Science Council, as well as encourage new interdisciplinary participation. Over the summer and fall of 2008, the NetSE Council held a number of disciplinary and interdisciplinary workshops that, together with several GENI and pre-GENI workshops and documents, resulted in the network science and engineering research agenda detailed in this report. The NetSE-sponsored interdisciplinary workshops were structured to bring participants from closely related fields together with networking researchers to explore problems and opportunities in the intersection. The diversity of backgrounds of the workshop participants highlights the breadth of the intellectual space.

Major special initiatives

- Transition Team white papers
- Library of Congress Symposium
- Computing Innovation Fellows project
- Landmark Contributions by Students
- NetSE Research Agenda
- Health IT

The screenshot shows the website for the Computing Community Consortium (CCC). The header includes the CCC logo and the text "Computing Community Consortium" with the tagline "We support the computing research community in creating compelling research visions and the mechanisms to realize these visions." Below the header is a navigation menu with links for HOME, YOUR VISION, PLANS, ACTIVITIES, RESOURCES, ABOUT, and CRA, along with a search bar. The main content area is titled "Discovery and Innovation in Health IT" and contains the following text:

This invitation only workshop, "Discovery and Innovation in Health IT," is sponsored by the National Science Foundation, the Office of the National Coordinator for Health Information Technology, the National Institute of Standards and Technology, the National Library of Medicine, the Agency for Healthcare Research and Quality, the Computing Community Consortium, and the American Medical Informatics Association. It will be held at the Parc 55 Hotel in San Francisco on October 29 and 30, 2009.

The talks and plenary discussions will be videotaped and a web presence will be developed to make the workshop material broadly available.

The goals of the workshop are to:

- Explore and define fundamental research challenges and opportunities in healthcare IT in both the near- and long-term;
- Provide opportunities for relevant academic and industrial researchers, healthcare practitioners and IT healthcare suppliers to identify mutual interests in healthcare IT, as they relate to both near- and long-term challenges and solutions;
- Identify a range of "model" proof-of-concept, integrative systems that might serve as motivating and unifying forces to drive fundamental research in healthcare IT and accelerate the transition of research outcomes into products and services;

The workshop will have four half-day sessions. Each of the first three sessions will have two plenary talks followed by small-group breakout discussions to define particular research challenges, multiple lines of attack, and possible test-beds or demonstration systems. Each of these sessions, which are further described subsequently, will end with short reports from the

On the right side of the page, there is a yellow box with the text: "Content is still being added to this site. Please Check back periodically. The last change was made on: December 16, 2009." Below this is a section titled "Session Videos" featuring a video player for "HIT - Thursday Morning Op...". At the bottom of the page, there are links for "Reply/Registration" and "Logistics", and a date: "Date: October 29-30, 2009".

Current initiatives



- Computing research and health care
- Computing research and sustainability / energy / transportation
- From Data to Knowledge to Action:
 - Enabling Evidence-Based Healthcare
 - Enabling the New Biology
 - Enabling 21st Century Discovery in Science and Engineering
 - Enabling Advanced Intelligence and Decision Making for America's Security
 - Enabling a Revolution in Transportation
 - Enabling a Transformation of American Education
 - Enabling the Smart Grid

The next ten years ...



Greatest Engineering Achievements OF THE 20TH CENTURY

◆ [About](#) ◆ [Timeline](#) ◆ [The Book](#)

Welcome!

How many of the 20th century's greatest engineering achievements will you use today? A car? Computer? Telephone? Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

- | | |
|--|--|
| 1. Electrification | 11. Highways |
| 2. Automobile | 12. Spacecraft |
| 3. Airplane | 13. Internet |
| 4. Water Supply and Distribution | 14. Imaging |
| 5. Electronics | 15. Household Appliances |
| 6. Radio and Television | 16. Health Technologies |
| 7. Agricultural Mechanization | 17. Petroleum and Petrochemical Technologies |
| 8. Computers | 18. Laser and Fiber Optics |
| 9. Telephone | 19. Nuclear Technologies |
| 10. Air Conditioning and Refrigeration | 20. High-performance Materials |



Greatest Engineering Achievements OF THE 20TH CENTURY

◆ About ◆ Timeline ◆ The Book

Welcome!

How many of the 20th century's greatest engineering achievements will you use today? A car? Computer? Telephone? Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials





GRAND CHALLENGES FOR ENGINEERING



Make solar energy economical



Provide energy from fusion



Develop carbon sequestration methods



Manage the nitrogen cycle



Provide access to clean water



Restore and improve urban infrastructure



Advance health informatics



Engineer better medicines



Reverse-engineer the brain



Prevent nuclear terror



Secure cyberspace



Enhance virtual reality



Advance personalized learning



Engineer the tools of scientific discovery



Make solar energy economical



Provide energy from fusion



Develop carbon sequestration methods



Manage the nitrogen cycle



Provide access to clean water



Restore and improve urban infrastructure



Advance health informatics



Engineer better medicines



Reverse-engineer the brain



Prevent nuclear terror



Secure cyberspace



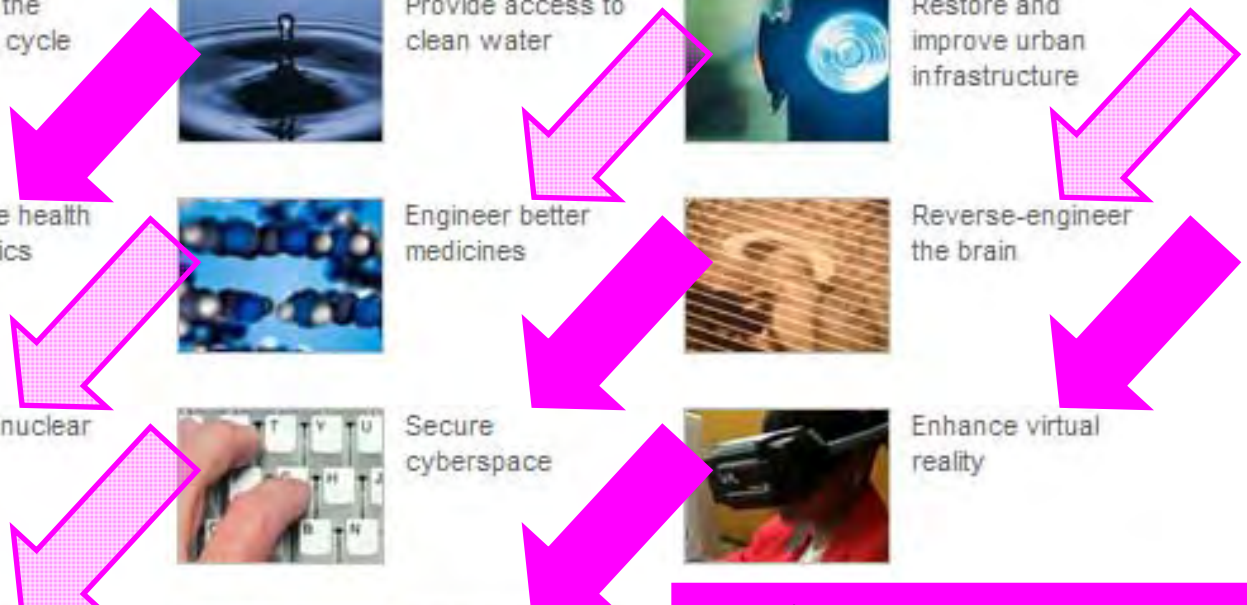
Enhance virtual reality



Advance personalized learning



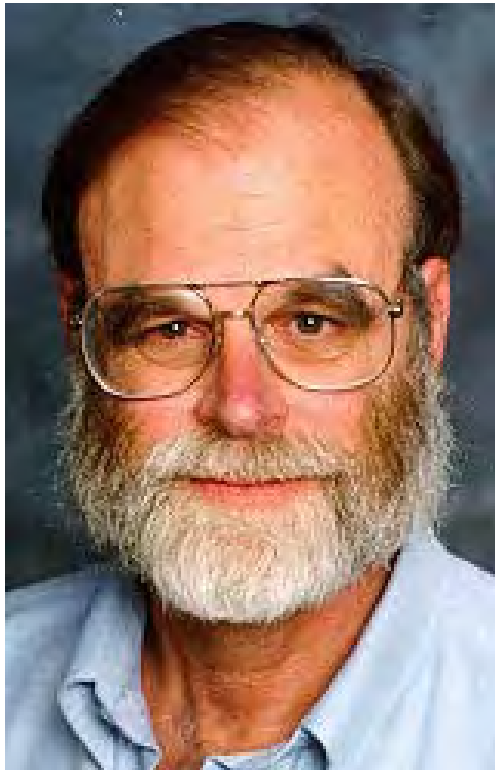
Engineer the tools of scientific discovery



