Computer Science: Past, Present, and Future

Ed Lazowska

Bill & Melinda Gates Chair in Computer Science & Engineering 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 ...

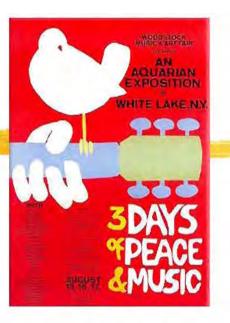








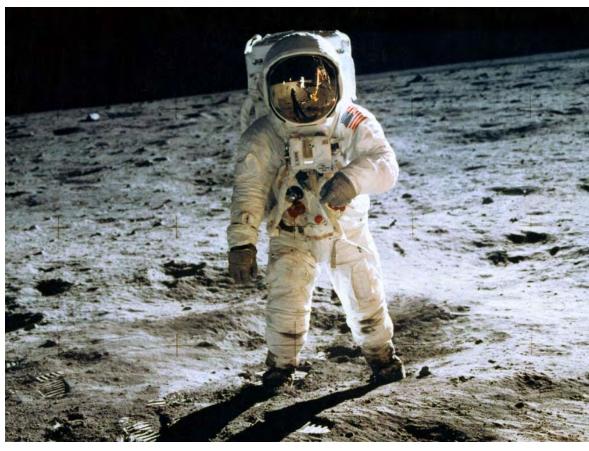




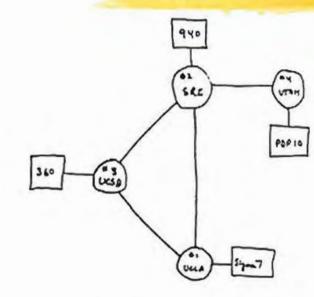








[Peter Lee, DARPA, and Pat Lincoln, SRI]



THE ARPA NETWORK DEC 1969 4 Nodes



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| | | a host dead message | |

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 ...

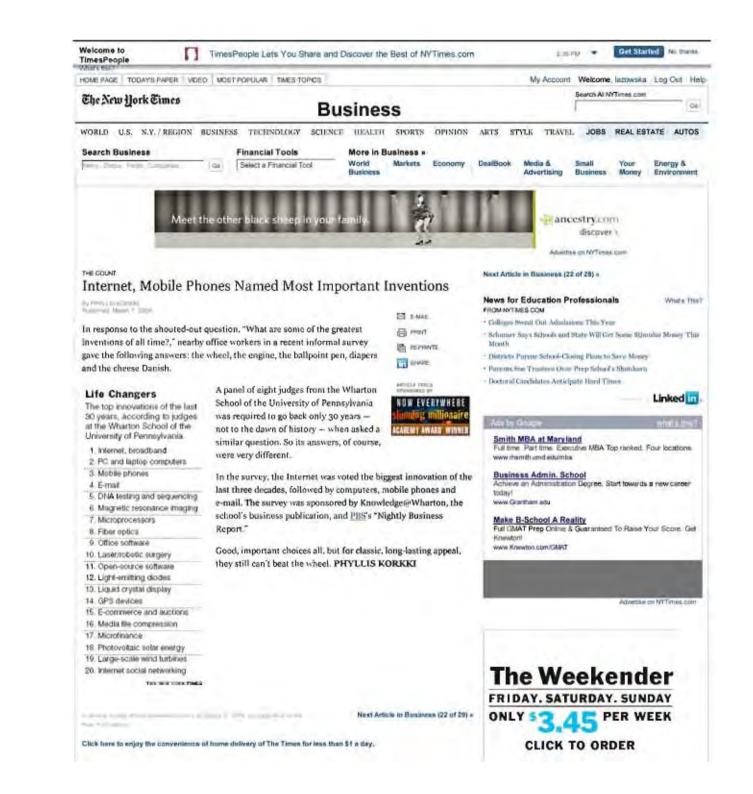
EXPONENTIALS STUS





And so is the reason ...

The past thirty years ...



Welcome to TimesPeople Lets You Share and Discover the Best of NYTimes.com TimesPeople A ROLLING MIC ULAR TIMES TOPCS Life Changers Business TECHNOLOGY SCIENCE HEALTH SPORTS OPINION ARTS ancial Tools

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

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

> > were very different.

Report."

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 optical

9. Office software 10. Laser/robelic surgery

11. Open-source software

12. Light-emilting dodes

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 WAY THREE THREE

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Next Article in Business (22 of 29) +

More in Business

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Economy

World

amed Most Important Inventions

e-mail. The survey was sponsored by Knowledge@Wharton, the

Good, important choices all, but for classic, long-lasting appeal,

school's business publication, and PBS's "Nightly Business

they still can't beat the wheel. PHYLLIS KORKKI

Business

ect a Financial Tool

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* Schumer Says Schools and State Will Get Some Stipulus Menny This Month IS REPRINTE. - Districts Purme School-Closing Plane to Save Money Grupe. · Patents Size Trustees Over Prep School a Shutdown - Doctoral Cardidates Anticipate Hard Times ARTICLE SPECE A panel of eight judges from the Wharton School of the University of Pennsylvania NOW EVERYWHERE was required to go back only 30 years not to the dawn of history - when asked a ACADEMY AWARD WINN Smith MBA at Maryland similar question. So its answers, of course, Full time. Part time. Executive MBA Top ranked. Four locations. www.msmith.amd.eduimba **Business Admin. School** In the survey, the Internet was voted the biggest innovation of the Achieve an Administration Degree, Start towards a new career last three decades, followed by computers, mobile phones and today!

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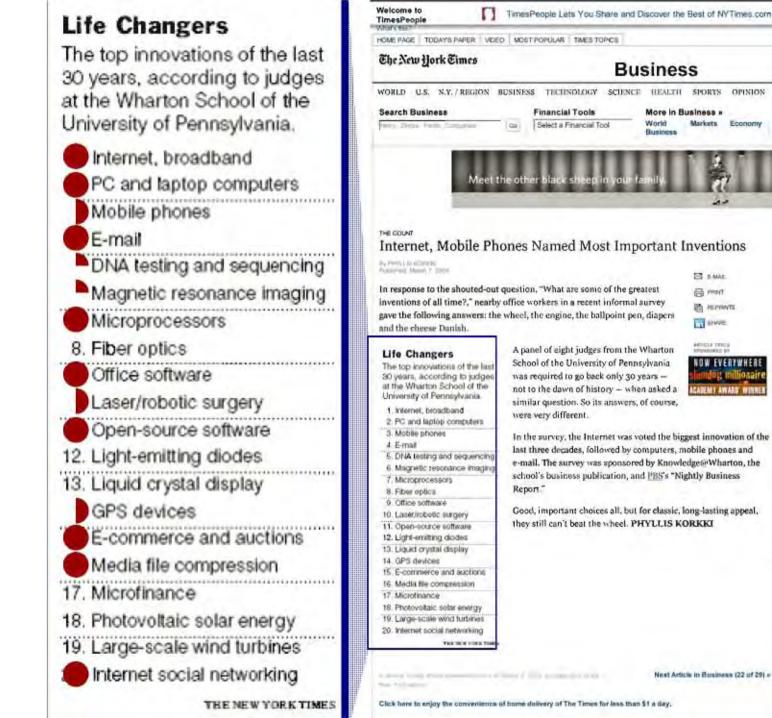
News for Education Professionals

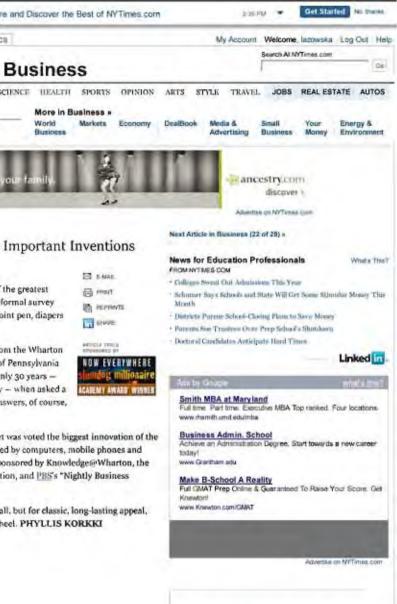
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DealBook



