Big Data, Enormous Opportunity

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Computer Science & Engineering
University of Washington

Critical Conversations Lecture Series
University at Buffalo
The State University of New York

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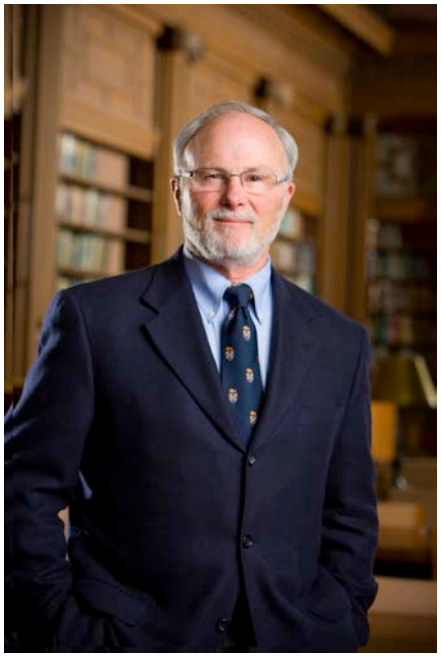
http://lazowska.cs.washington.edu/buffalo.pdf

Dr. John Zahorjan



Former President John Simpson

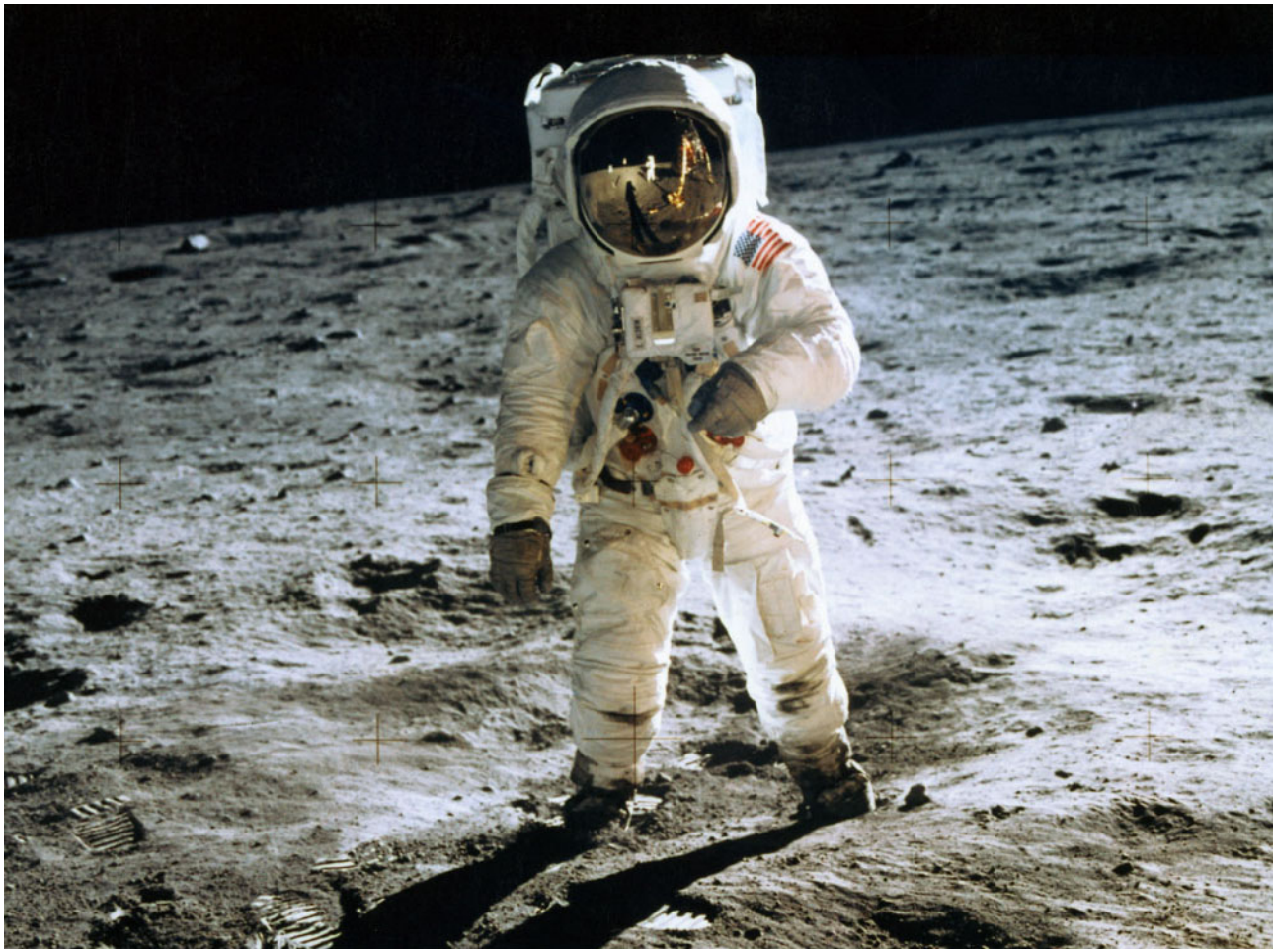
President Satish Tripathi

This afternoon …

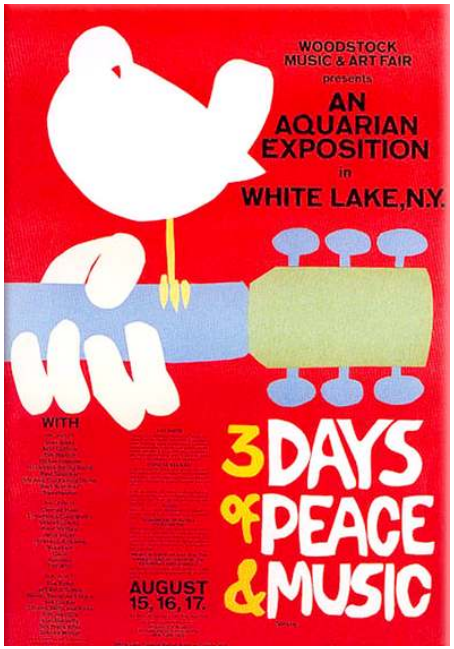
- A reminder of the extraordinary progress that computer science has made
- A preview of the next ten years – advances driven by "big data"
- "Smart discovery" – the application of big data to scholarship
- Implications for computer science, for universities, and for students