Predominant CS component

Significant CS component

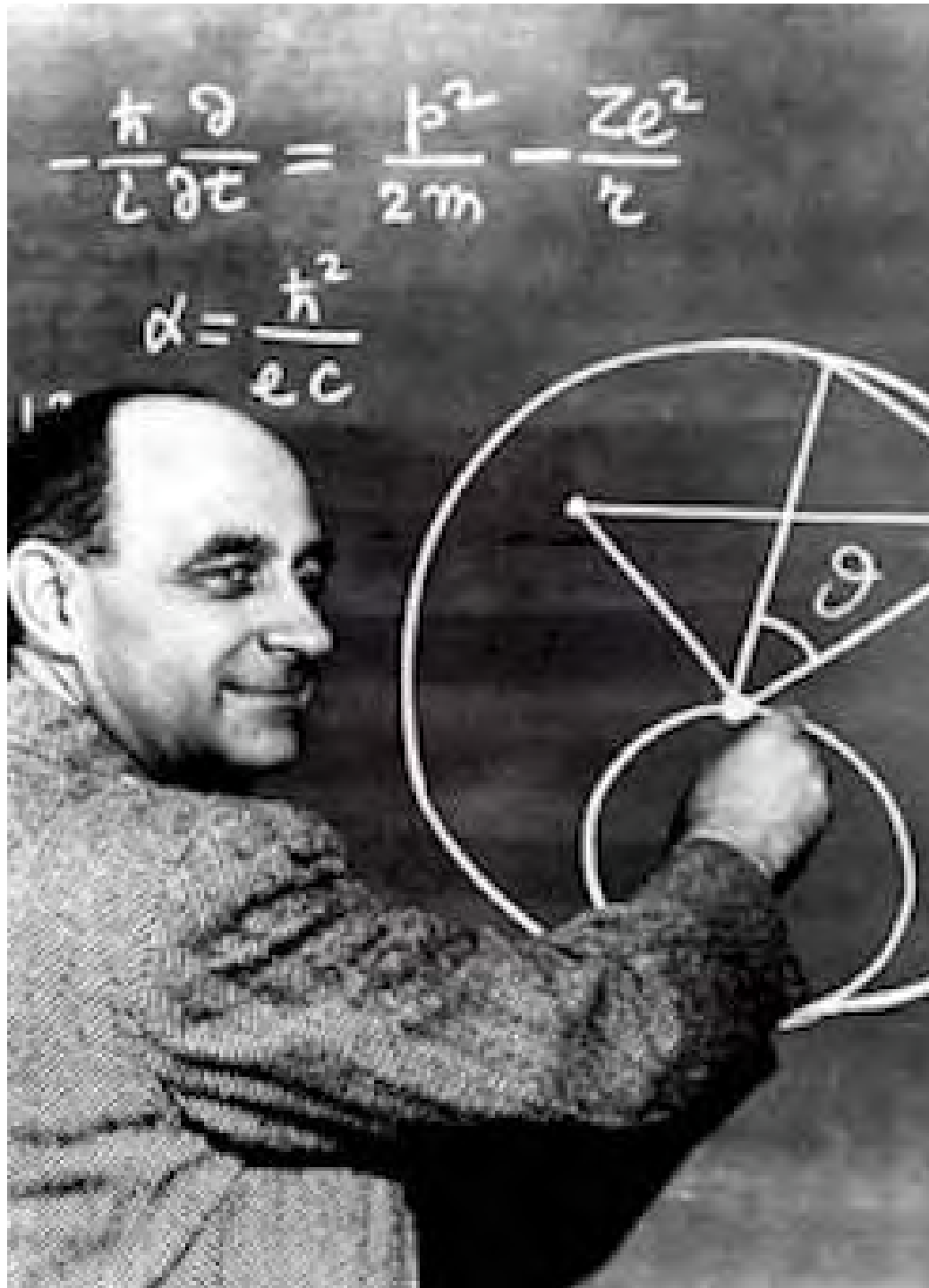
eScience: Sensor-driven (data-driven) science and engineering



Jim Gray



Transforming science (again!)



Theory
Experiment
Observation



Theory
Experiment
Observation

Theory
Experiment
Observation



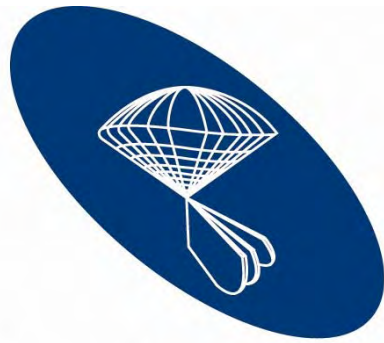
[John Delaney, University of Washington]