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| University of Pennsylvania. | Fern Den Feit fürster | a Select a Financial Tool World Business | | DealBook Media & Small Your Advertising Business Money | Energy & Environment |
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| 2. PC and laptop computers | Meet t | he other black sheep in your family. | 77 | ancestry.com | |
| 3. Mobile phones | | | 44 | discover 1 Adustas on M/Tenas cur | |
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| 5. DNA testing and sequencing | Avreni avelanni Avreni avelanni | ones maniet most important | | News for Education Professionals | Whate The? |
| 6. Magnetic resonance imaging | | question, "What are some of the greatest | 日 n-MAE | Colleges Sweet Out Administers This Year Schumer Says Schools and State Will Get Some St | Intuities Memory This |
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| 7. Microprocessors | and the cheese Danish. | | ARTICLA TRACE | Parents See Trustees Over Prep School a Shatday Doctoral Condidates Anticipate Hard Times | m, |
| 3. Fiber optics | Life Changers The top innovations of the last | A panel of eight judges from the Wharton School of the University of Pennsylvania | NOW EVERYWHERE | | Linked |
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| 1. Open-source software | 2. PC and laptop computera 3. Mobile phones | In the survey, the Internet was voted the | biggest innovation of the | Business Admin. School | |
| 2. Light-emitting diodes | 4 E-mail 5. DNA testing and sequencing | last three decades, followed by computers e-mail. The survey was sponsored by Kno | | Achieve an Administration Degree, Start toward today/ www.Grantham.adu | ts a new career |
| 3. Liquid crystal display | Magnetic resonance imaging Microprocessors | school's business publication, and <u>PBS</u> 's * Report." | | Make B-School A Reality Full GMAT Prep Online & Guatanised To Raise | Your Scree Get |
| 4. GPS devices | 8. Fiber optica 9. Office software 10. Laser/indexic surgery | Good, important choices all, but for classi | c, long-lasting appeal, | Knewtont www.Knewton.com/GMAT | |
| 5. E-commerce and auctions | 11. Open-source software 12. Light-emitting dodes | they still can't beat the wheel. PHYLLIS | KORKKI | | |
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| 7. Microfinance | 17. Microfinance 18. Photovoitaic solar energy | | | | |
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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



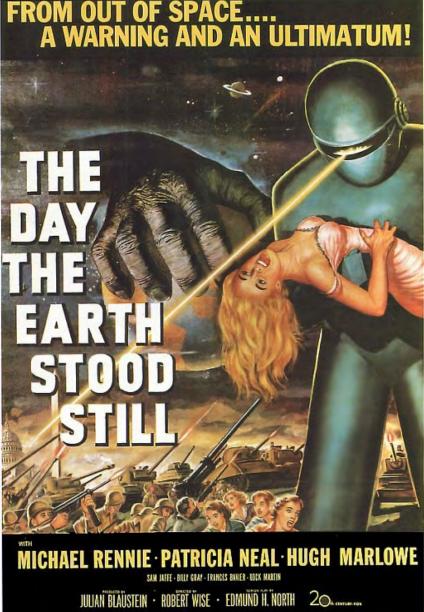


Imagine spending a day without information technology

- 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 FROM OUT OF A WARNING

- A day without the Internet and
- A day without diagnostic medic
- A day during which automobiles antilock brakes, and electronic
- A day without digital media w high-definition televisions, MP3 computer animation, and videog
- A day during which aircraft counavigate without benefit of GP: had no models, banks and mercl funds electronically, factory au function, and the US military lc supremacy



2004: 10,000,000,000,000,000,000 grains of rice

Ten quintillion: 10*10¹⁸

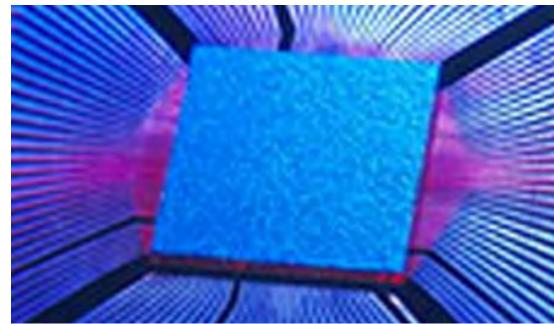
The number of grains of rice harvested in 2004



2004: 10,000,000,000,000,000,000 transistors

Ten quintillion: 10*10¹⁸

- The number of grains of rice harvested in 2004
- The number of transistors fabricated in 2004