Forty years ago …

Credit: Peter Lee, Microsoft Research

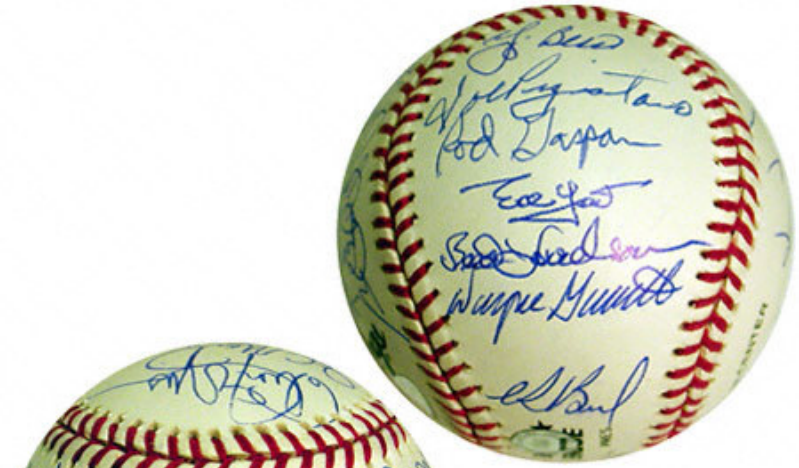


1969


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

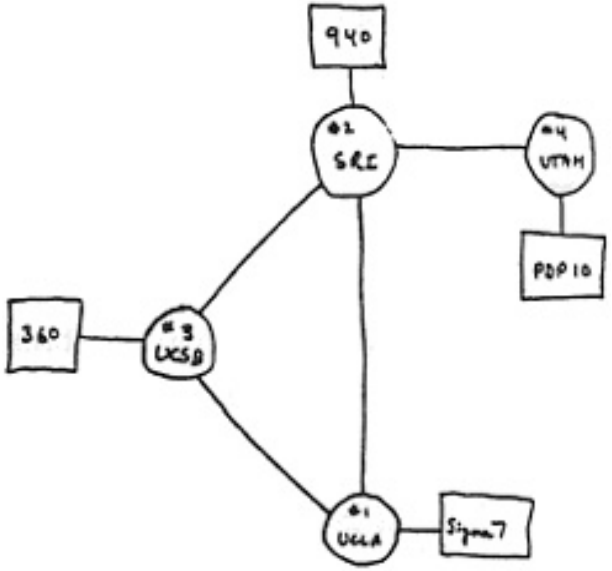
1969


1969 WORLD SERIES
NEW YORK METS




WORLD
NEW YORK METS
CHAMPIONS
1969


1969



THE ARPA NETWORK
DEC 1969
4 NODES

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

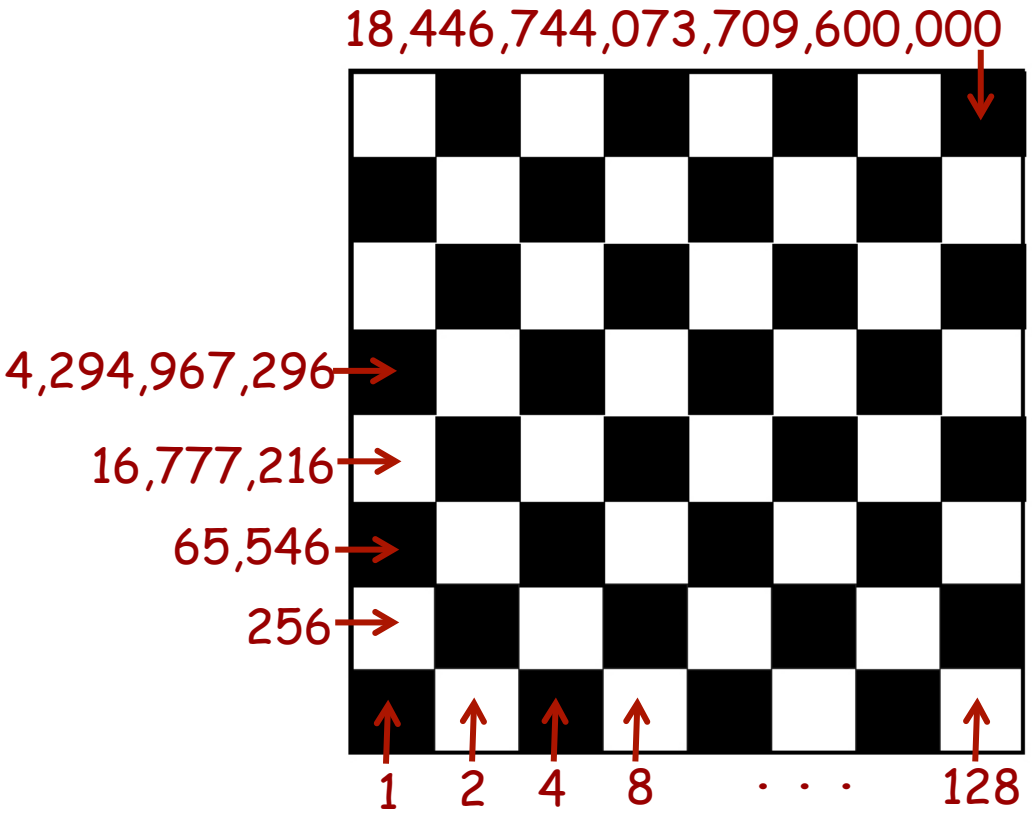
With forty years hindsight, which had the greatest impact?