Theory
Experiment
Observation
**Computational
Science**



Theory
Experiment
Observation
Computational
Science
eScience



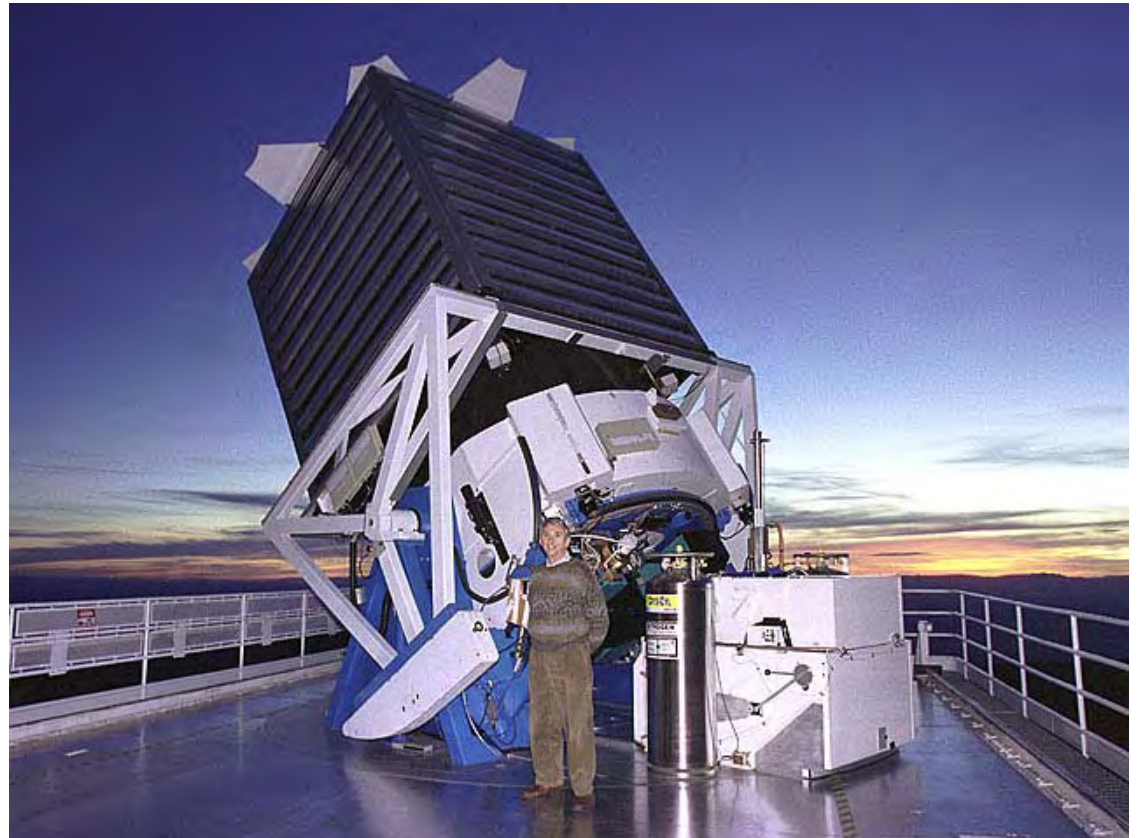
SLOAN DIGITAL SKY SURVEY

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**

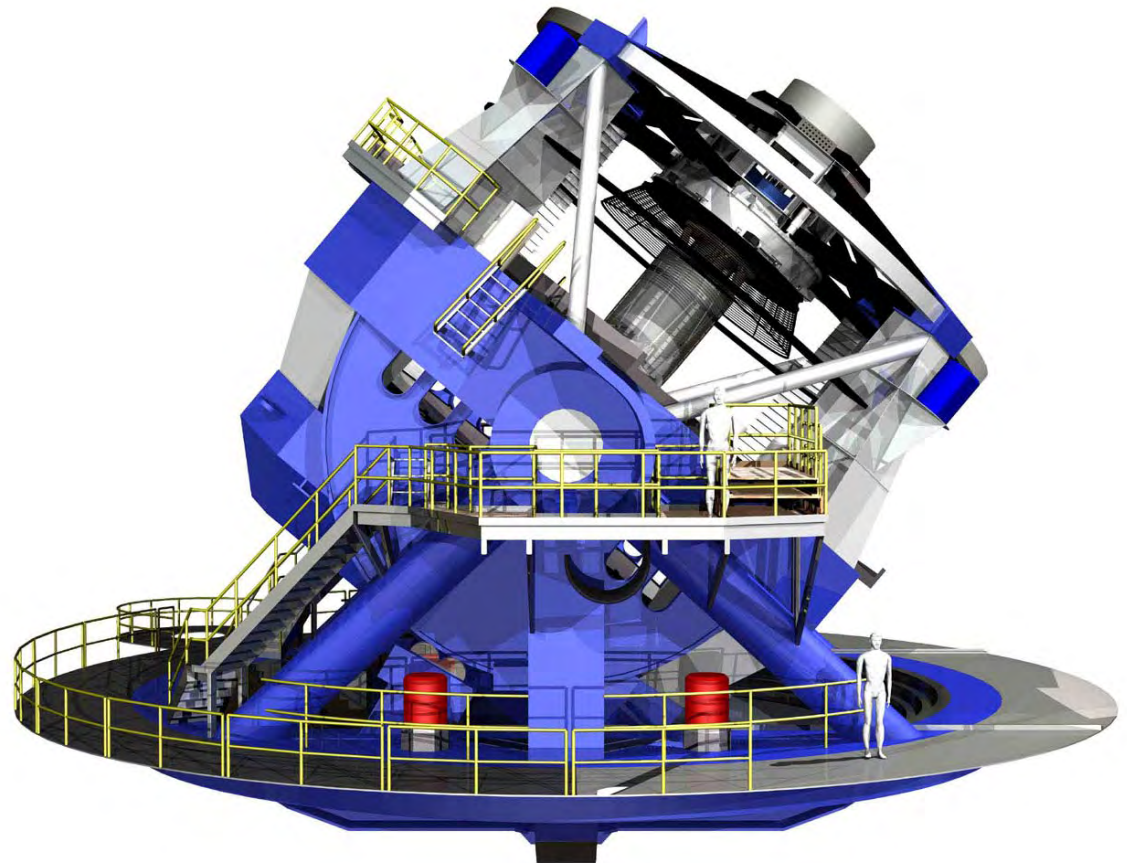




**Large Synoptic Survey
Telescope (LSST)**

**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**

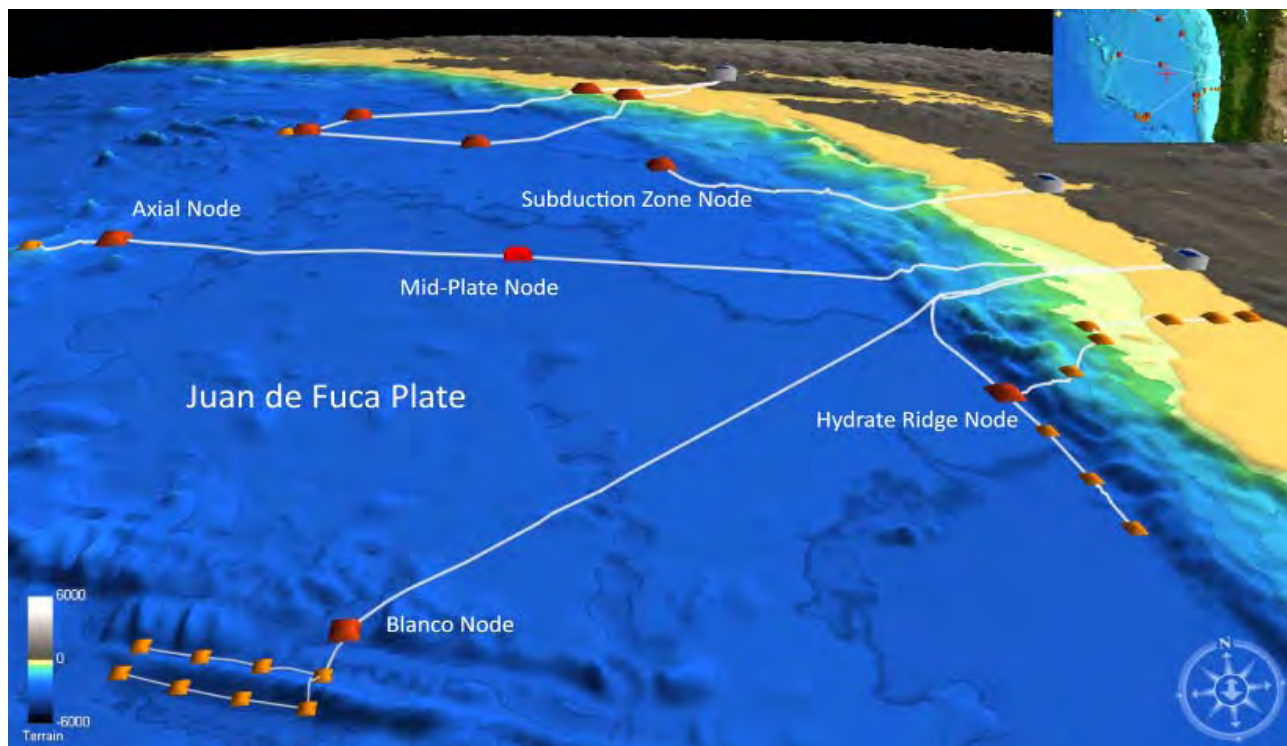


**Major labs
have 25-100
of these
machines**



**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**

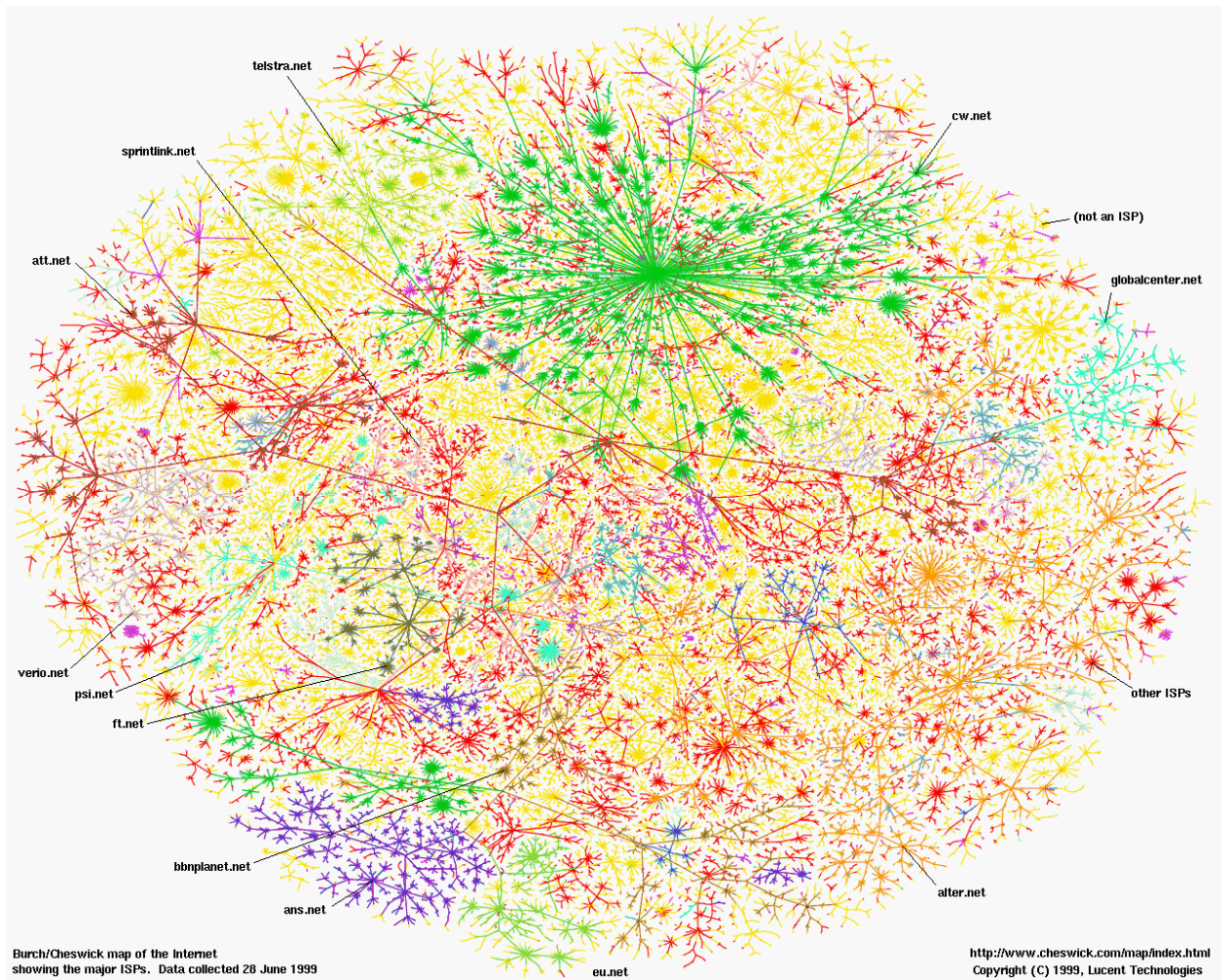




The Web

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

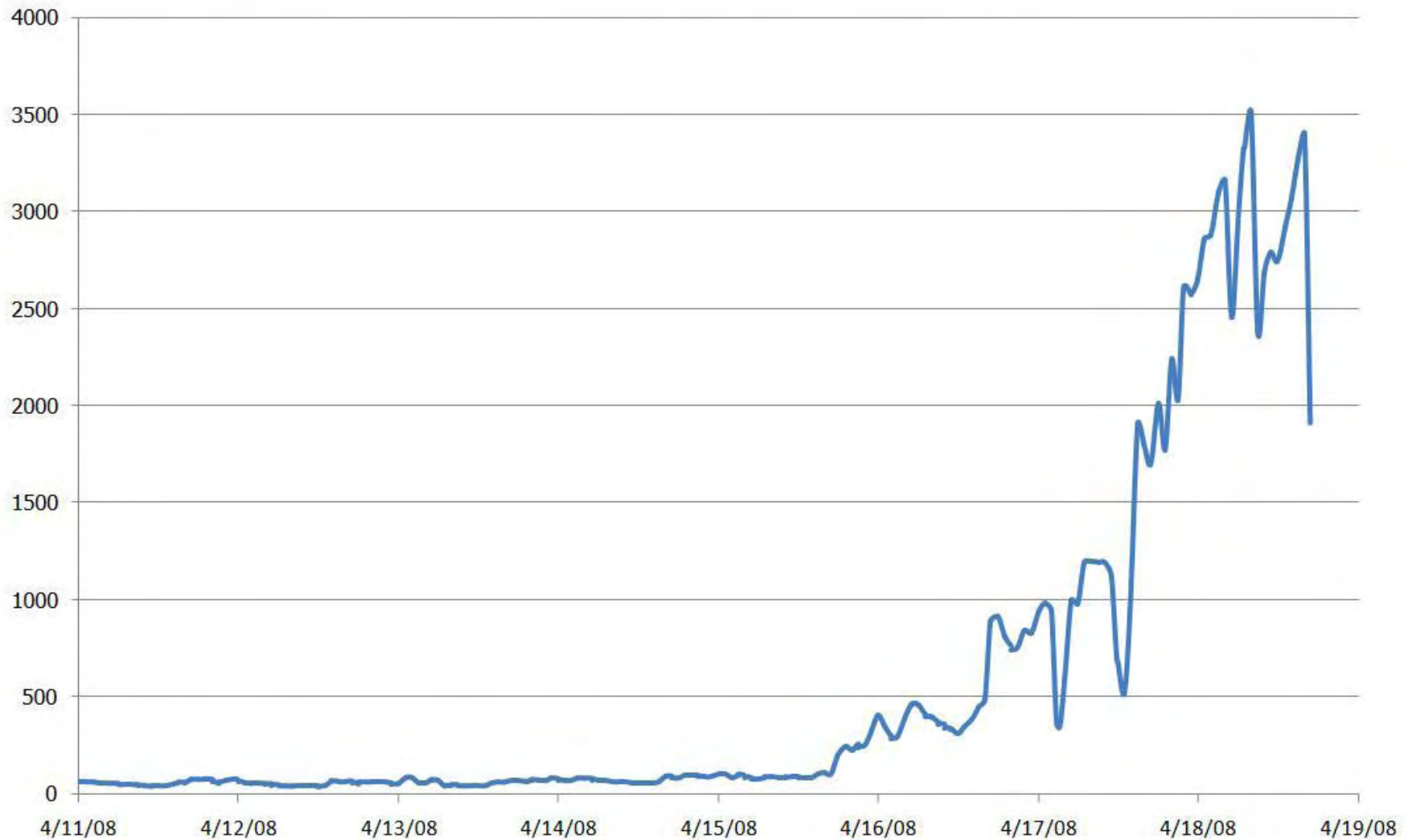


eScience is married to the cloud: Scalable computing and storage for everyone

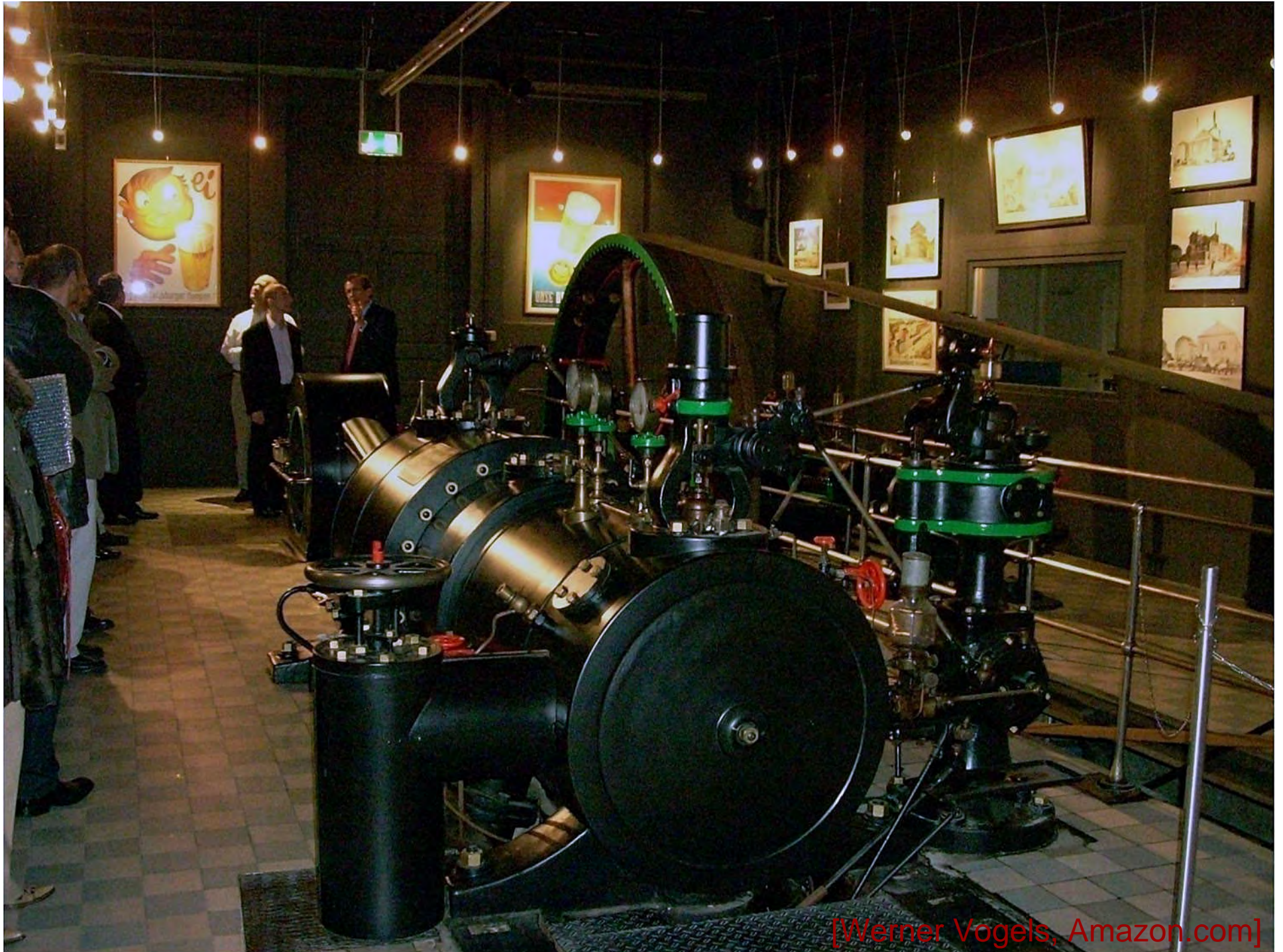
The collage features three overlapping elements:

- BusinessWeek Magazine:** The top-left corner shows the magazine cover for December 24, 2007. The title "BusinessWeek" is in large white letters on a red background. Below it, the word "NEXT" is prominent, followed by the tagline "Imagine what you can do". Several article teasers are visible: "MEXICO: THE UGLY SIDE OF MICRO-LOANS 038", "CENTRAL BANKERS TO THE RESCUE 025", and a photo of Christophe Bisciglia, Google's master of "cloud" computing.