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



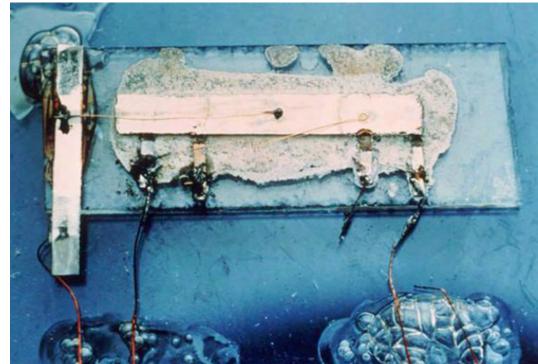


The integrated circuit

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

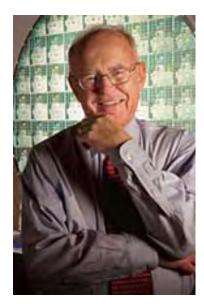


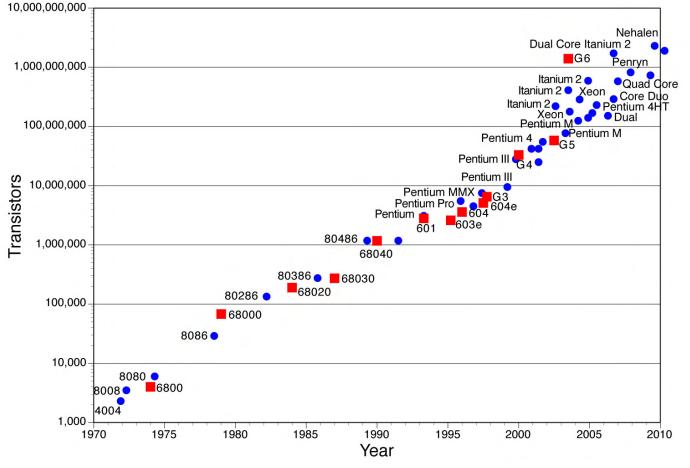




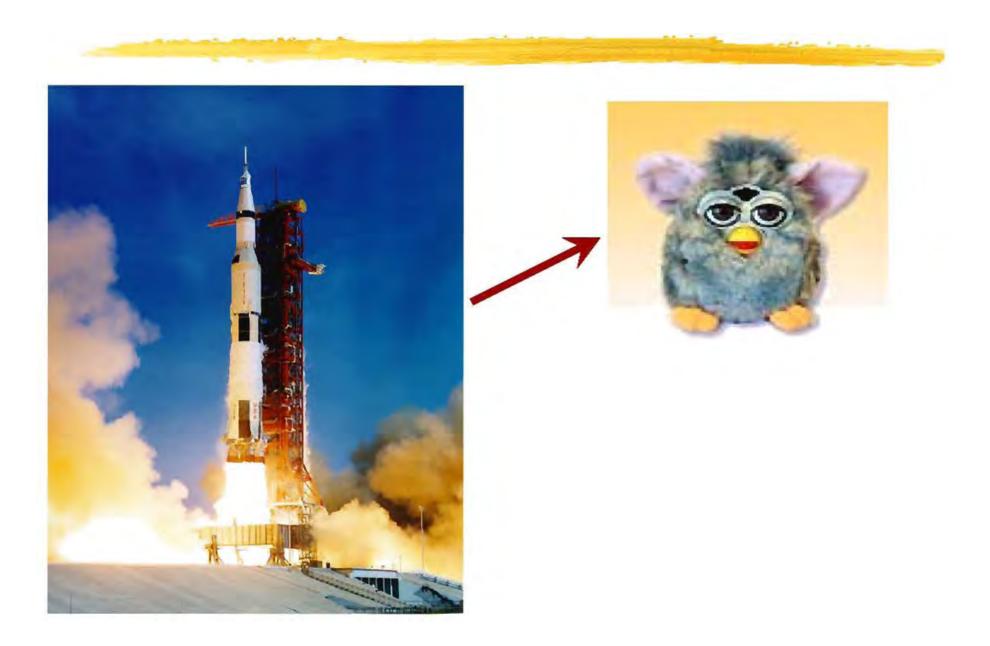
Exponential progress

Gordon Moore, 1965









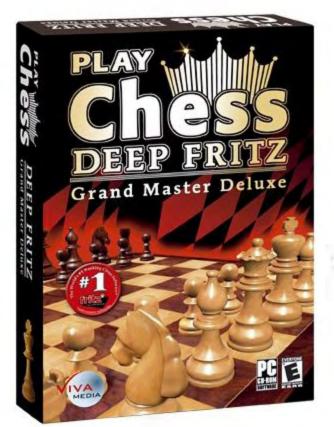
Software makes equal progress



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





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

1,000,000,000

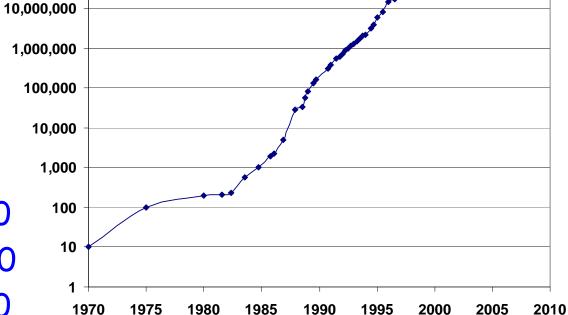
100,000,000

- 1970: 10
- 1975: 100
- 1980: 200
- 1985: 2,000
- 1990: 350,000
- **1995: 10,000,000**
- 2000: 100,000,000

- 2010: 700,000,000
- 2005: 375,000,000







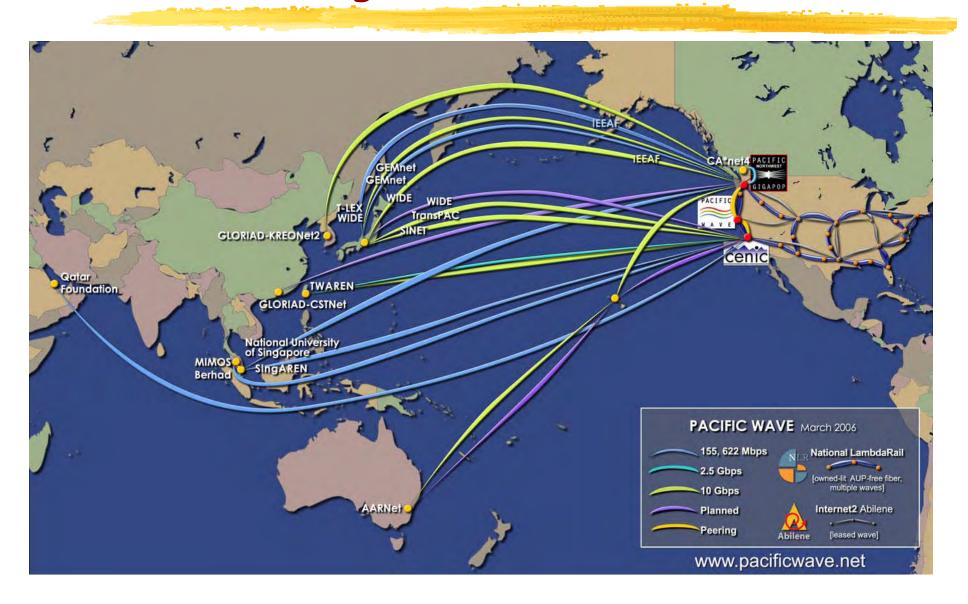
A connected region - then



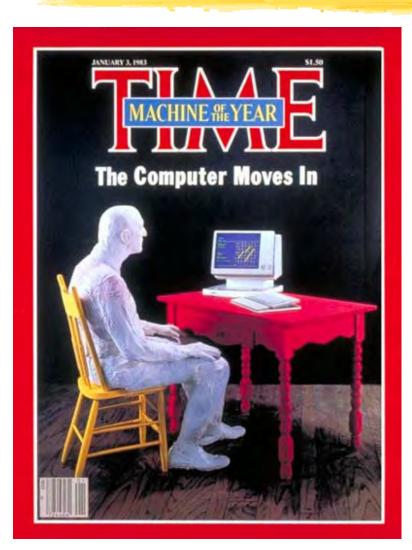




A connected region - now

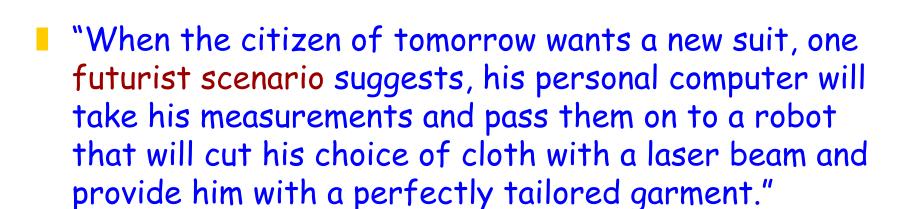


The Computer: *Time* Magazine's 1982 "Machine of the Year"



"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."



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





vacuum your carpet





wash your floor











scrub your pool







clean your gutters



imagining machines performing domestic chores."





amuse your pet



detonate your IED's





The Computing Community Consortium



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



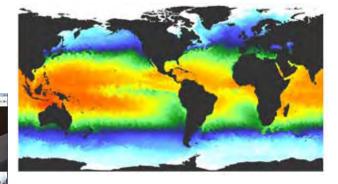
Computing has changed the world

- 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









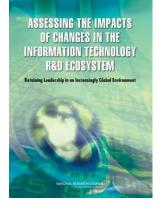
Research has built the foundation

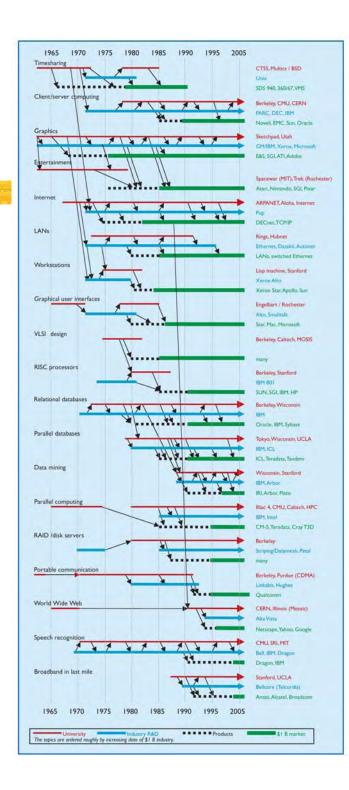
Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure

> Computer Science and Telecommunication NATIONAL RESEARCH COUNCIL



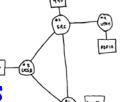
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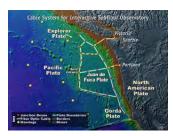




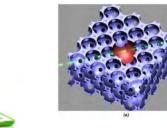
The future is full of opportunity

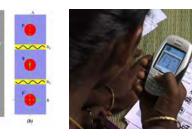
- Creating the future of networking
- Driving advances in all fields of science and engineering
- Revolutionizing transportation
- Personalized education
- The smart grid
- Predictive, preventive, personalized medicine
- Quantum computing
- Empowerment for the developing world
- Personalized health monitoring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

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/



Countless talksCountless 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. ow can we work together to | many Internet hosts. try: timesharing, computer graphics, establish, articulate, and It was only 10 years ago that Deep networking (LANs and the Internet), pursue compelling visions Blue-a supercomputer by any defipersonal workstation computing, winfor our field-visions that nition-defeated world chess chamdows and the graphical user interface, will shape the intellectual pion Garry Kasparov. Today, thanks RISC architectures, modern integratfuture of the field, that will catalyze more to progress in software than to ed circuit design, RAID storage, and research investment and public supparallel computing. In each case, the progress in hardware, you can downport, and that will attract the best and | load for your PC a chess engine with role of federally sponsored research

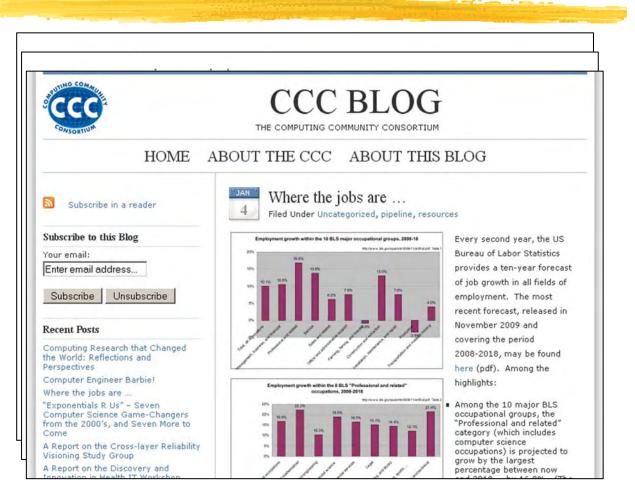
a rating 10% higher than any human was clear.