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

- And so is the reason …

EXPONENTIALS 'R' US

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



Every aspect of computing has experienced exponential improvement

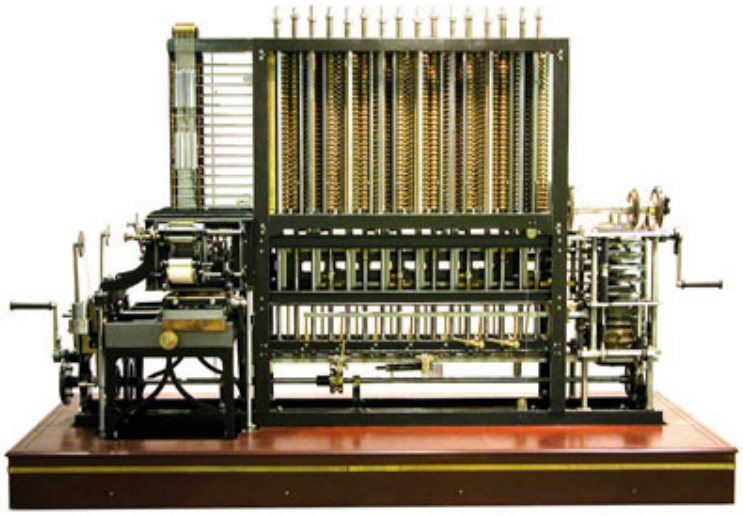
- Processing capacity
- Storage capacity
- Network bandwidth
- Sensors
- (Astonishingly, even algorithms in some cases!)

You can exploit these improvements in two ways

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

EXPONENTIALS R US

- Mechanical



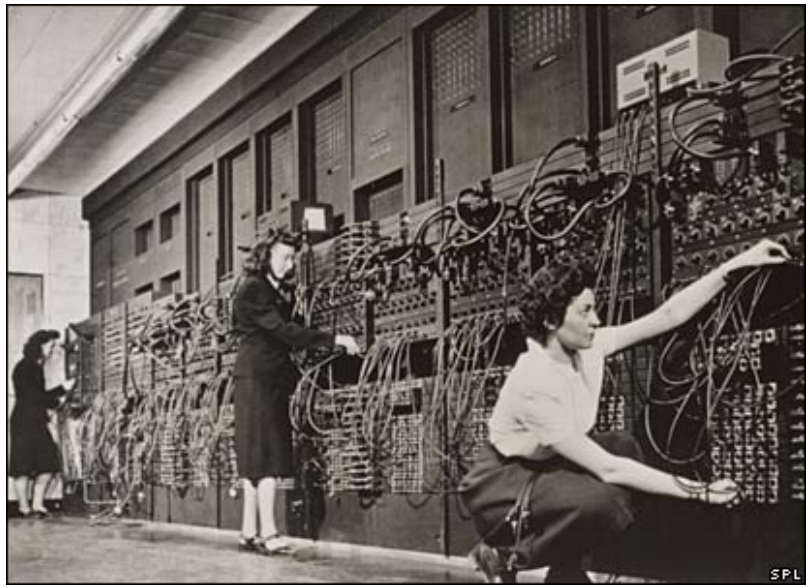
Babbage's Difference Engine No. 2
(designed 1847-1849,
constructed 1989-2000)
[11'x7', 8000 parts, 5 tons]

Vannevar Bush's Differential Analyzer (1931)

- Vacuum tube electronic

ENIAC (constructed 1943-1946)

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

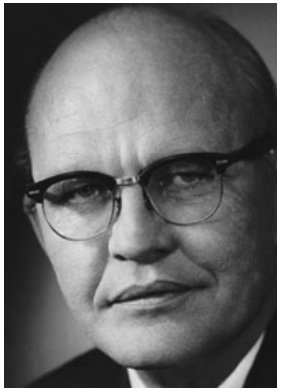


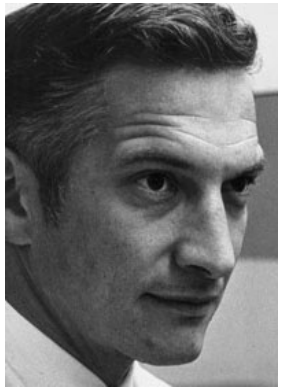
The transistor (1947)