- Google App Engine:** The middle-left portion shows the Google App Engine website. It features the Google logo with the tagline "Code", a search bar, and navigation links for Home, Docs, FAQ, Articles, Blog, Community, Terms, and Download. The main heading is "Google App Engine" with a rocket icon. Below it, there's a section titled "An Early Look at J..." with a video player showing a man speaking.
- Amazon Web Services:** The right and bottom portions show the AWS website. The top navigation bar includes "Home", "About", "Solutions", "Services", "Resources", "Community", and "Sign In". The main heading is "amazon web services". A prominent banner advertises "Hadoop + The AWS Cloud" with the text "Introducing Amazon Elastic MapReduce—the Hadoop-based infrastructure service that lets you build and deploy large-scale data processing applications in the cloud." Below this, there are sections for "Explore Products" (listing services like Amazon Elastic Compute Cloud, Amazon SimpleDB, Amazon Simple Storage Service, Amazon CloudFront, Amazon Simple Queue Service, and Amazon Elastic MapReduce) and "News & Events" (listing updates from May 07, 2009, to Apr 09, 2009).

Animoto: EC2 Instance Usage



[Werner Vogels, Amazon.com]



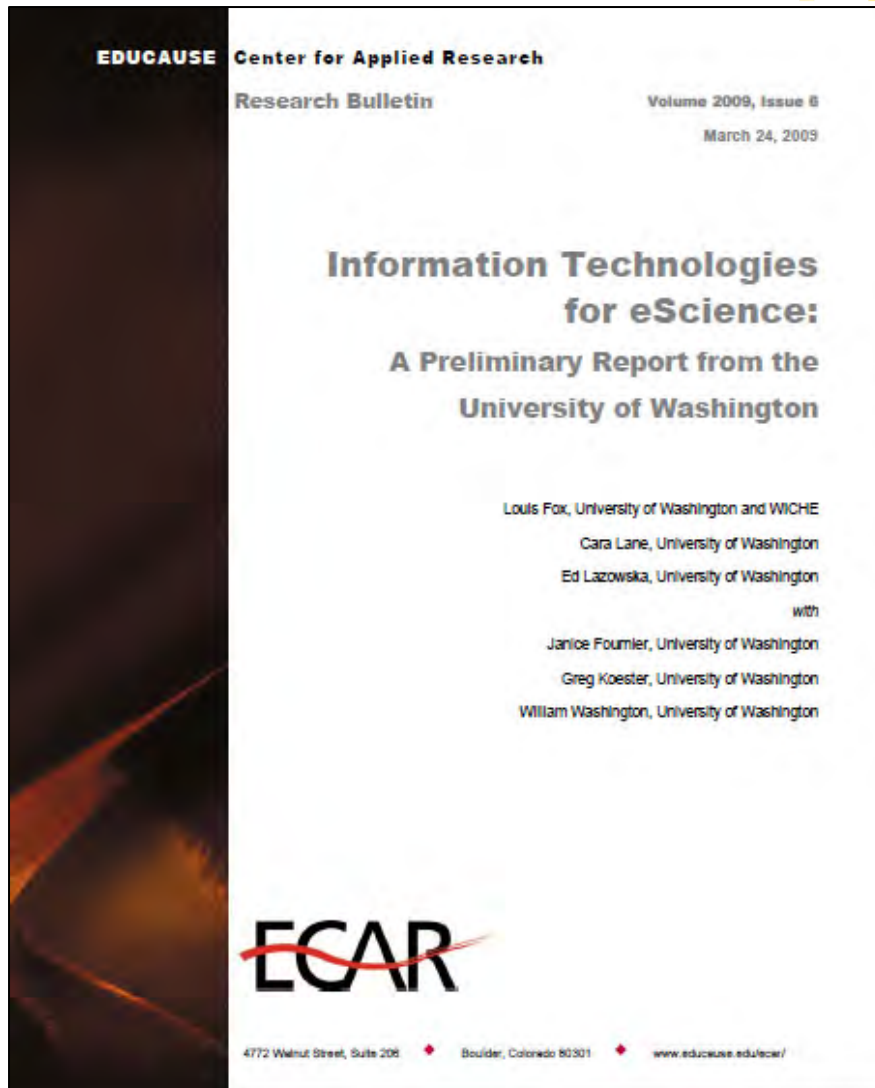
[Werner Vogels, Amazon.com]

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, tools, tools!