Most of the "futuric

brightest minds of a new generation?

The National Science Foundation

Countless talks
Countless articles
CCC blog



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



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

| TING COMM. | | | | | | | |
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| -11/Jan- | | | | | | | |
| Computing Community Consortium We support the computing research community in creating compelling research visions and the mechanisms to realize these visions. | | | | | | | |
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| our intellectua future? »» NetSE Cyber Physical Systems Robotics Bit | and a set of the set o | | | | | | |
| FOSS Online Education XLayer Global Development | aent ACAR HealthIT | | | | | | |
| Computing Research that Changed the World | Highlight of the Week | | | | | | |
| This invitation only symposium, "Computing Research that Chang the World: Reflections and Perspectives," was organized by the Computing Community Consortium in collaboration with Congressman Bart Gordon (D-TN), Congressman Ralph Ha (R-TX), Congressman Daniel Lipinski (D-LL), Congressman Vern Ehlers (R-MI), Congressman Rush Holt (D-N3) and Se Jay Rockefeller (D-W9). It was held in the Library of Congre | Luiversity of Washington computer science undergraduates have developed a system that | | | | | | |

Transition Team white papers

| CC | | | | inity Cons y in creating compelli | | | echanisms to rea | alize these visions. |
|-------------|---|---------------|---|--|----------------|-------------|------------------|----------------------|
| HOME | YOUR VISION | PLANS | ACTIVITIES | RESOURCES | ABOUT | CRA | GO | |
| Computi | ing Researc | h Initiativ | es for the 2 | 1st Century | | | | |
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| | | | novation (Word on, Ed Lazowska, L | version) Iniversity of Washing | ton, and Peter | Lee, Carneg | ie Mellon Unive | rsity) |
| | arnegie Mellon Un | | andy H. Katz, UC B | erkeley) | | | | |
| Unleashing | Waves of Innov | ation: Transf | ormative Broadb | and for America's | Future (Wor | d version) | | |
| | | | | cation (Word versi ellon University, Chip | | | and Larry Smar | r, UCSD) |
| | | | orward for Cybe chneider, Cornell I | rsecurity Researc University) | h (Word vers | ion) | | |
| | | | Energy Future (W King, University of | | | | | |
| | hrun, Stanford Uni | | | ion of American Scie | ntists) | | | |
| | d": R&D for an Ir atz, UC Berkeley) | telligent 21s | t Century Electri | cal Energy Distrib | ution Infrast | ructure (Wo | rd version) | |
| Synthetic B | iology (Word ve | rsion) | | | | | | |

- Transition Team white papers
- Library of Congress Symposium

The LIBRARY of CONGRESS

- 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)



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

TIDDIDU CONIOD

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, <u>http://www.cccblog.org/2009/08/28/landmark-contributions-by-students-in-computer-science/</u>, or send them to Ed Lazowska, <u>lazowska@cs.washington.edu</u>.

- 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

AGONTORIO

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.

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

| MICON | | | | |
|--|---|--|--|--|
| CCC Computing Community Consortiun | h | | | |
| We support the computing research community in creating compelling research visio | | | | |
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| HOME YOUR VISION PLANS ACTIVITIES RESOURCES ABOUT | CRA GO | | | |
| The second s | 1 | | | |
| Discovery and Innovation in Health IT | Content is still being added to this site. Please Check back periodically. | | | |
| This invitation only workshop, "Discovery and Innovation in Health IT," is sponsored by the | The last change was made on: | | | |
| National Science Foundation, the Office of the National Coordinator for Health Information Technology, the National Institute of Standards and Technology, the | Session Videos | | | |
| 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. | HIT - Thursday Morning Op | | | |
| The talks and plenary discussions will be videotaped and a web presence will be | | | | |
| developed to make the workshop material broadly available. | and a | | | |
| 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 | Visit | | | |
| practitioners and IT healthcare suppliers to identify mutual interests in healthcare IT, as they relate to both near- and long-term challenges and solutions; | 0:00:00 / 1:45:22 | | | |
| | | | | |
| 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 | Reply/Registration | | | |
| accelerate the transition of research outcomes into products and services; | Link to Reply/Registration Form | | | |
| 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 | Logistics | | | |

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 ...



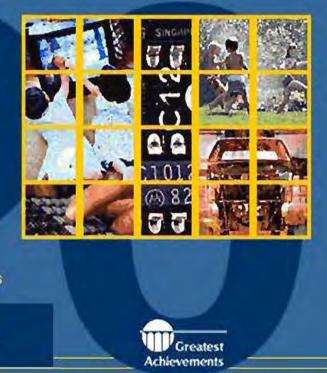
Greatest Engineering Achievements OF THE 20TH CENTURY

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

- Electrification
- 2 Automobile
- Airplane
- Water Supply and Distribution 14 Imaging 4
- Electronics
- 6. Radio and Television
- Agricultural Mechanization
- Computers 8.
- Telephone 9.
- 10. Air Conditioning and Refrigeration

- 11. Highways 12 Spacecraft
- 13 Internet
- 15 Household Appliances
- 16 Health Technologies
- 17 Petroleum and **Petrochemical Technologies**
- 18. Laser and Fiber Optics
- 19. Nuclear Technologies
- 20 High-performance Materials



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About Timeline The Book

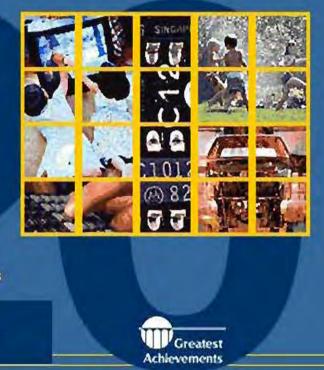
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- 1. Electrification
- 2 Automobile
- 3. Airplane
- Water Supply and Distribution 14.
- 5 Electronics
- 6. Radio and Television
- 7 Agricultural Mechanization
- Computers
- 9. Telephone
- 10. Air Conditioning and Refrigeration

- 11. Highways 12. Spacecraft
 - Internet
 - Imaging
 - n maging
- 15 Household Appliances
- 16 Health Technologies
- 17 Petroleum and Petrochemical Technologies
- 18. Laser and Fiber Optics
- 19. Nuclear Technologies
- 20 High-performance Materials