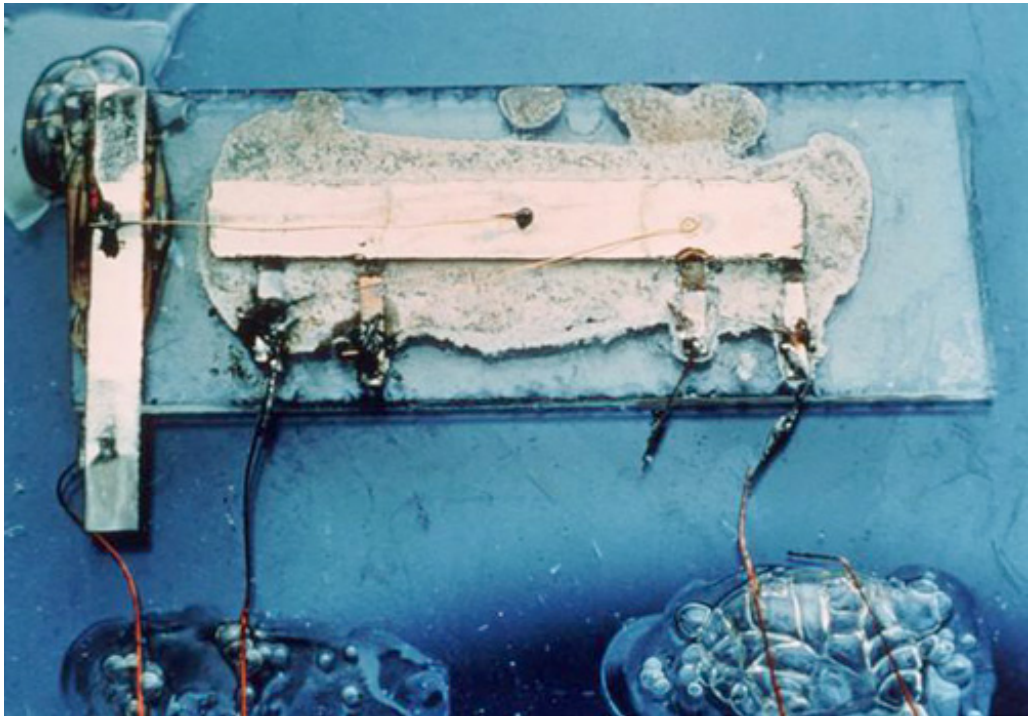
- William Shockley, Walter Brattain and John Bardeen, Bell Labs

The integrated circuit (1958)