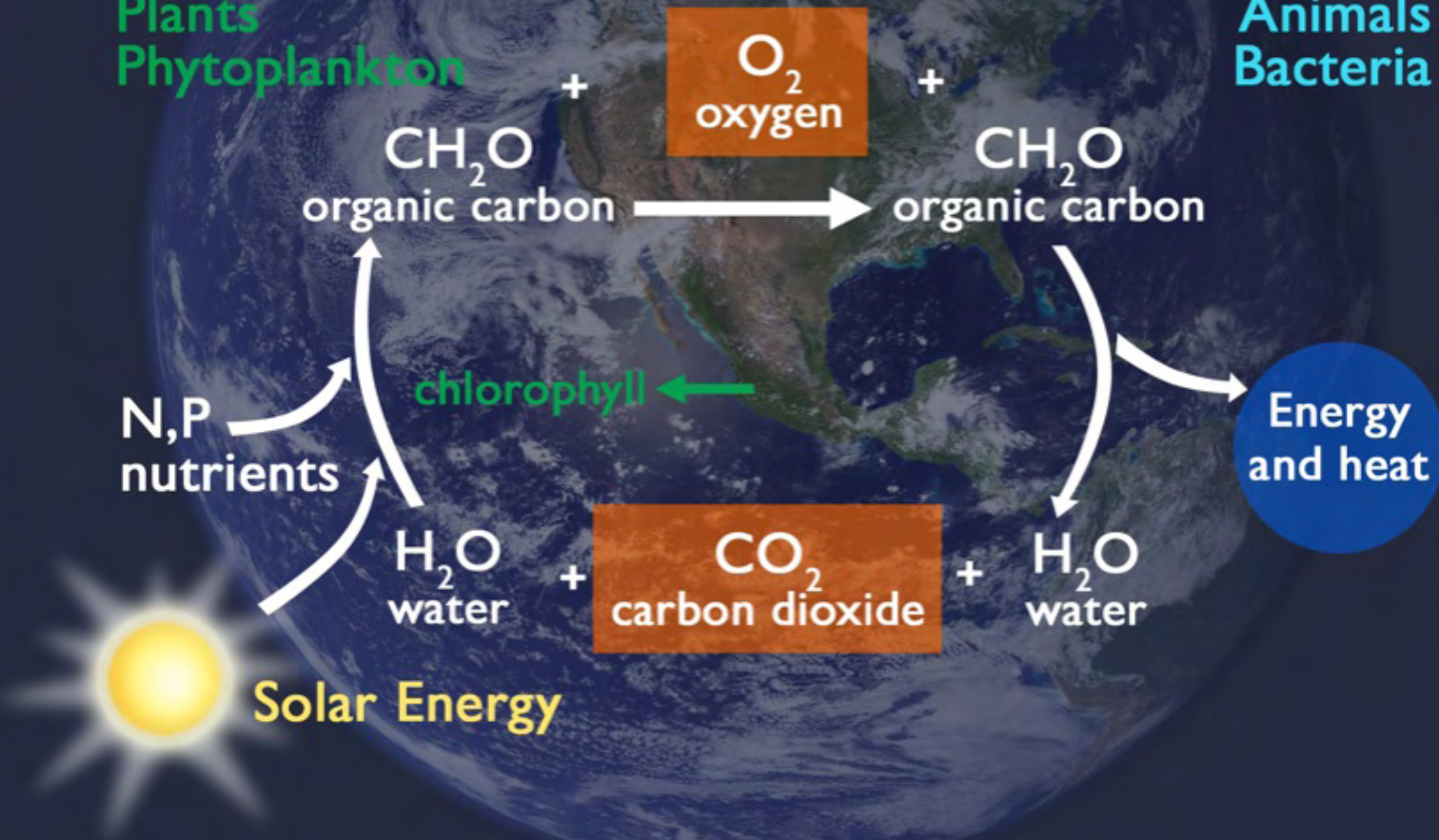
Life on Planet Earth

Photosynthesis

Plants
Phytoplankton

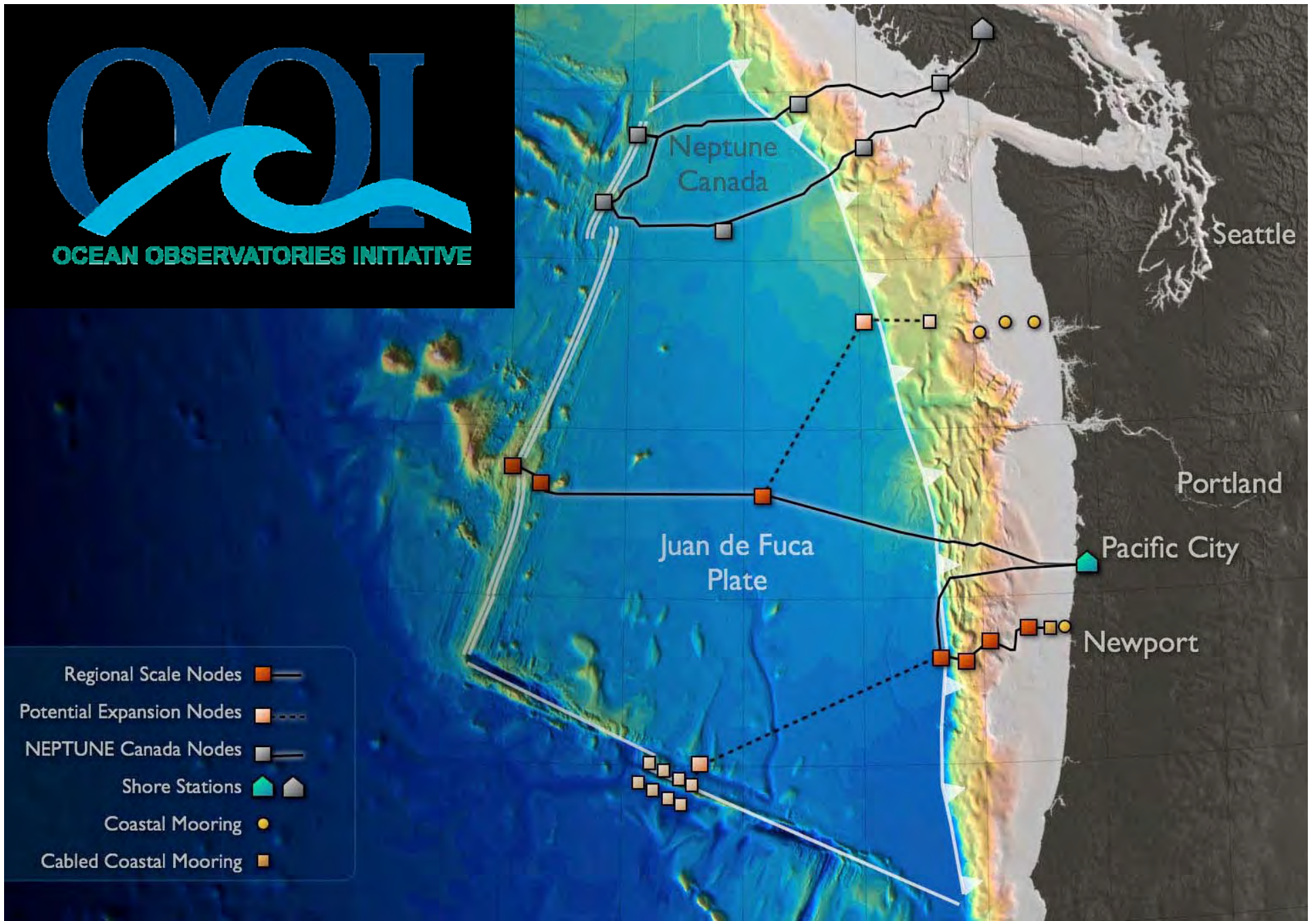
Respiration

Animals
Bacteria





[John Delaney, University of Washington]



[John Delaney, University of Washington]

Human computation, and the wisdom of crowds



Luis von Ahn

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)

The screenshot shows the Google Image Labeler interface. At the top, a timer indicates "Time left: 16". Below this, a box contains the word "overlooks" written in a stylized, handwritten font. To the right, another box contains the word "inquiry" in the same font. Below these boxes, a yellow bar says "Type the two words:" followed by a red "S" button and a white refresh button. The Google logo and "Image Labeler BETA" are visible. Below the interface, a statistics table shows:

<u>time left</u>	<input type="text"/>	<input type="button" value="label"/>	<input type="button" value="pass"/>
01:52	Your partner has suggested 3 labels.		
<u>score</u>			
0			
<u>passes</u>			
0			

To the right of the statistics is a list of "off-limits" labels: building, hotel, car, cars, sky. Below the statistics is a photograph of a multi-story building with a red facade. A "zoom out" button is located below the photo.



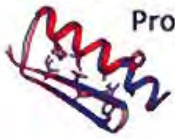
David Baker





Rosetta@home

Protein Folding, Design, and Docking



BOINC Application version 480 [workunit:]

<p>Searching...</p>	<p>Accepted</p>	<p>Low Energy</p>	<p>RMSD</p>
		<p>Native</p>	

Accepted Energy

1.5% Complete
CPU time: 0 hr 18 min 54 sec
Jack Schonbrun - Total credit: 1000 - RAC: 500
Baker Lab
Rosetta@home v4.8 <http://boinc.bakerlab.org/rosetta/>

Stage: Ab initio
Step: 9621
Accepted RMSD: 11.12
Accepted Energy: -29.31936



What's New

Small Update

We've posted a small update today, here's what's in it:

Some stability fixes, particularly with crashes when canceling recipes.