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About Timeline The Book







Make solar energy economical



from fusion

sequestration methods



Manage the nitrogen cycle



Provide access to clean water



Restore and improve urban infrastructure



Advance health in formatics



Engineer better medicines



Reverse-engineer the brain



Prevent nuclear terror



Secure cyberspace



Enhance virtual reality



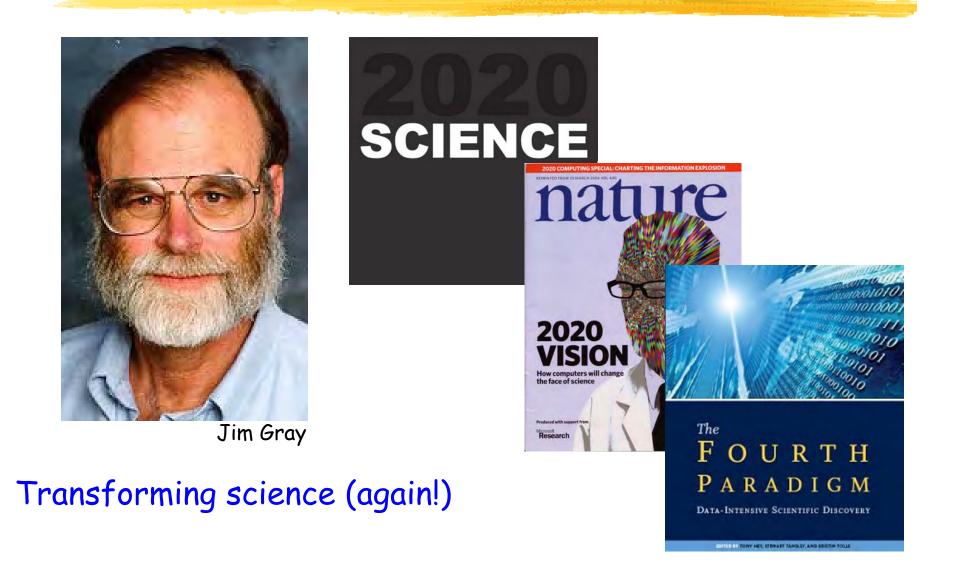
Advance personalized learning

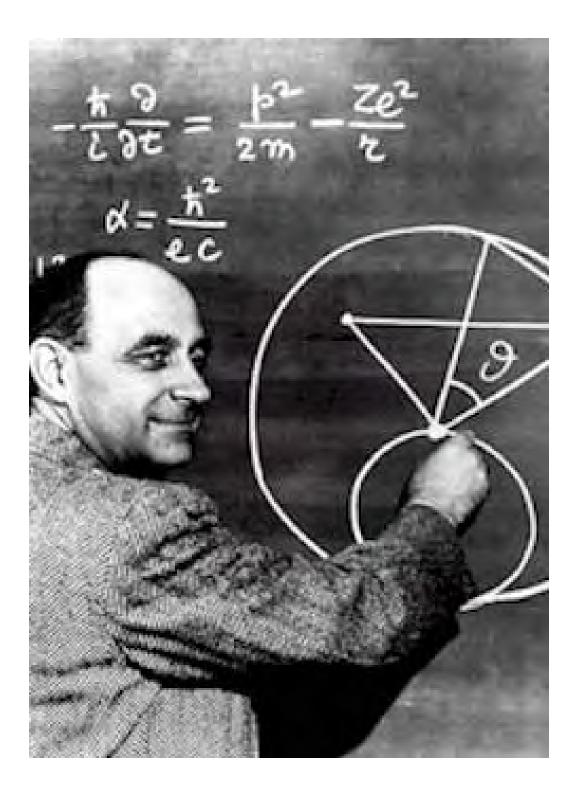


Engineer the tools of scientific discovery



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





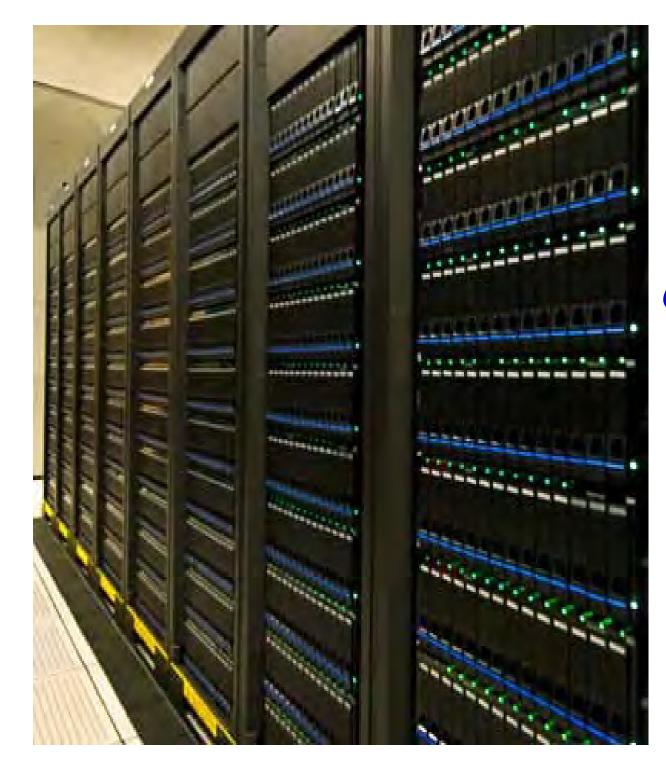
Theory Experiment Observation



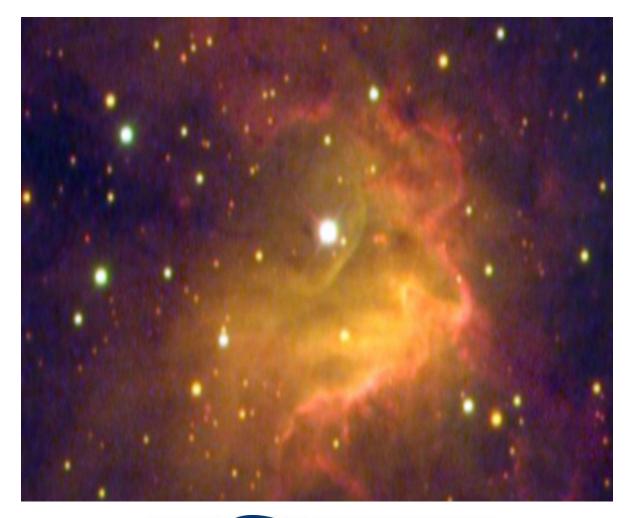
Theory Experiment Observation

Theory Experiment Observation

[John Delaney, University of Washington]



Theory Experiment Observation Computational Science



Theory Experiment Observation Computational Science eScience



eScience is driven by *data* more than by cycles

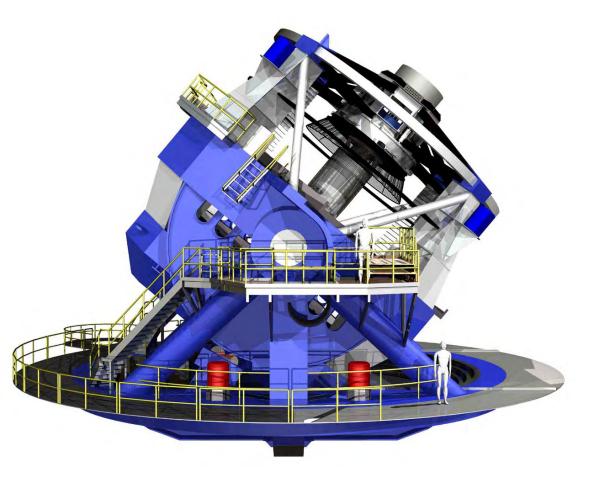
Massive volumes of data from sensors and networks of sensors



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







Major labs have 25-100 of these machines

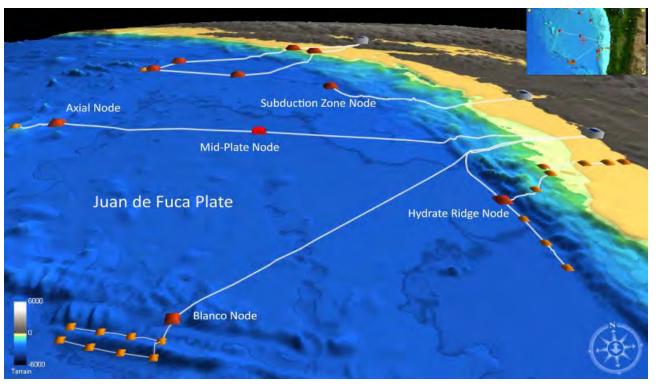
Illumina HiSeq 2000 Sequencer

~1TB/day

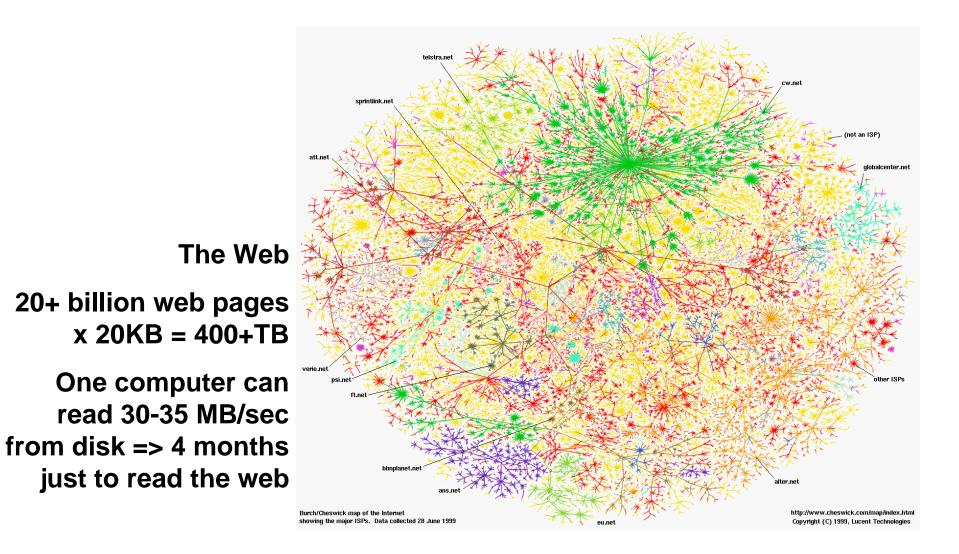


Regional Scale Nodes of the NSF Ocean Observatories Initiative

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











Point-of-sale terminals

eScience is about the analysis of data

The automated or semi-automated extraction of knowledge from massive volumes of data