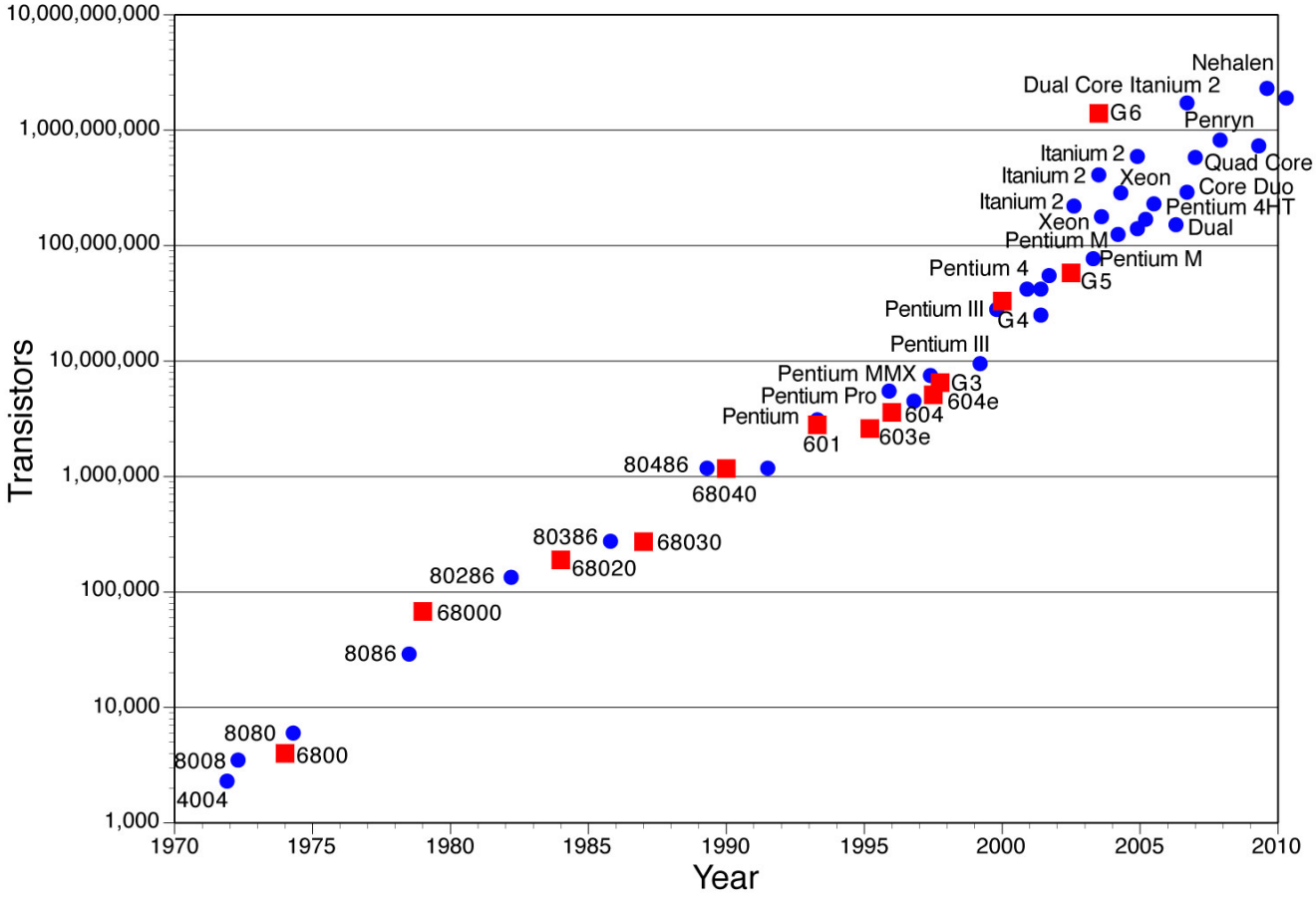
- Jack Kilby, Texas Instruments, and Bob Noyce, Fairchild Semiconductor Corporation