Improvements to scoring of sequence alignment. The scores of your existing alignments will change in the Sequence Alignment Tool due to this, but it won't affect your actual scores for the puzzles.

GET STARTED: DOWNLOAD



Win Beta

Win XP/Vista



Mac Beta

Intel OS X 10.4
or later



Linux Beta

Linux

RECOMMEND FOLDIT

Send

USER LOGIN

Username: *

Password: *

Log in

- [Create new account](#)
- [Request new password](#)

• [Sign in using Facebook](#)

[Connect with Facebook](#)



foldit BETA

20:46:49 GMT

Solve Puzzles
for Science

[BLOG](#) [GROUPS](#) [PLAYERS](#) [PUZZLES](#)



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.

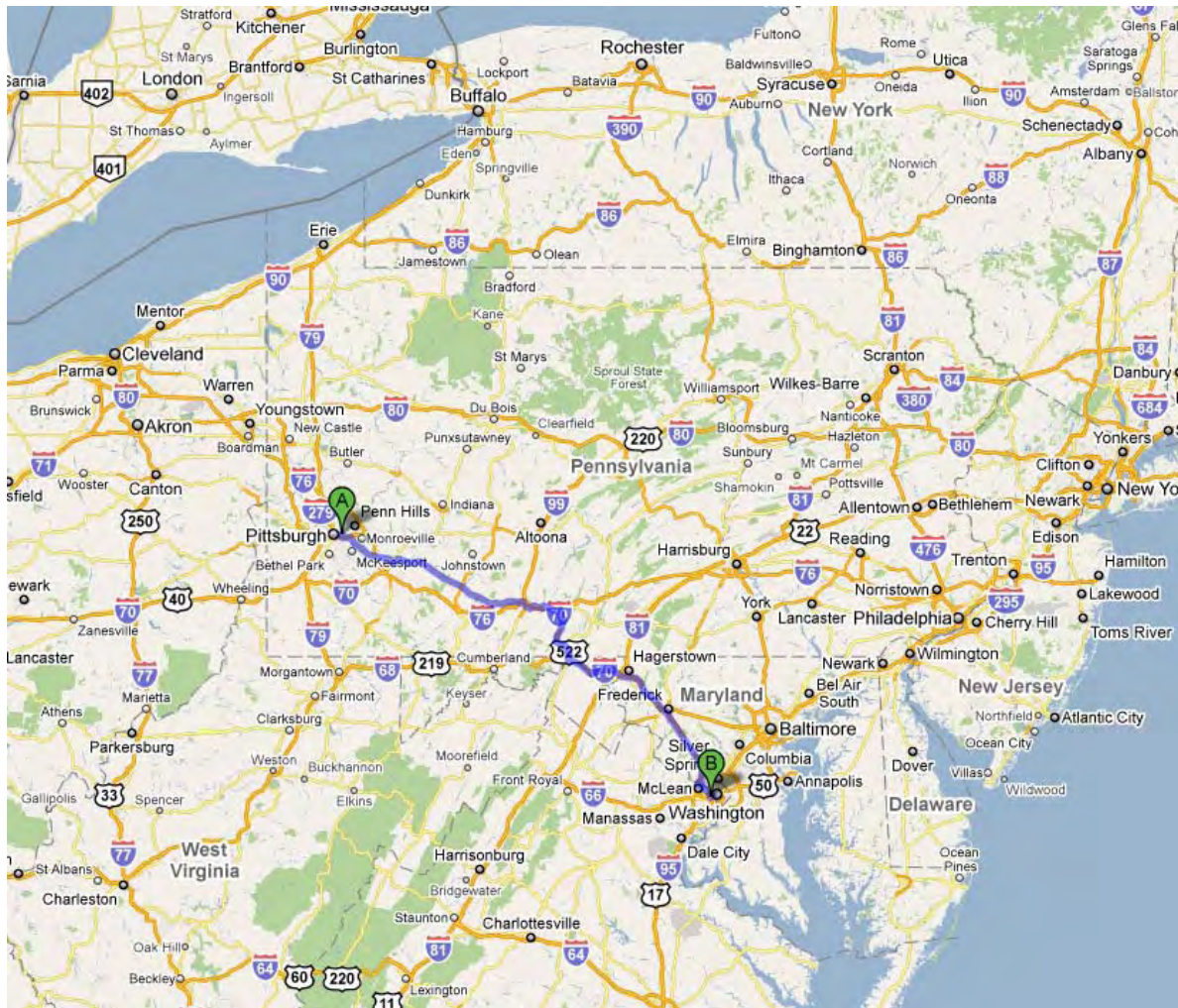
Group: **Contenders**



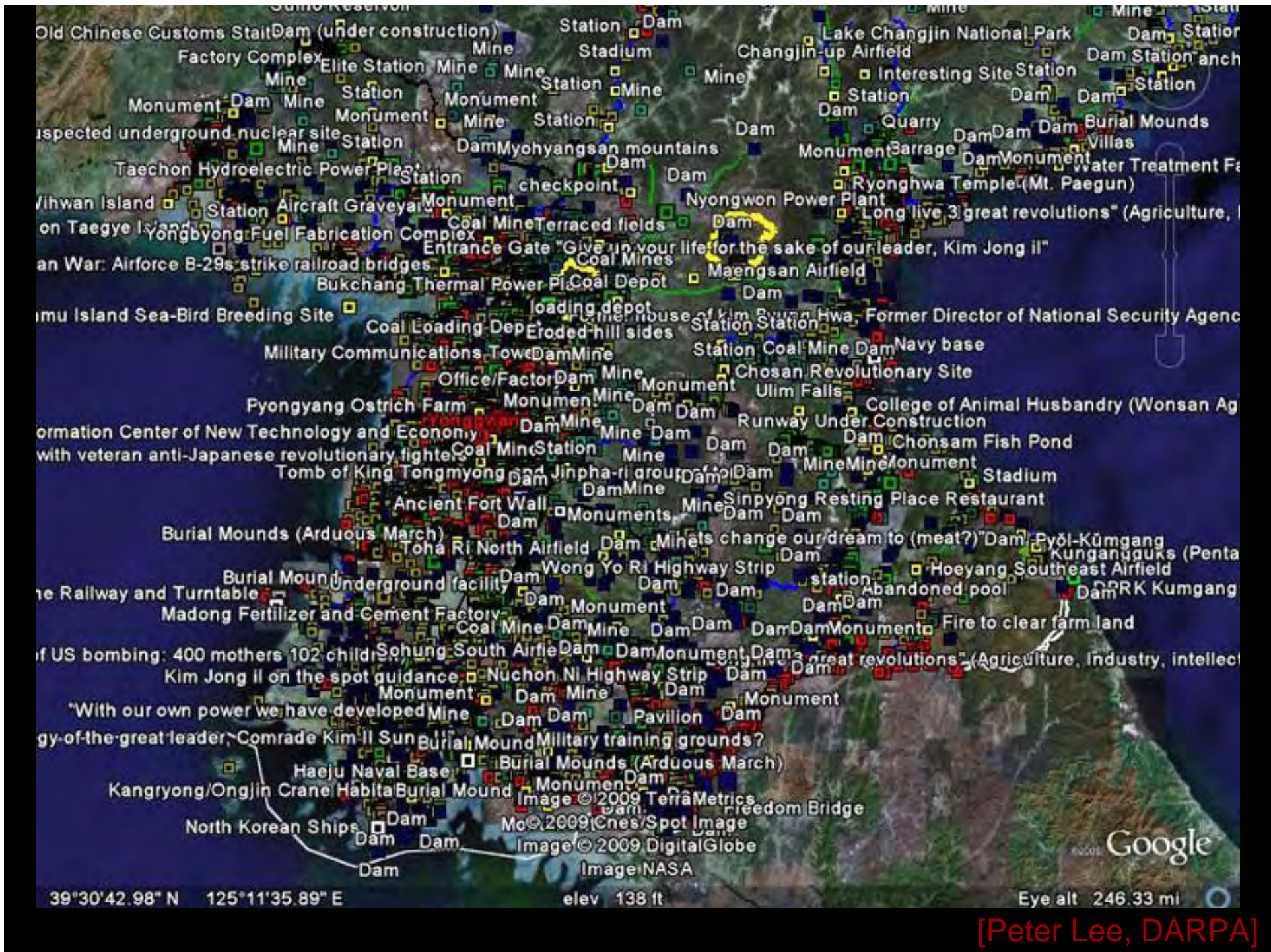
Regina Dugan



Peter Lee



[Peter Lee, DARPA]



[Peter Lee, DARPA]

DARPA NETWORK CHALLENGE



40th Anniversary of the Internet

29 Oct – Announced
5 Dec – Balloons Up

\$40k Prize



4367 registrants
39 countries
922 submissions
370 correct locations

[Peter Lee, DARPA]

Revolutionizing transportation



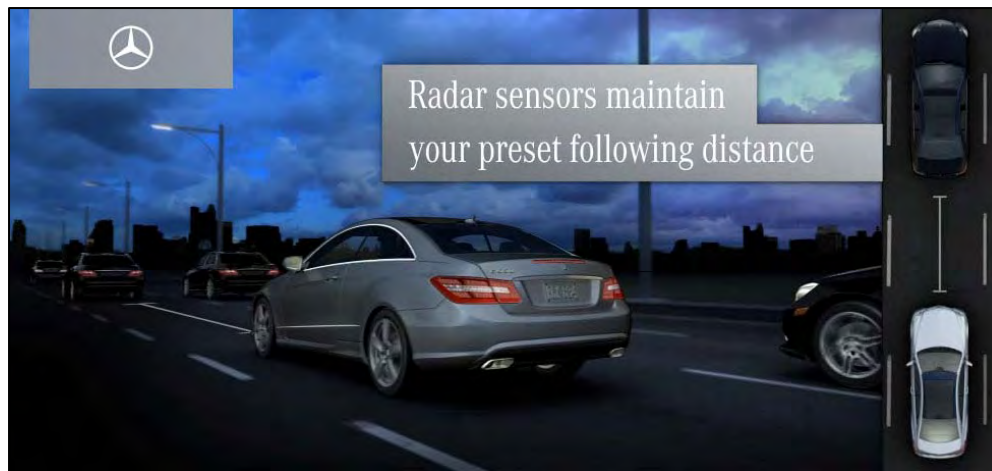


← Lane departure warning

Stay on track.