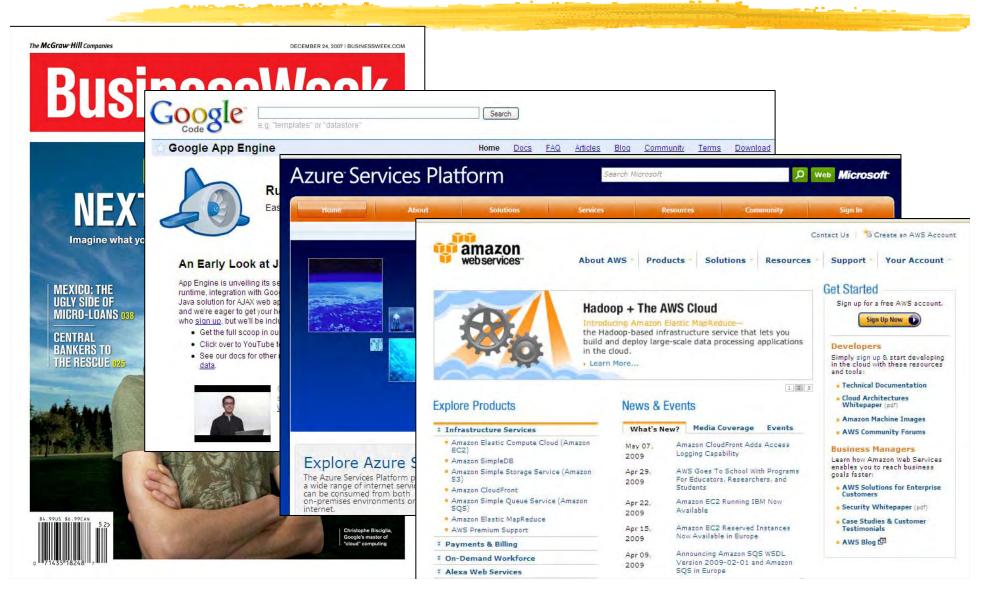
- There's simply too much of it to look at
- It's not just a matter of volume
 - Volume
 - Rate
 - Complexity / dimensionality

eScience utilizes a spectrum of computer science techniques and technologies

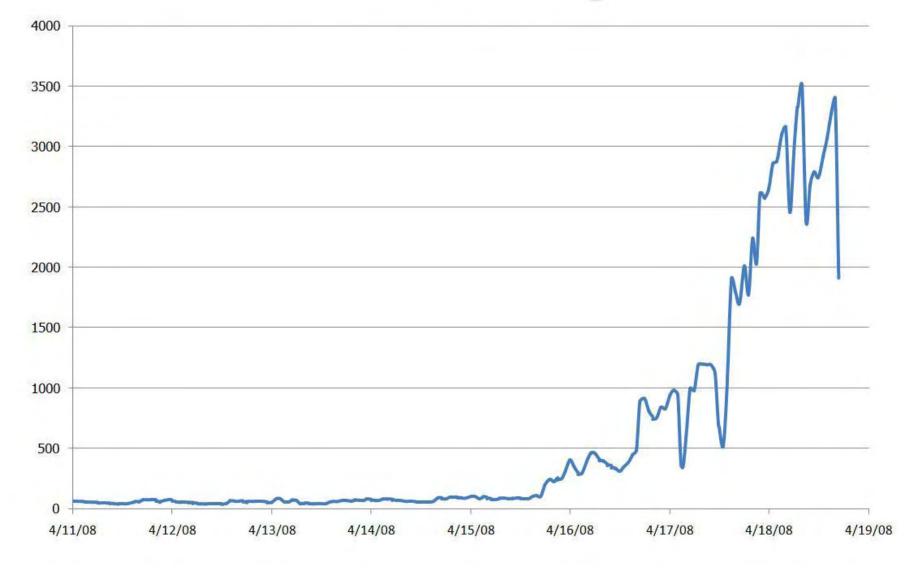
- Sensors and sensor networks
- Backbone networks
- Databases
- Data mining
- Machine learning
- Data visualization
- Cluster computing at enormous scale



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



Animoto: EC2 Instance Usage



[Werner Vogels, Amazon.com]