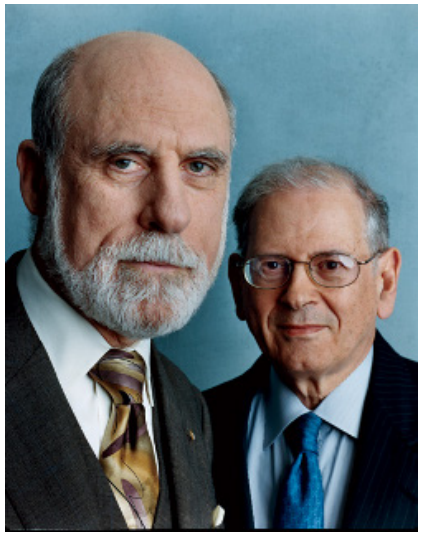


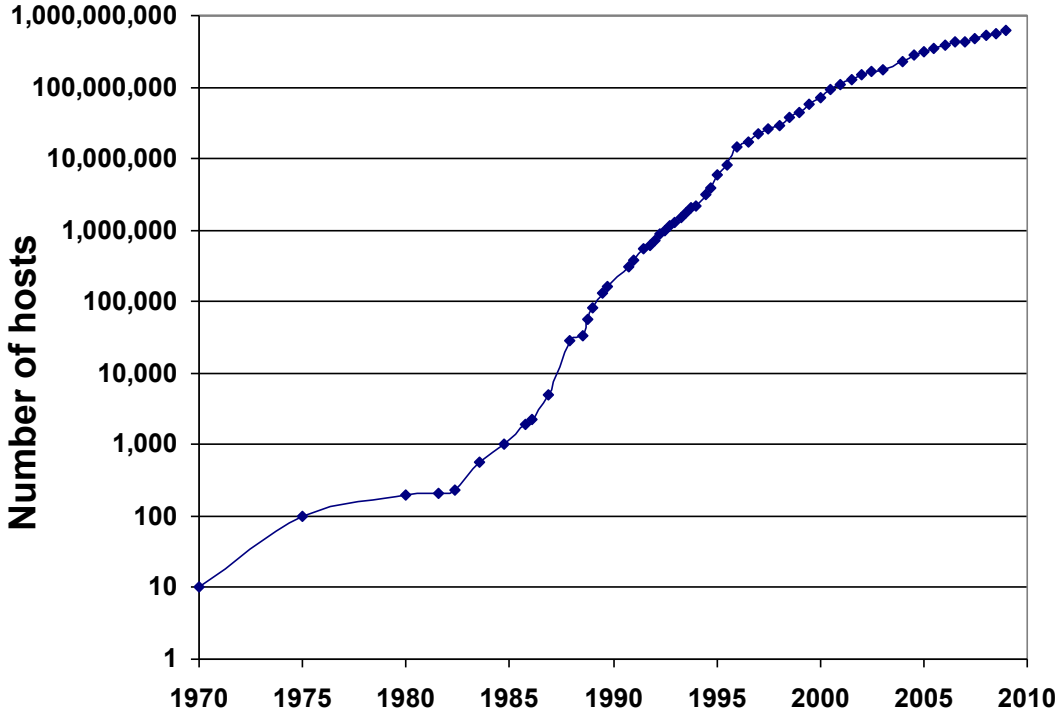
Moore's Law and exponential progress (1965-today)