Lane Departure Warning on the BMW 5 Series Sedan.

The optional Lane Departure Warning gently vibrates the steering wheel just before you veer away from your lane - and only then. A camera mounted between the rear-view mirror and the windscreen "sees" the markings on the road ahead. Lane Departure Warning is deactivated when the indicator is used, so that you are not distracted by false signals.



← Adaptive cruise control



← Self-parking

■ 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

Transportation is one dimension of energy

■ The smart grid

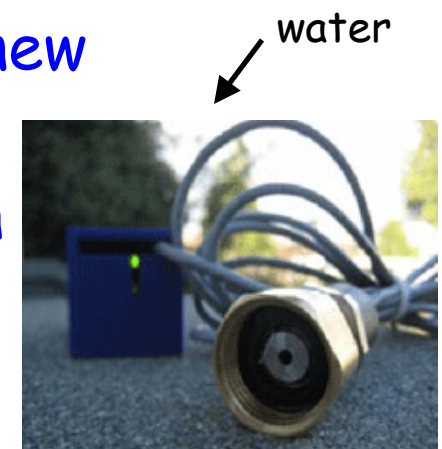
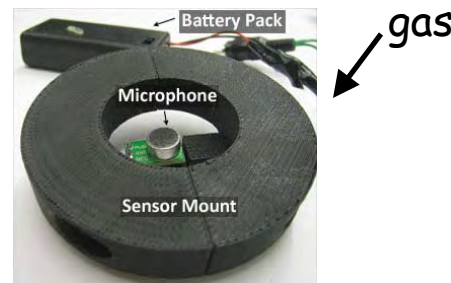
- Engineering
- Control
- Conservation (intelligent structures)



■ IT as a substitute for energy-intensive goods and services

■ IT as a tool for discovering and designing new energy sources

■ Improved energy efficiency in computation



[Shwetak Patel, UW]

Health: Personalized health monitoring



Omron pedometer



Nike + iPod



Bodymedia multi-function



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



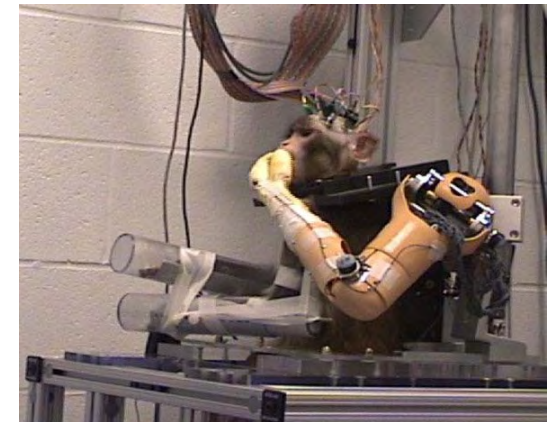
Glucowatch: measuring body chemistry

Health: Evidence-based medicine

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



Health: Neurobotics



[Yoky Matsuoka and Raj Rao, UW]

Health: P4 medicine



ICTD: Empowering the developing world



***3 billion people in the rural developing world
need the same information we do***

- ✓ Business: new opportunities
- ✓ Finance: capital to invest
- ✓ Government: services & programs
- ✓ Health: informed, consistent care
- ✓ Education: personal advancement



[Tapan Parikh, UW and UC Berkeley]

*3 billion people in the rural **developing world**
have different limitations and capabilities*

- ✗ Money: to buy technology
- ✗ Education: to use technology
- ✗ Infrastructure: power, connectivity
- ✓ Time: lots of available labor
- ✓ Community: lots of relations



[Tapan Parikh, UW and UC Berkeley]

CAM: Managing Information from the Grassroots

Information systems are key to scaling microfinance

- *Transaction processing*
- *Monitor members and groups*
- *Analyse performance and impact*
- *Offer more services*
- *Link to formal institutions*

Can we design a UI to document member-level SHG transactions?

- *Accurate and efficient*
- *Accessible to a variety of users*



[Tapan Parikh, UW and UC Berkeley]



[Tapan Parikh, UW and UC Berkeley]



open-data-kit

Open Data Kit is a suite of tools to help organizations collect, aggregate and visualize their data.

[Project Home](#) [Downloads](#) [Wiki](#) [Issues](#) [Source](#)

[Summary](#) | [Updates](#) | [People](#)

Welcome to ODK

Open Data Kit (ODK) is a suite of tools to help organizations collect, aggregate and visualize their data. Our goals are to make open-source and standards-based tools which are easy to try, easy to use, easy to modify and easy to scale. To this end, we are proud members of the [OpenMobile Consortium](#), the [OpenRosa Consortium](#), and active participants in the [JavaRosa](#) project.

Google maps Search Maps [Show search options](#)

Find businesses, addresses and places of interest.

[Get Directions](#) [My Maps](#) [Save to My Maps](#) [RSS](#) [Print](#) [Send](#) [Link](#)

More... [Map](#) [Satellite](#) [Terrain](#)

ODK Deployments

322 views - Public
Created on Aug 21, 2009 - Updated Oct 20, 2009
By ODK
[Rate this map](#) - [Write a comment](#)

- [USAID-AMPATH \(Kenya\)](#)
AMPATH is the largest HIV treatment program in
- [Grameen Foundation Application Laboratory \(Uganda\)](#)
ODK Collect has been used by AppLab since November
- [DataDyne \(Kenya\)](#)
DataDyne is active in over 20 countries in sub-Saharan
- [Human Rights Center at UC Berkeley \(Central African\)](#)
The Human Rights Center investigates war crimes and
- [Wharton School of Business at University of](#)
A team from UPenn's Wharton School of Business is
- [Information School and Haas School at UC Berkeley](#)
Teams from University of California, Berkeley Information
- [Information School and Haas School at UC Berkeley](#)
Teams from University of California, Berkeley Information
- [Information School and Haas School at UC Berkeley](#)
Teams from University of California, Berkeley Information
- [Information School and Haas School at UC Berkeley](#)
Teams from University of California, Berkeley Information
- [Vetaid \(Zanzibar\)](#)
Vetaid supports animal health projects in Africa by
- [D-Tree \(Tanzania\)](#)
D-Tree is putting the Integrated Management of
- [Frogtex \(Colombia\)](#)
Frogtex is a social venture dedicated to creating
- [Brazilian Forest Service \(Brazil\)](#)
The Brazilian Forest Service is piloting Open Data Kit for
- [Change at University of Washington \(Seattle\)](#)
ODK's core developers are from the UW's Computer
- [Johns Hopkins Center for Clinical Global Health](#)
eMOCHA is a free open-source application, developed
- [VillageReach \(Mozambique\)](#)
VillageReach develops logistics and management

Antarctica

[Gaetano Borriello, UW]

Personalized education



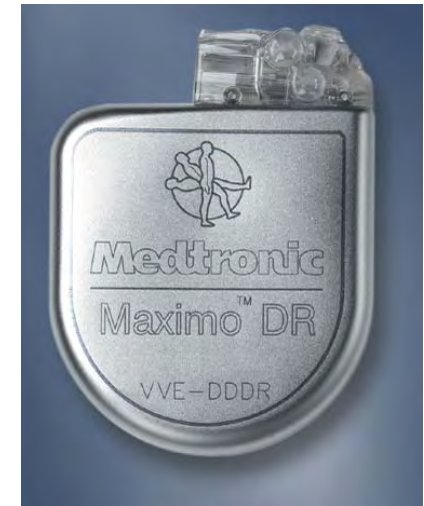
Transforming American Education:
Learning
Powered by Technology