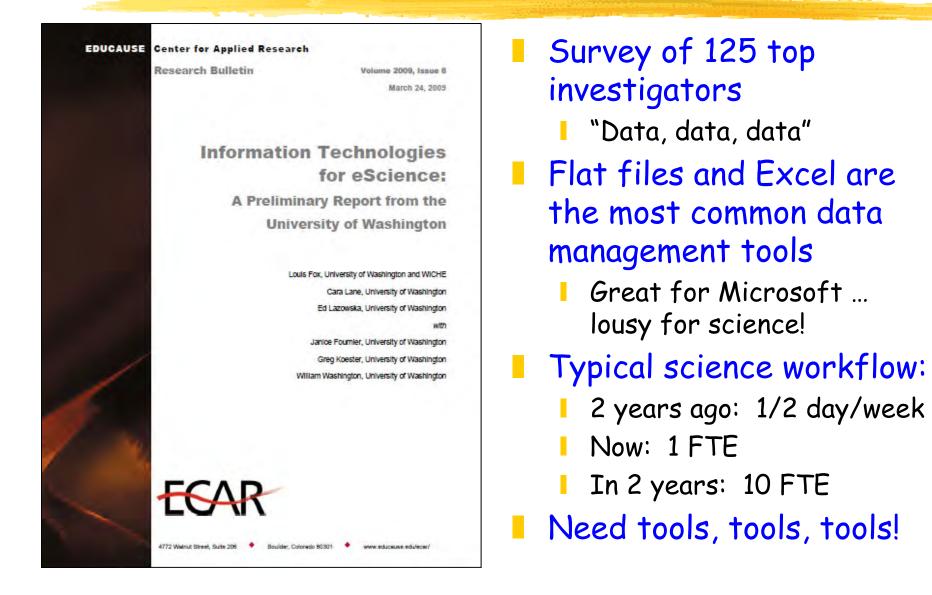


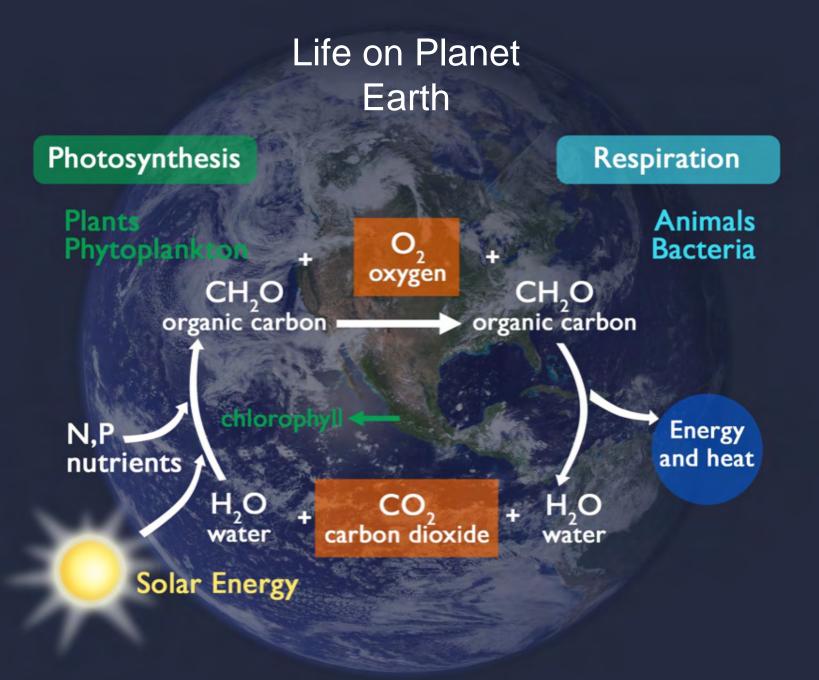
eScience will be pervasive

- 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

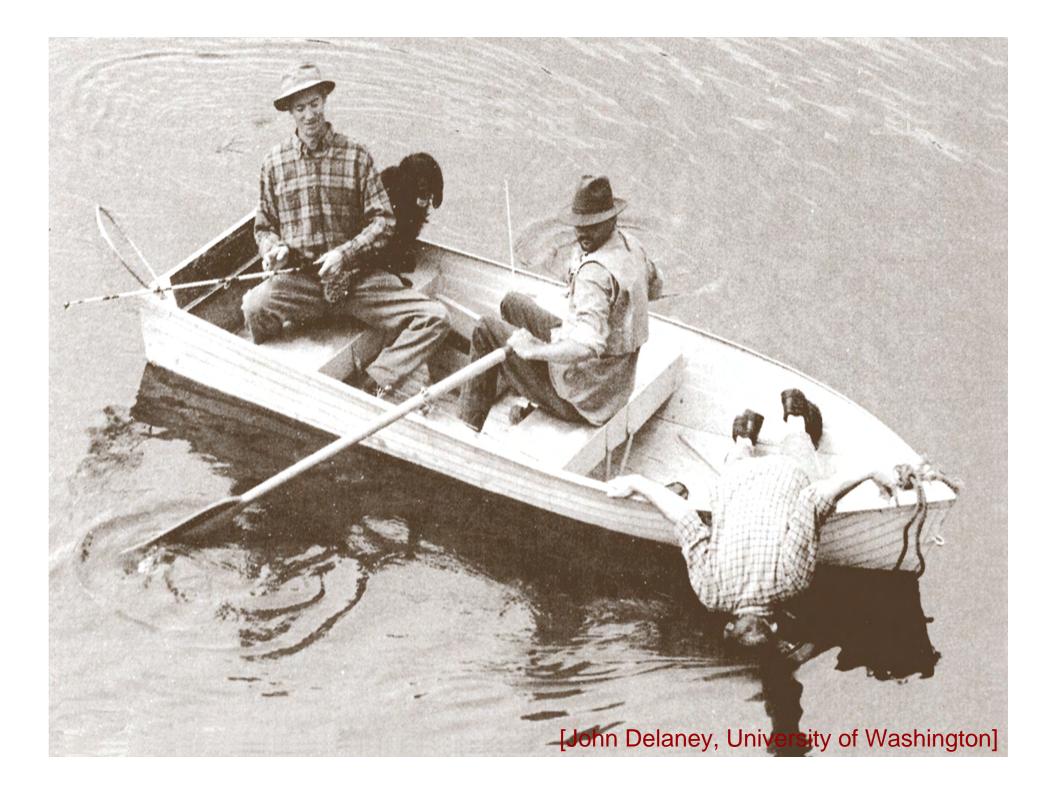


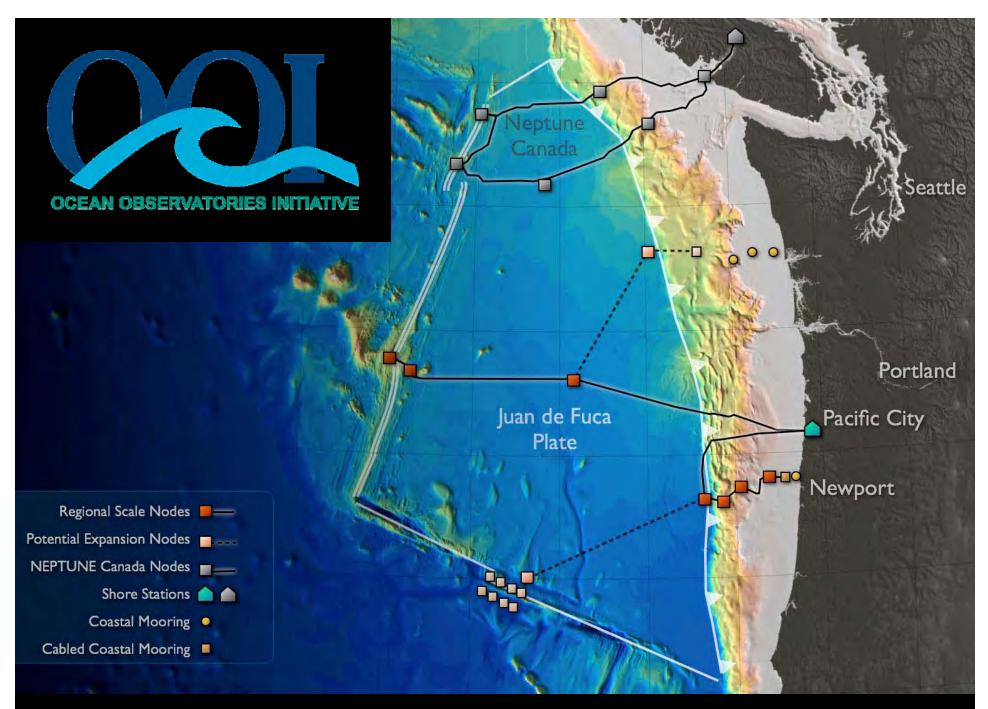
Top scientists across all fields grasp the implications of the looming data tsunami





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)

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David Baker







| fold it BETA | |
|---|--|
| Solve Puzzles | PUZZLES RECIPES FORUM WIKI FEEDBACK ABOUT |
| Click to learn how you contribute to science by playing Foldit. | Win Beta Mac Beta Linux Beta Win XP/Vista Intel OS X 10,4 or later End |
| | USER LOGIN Username: * Password: * |
| What's New | |
| Small Update | Log in Create new account |
| | Request new password |
| Ve've posted a small update today, here's what's in it. | |



BLOG GROUPS PLAYERS PUZZLE



BootsMcGraw

Global Soloist Rank: #6 Global Soloist Score: 3784 Cases

20:46:49 GMT

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 1885 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 |