UNIVAC

Ditto the Internet

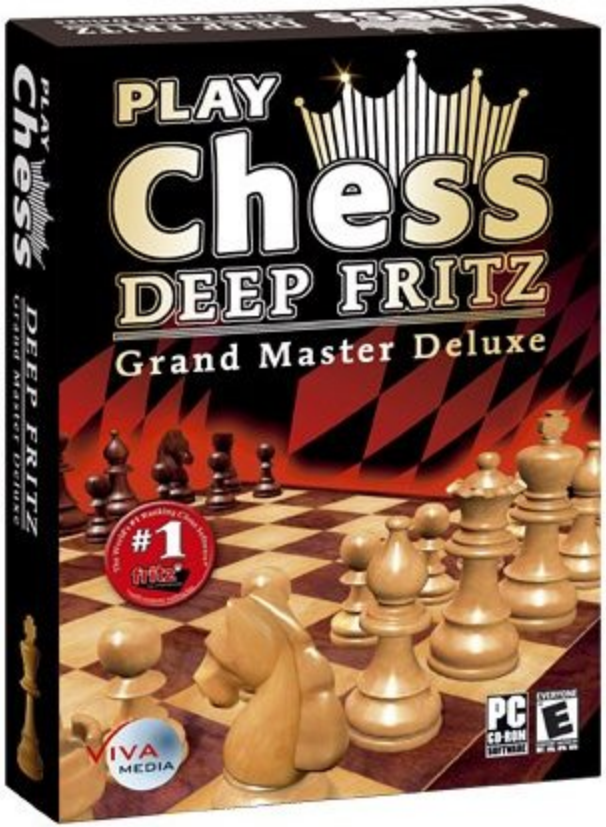




In the past 20 years (1993-2013), the number of Internet hosts and the number of transistors on a die each have increased 2000x!

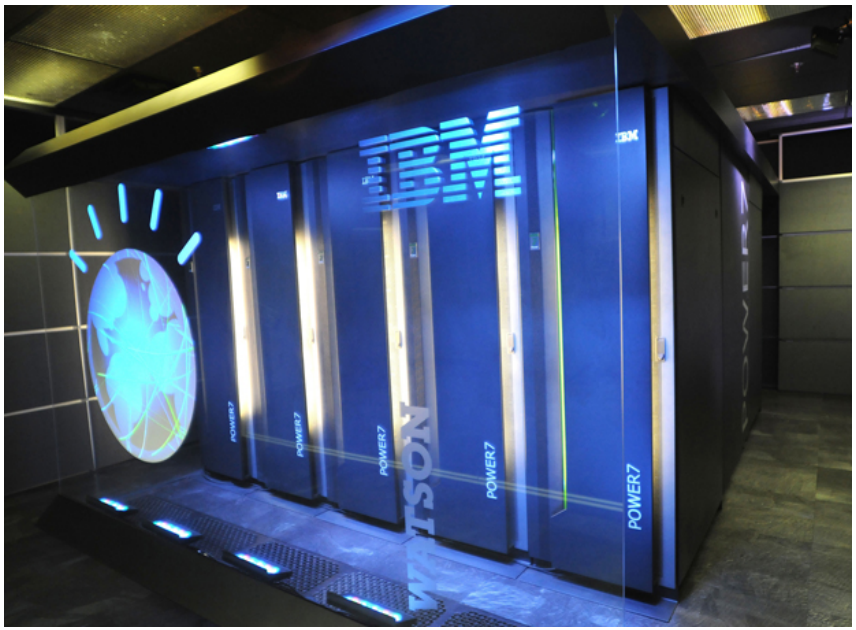
- Ditto software (algorithms) in many cases