DRAFT
National Educational Technology Plan 2010

March 5, 2010

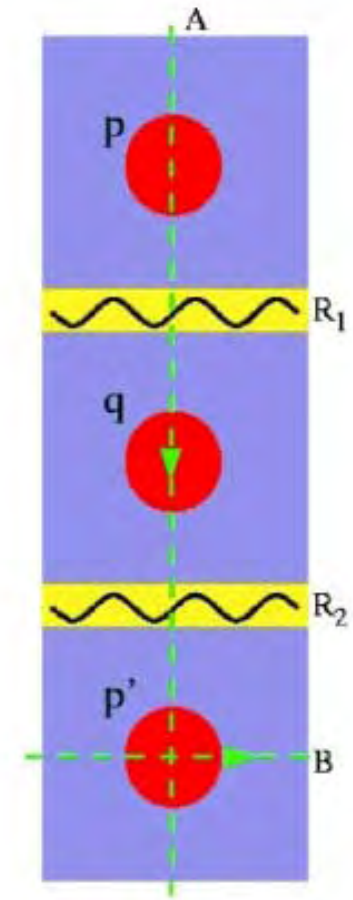
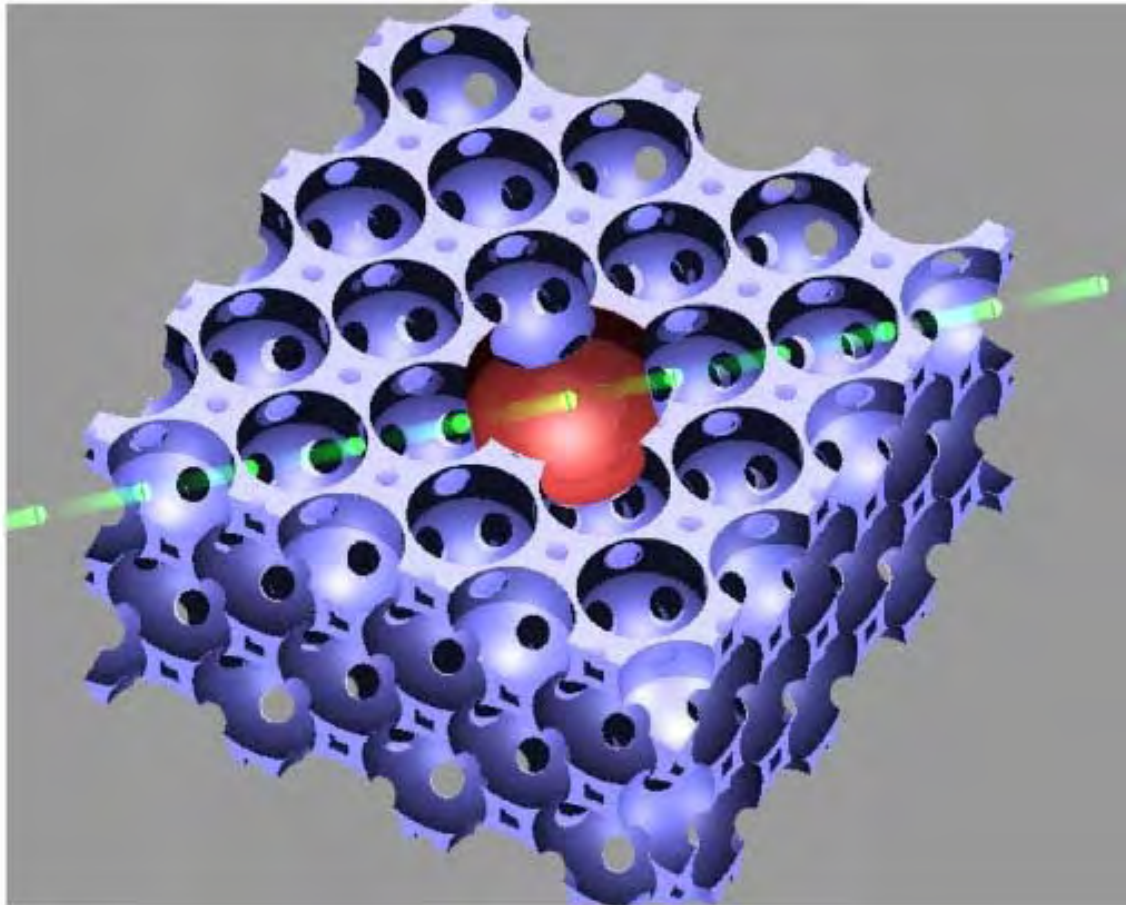
Office of Educational Technology
U.S. Department of Education

Security and privacy

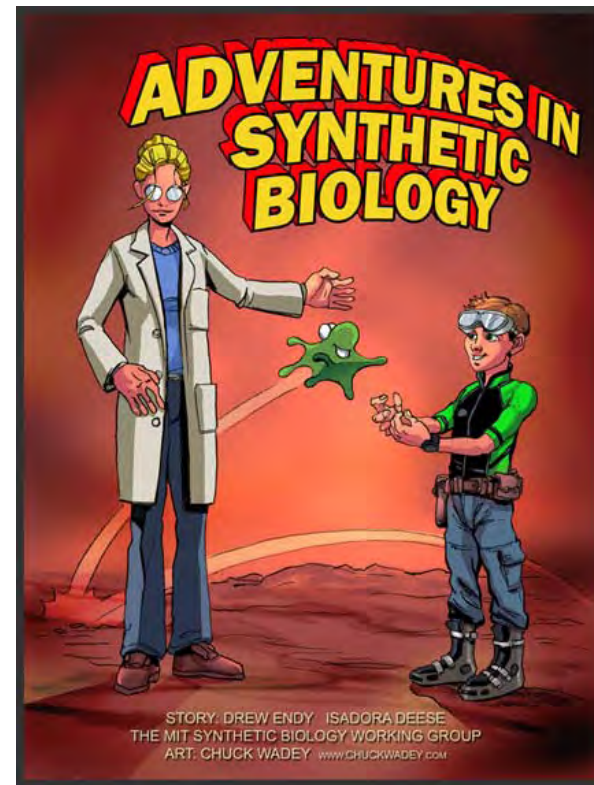
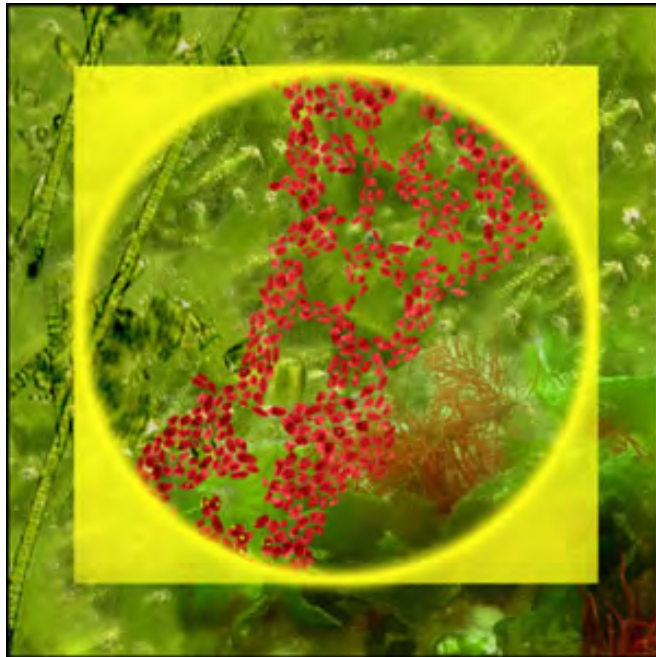


[Yoshi Kohno, UW]

Quantum computing



Synthetic biology / molecular engineering





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.



MYTHBUSTERS
WEDNESDAYS AT 9PM

An electric eel skin wallet can demagnetize credit cards.

BUSTED

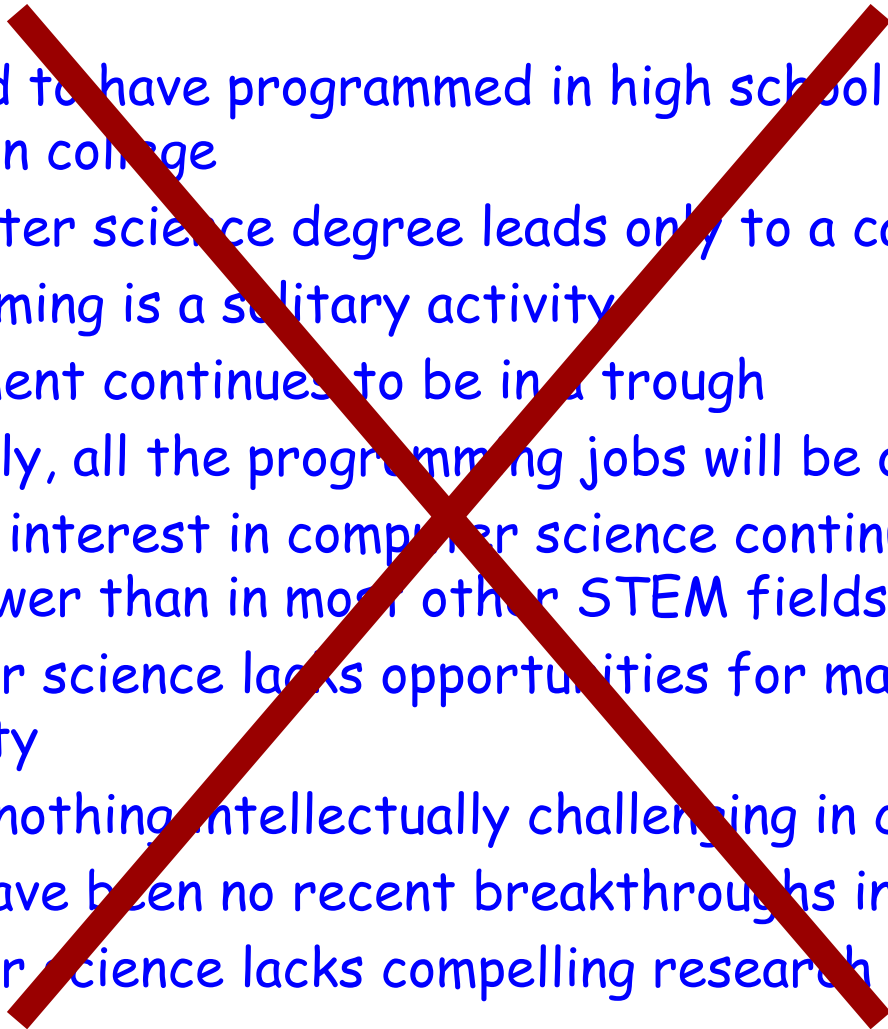
VIDEO HIGHLIGHT >>
Big Rig Myths
And See the Full Video Collection Now.



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 continues to be in a trough
 - Eventually, all the programming jobs will be overseas
 - Student interest in computer science continues to be 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
 - There have been no recent breakthroughs in computer science
 - Computer science lacks compelling research visions

We put the "smarts" in ...

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



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



<http://lazowska.cs.washington.edu/harvard.pdf>

<http://www.cra.org/ccc/>

<http://www.cs.washington.edu/WhyCSE/>