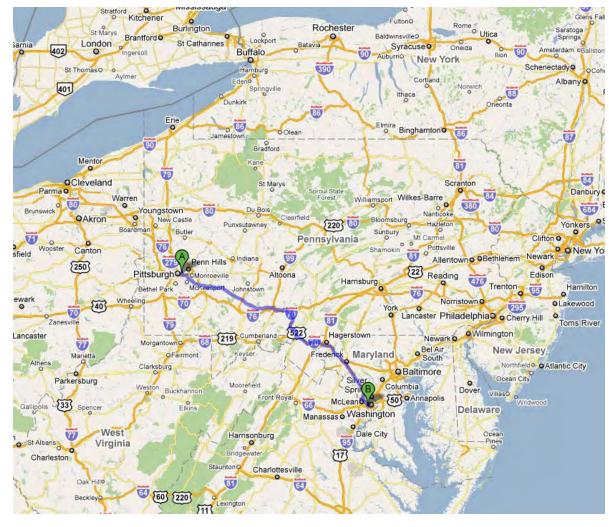




Peter Lee

Regina Dugan







Mine Station Dam Old Chinese Customs StaitDam (under construction) Lake Changjin National Park Dam Station Changjin-up Airfield Factory ComplexElite Station Mine Mine Mine Stadium Dam Station anch Interesting Site Station Mine) Station Mine Station Dam Station Station Dam Monument Monument Dam Mine Monument Mine Dam DamDam Dam Burial Mounds Quarry Station spected underground nuclear site Station MonumentBarrage DamMonumentater Treatment Fa Dam DamMyohyangsan mountains Taechon Hydroelectric Power PleStation Dam Ryonghwa Temple (Mt. Paegun) checkpoint Nyongwon Power Plant - Long live 3 great revolutions" (Agriculture, I /ihwan Island B Station Aircraft Graveyai Monument on Taegye I Yongbyong Fuel Fabrication Complex Entrance Gate "Give un your lifetor the sake of our leader, Kim Jong il" Maengsan Airlield Bukchang Thermal Power Pi Coal Depot Dam loading depotuse Station Station Hwa, Former Director of National Security Agenc imu Island Sea-Bird Breeding Site 📮 Coal Loading DepEroded hill sides Station Coal Mine DamNavy base Military Communications ToweDamMine Office/FactorDam Mine Pyongyang Ostrich Farm MonumenMine Dam Dam Runway Under Construction Technology and Economy Dam Mine Dam Dam Runway Under Construction ese revolutionary Links Coal Mine Station College of Animal Husbandry (Wonsan Ag ormation Center of New Technology and Economy Dam Dam Chonsam Fish Pond with veteran anti-Japanese revolutionary fighte Coal Min Station Mine Tomb of King Tongmyong Dam Jinpha-ri groutDam Dam Mine Mine Mine Mine Onument Stadium Ancient Fort Wall DamMine MineSinpyong Resting Place Restaurant Dam Dam Burial MounUnderground facility and Wong Yo Ri Highway Strip station Hoeyang Southeast Airfield Burial Mounds (Arduous March) Kungangguks (Penta station Hoeyang Southeast Airfield DamRK Kumgang Madong Fertilizer and Cement Factory Dam Monument he Railway and Turntable DamDam Coal Mine DamMine DamDam DamDamMonumento Fire to clear farm land f US bombing: 400 mothers 102 child Schung South Airfie Dam Dam/onument Dam Great revolutions (Agriculture, Industry, intellect Kim Jong II on the spot guidance o Nuchon Ni Highway Strip Dam Dam Dam Dam Dam Monument "With our own power we have developed Mine Dam Dam Dam Dam gy-of-the-great leader, Comrade Kim II Sun Burial Mound Military training grounds? Haeju Naval Base Burial Mounds (Arduous March) Haeju Naval Baser A MonumenDam Kangryong/Ongjin Crane HabitaBurial Mound Image © 2009 TerraMetrics Jarri Crane HabitaBurial Mound Image © 2009 TerraMetrics North Korean Ships Mc@,2009(Cnes/Spot Image Dam Dam Image © 2009 DigitalGlobe (100)Image NASA Dam 39"30'42.98" N 125°11'35.89" E Eye alt 246.33 m elev 138 ft



Revolutionizing transportation







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 E350 BlueTEC and 4MATIC models is delayed. See dealer for details.
- 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.
- 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

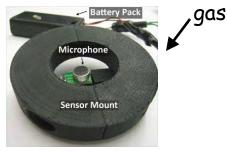


- Routing around congestion, for transit and personal vehicles
- Greater vehicle density through semi-automated control

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





water

power

LAMP A

[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

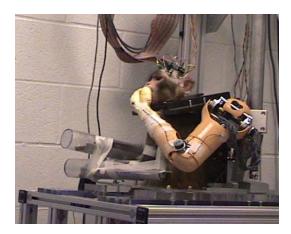
- Machine learning for clinical care
- Predictive models
- Cognitive assistance for physicians



Health: Neurobotics



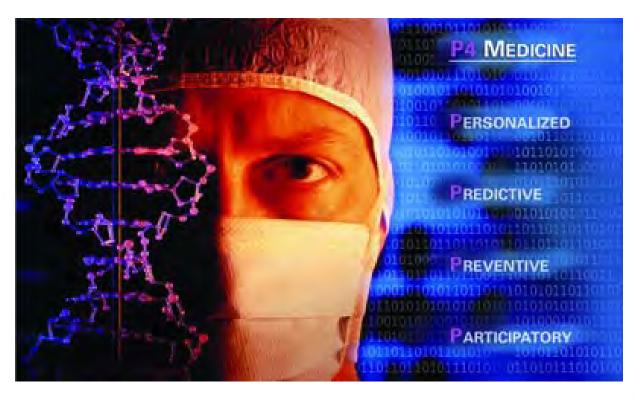






[Yoky Matsuoka and Raj Rao, UW]

Health: P4 medicine





ICTD: Empowering the developing world



3 billion people in the **rural developing world need the same** <u>information</u> we do

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



[Tapan Parikh, UW and UC Berkeley]

3 billion people in the rural **developing world have different** <u>limitations</u> and <u>capabilities</u>

- **✗** <u>Money</u>: to buy technology
- X Education: to use technology
- X Infrastructure: power, connectivity
- ✓ <u>Time</u>: 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



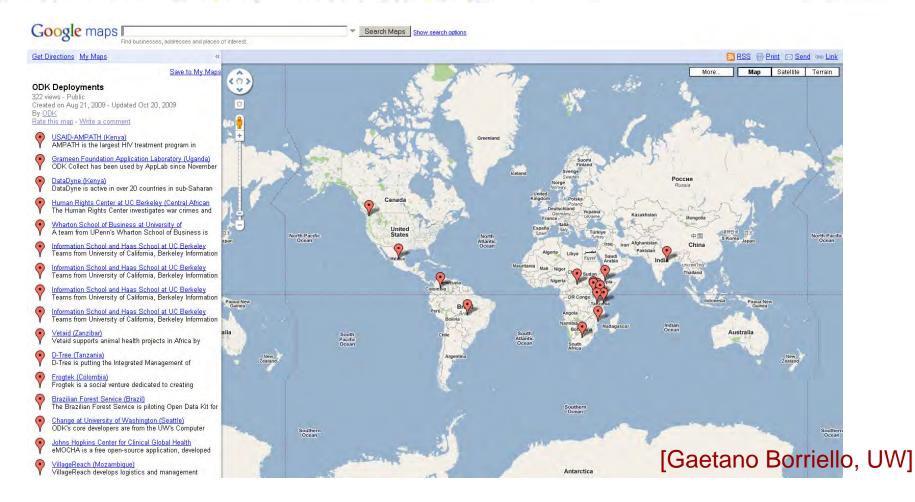
[Tapan Parikh, UW and UC Berkeley]





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 <u>OpenMobile</u> <u>Consortium</u>, the <u>OpenRosa Consortium</u>, and active participants in the <u>JavaRosa</u> project.



Personalized education





Transforming American Education: Learning Powered by Technology

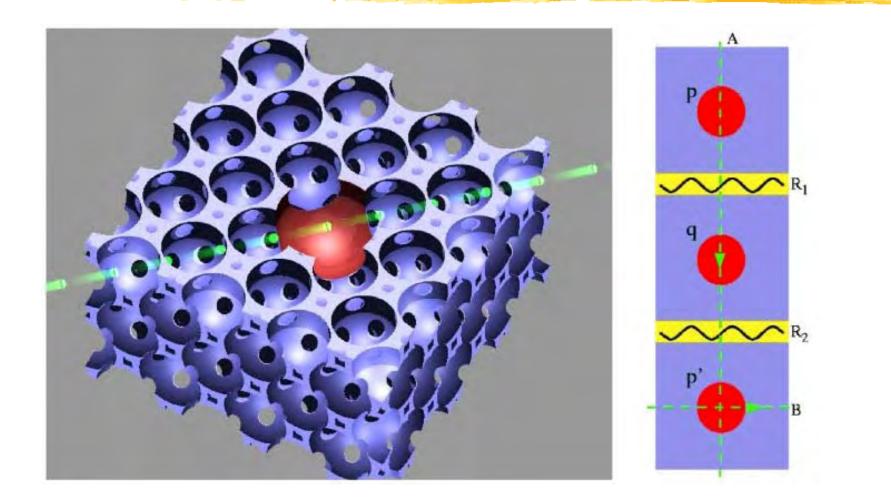
> unaei National Educational Technology Plan 2010 March 5, 2010

Security and privacy

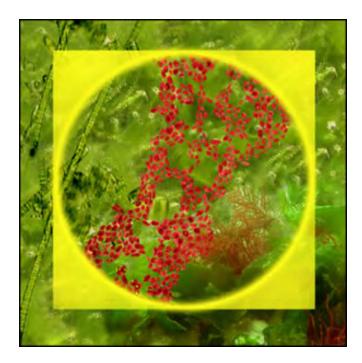


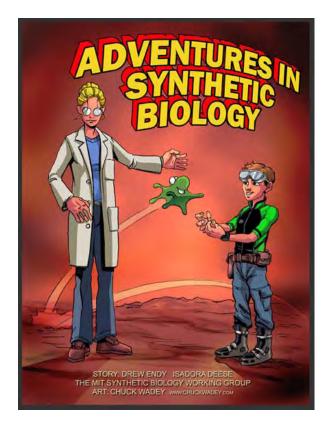
[Yoshi Kohno, UW]

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.

VIDEO HIGHLIGHT>>

42

Big Rig Myths And See the Full Video Collection Now.

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

WEDNESDAYS AT 9PM An electric eel skin wallet can demagnetize credit

2 11

MYTHBUSTERS

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 more 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 cience 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 humancomputer systems
- Smart interaction (virtual and augmented reality)





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