Deep Blue, 1997



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

Deep Fritz, 2002



Watson, 2011

Ken Jennings, Watson, Brad Rutter

The most recent ten years …

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

Xconomy
Business + Technology in the Exponential Economy

What Happens in an **Internet Minute?**

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

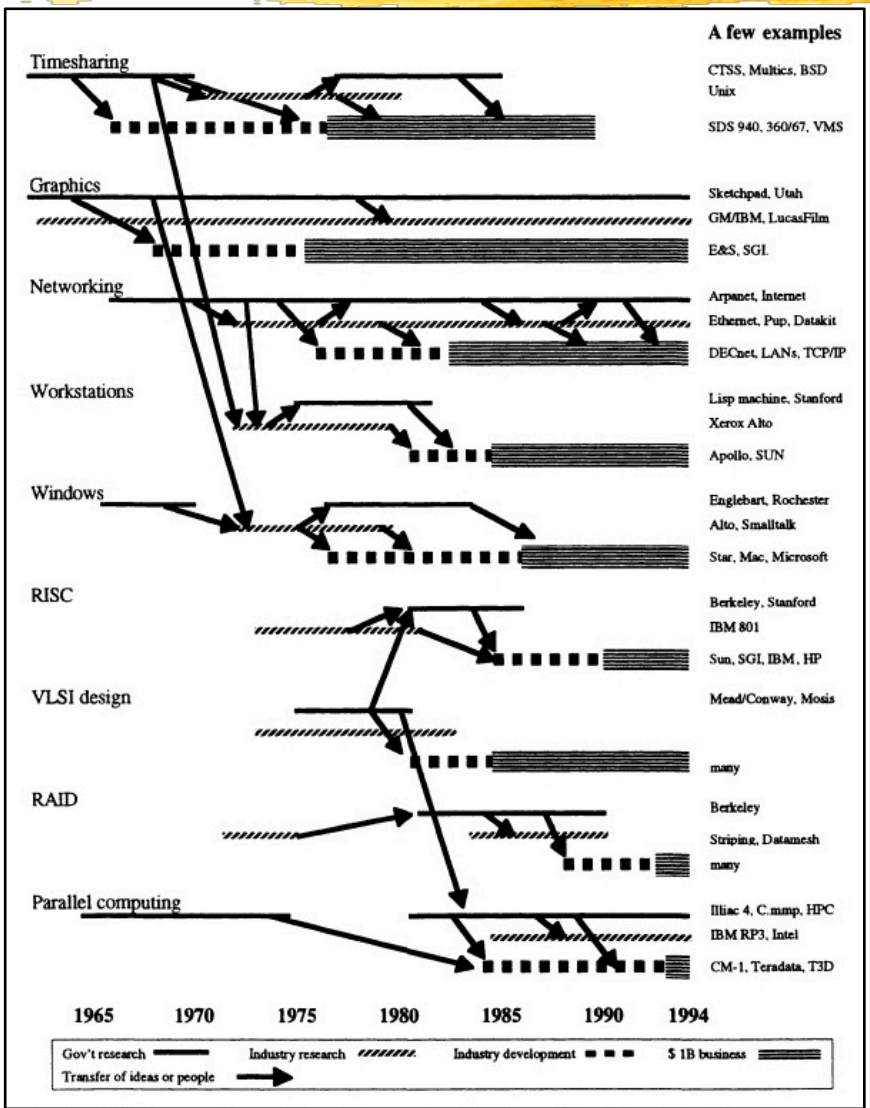
Today, the number of networked devices = the global population

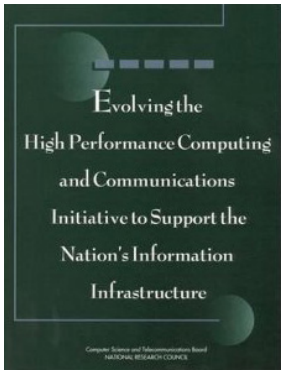
By **2015**, the number of networked devices = 2x the global population

In **2015**, it would take you **5 years** to view all video crossing IP networks each **second**

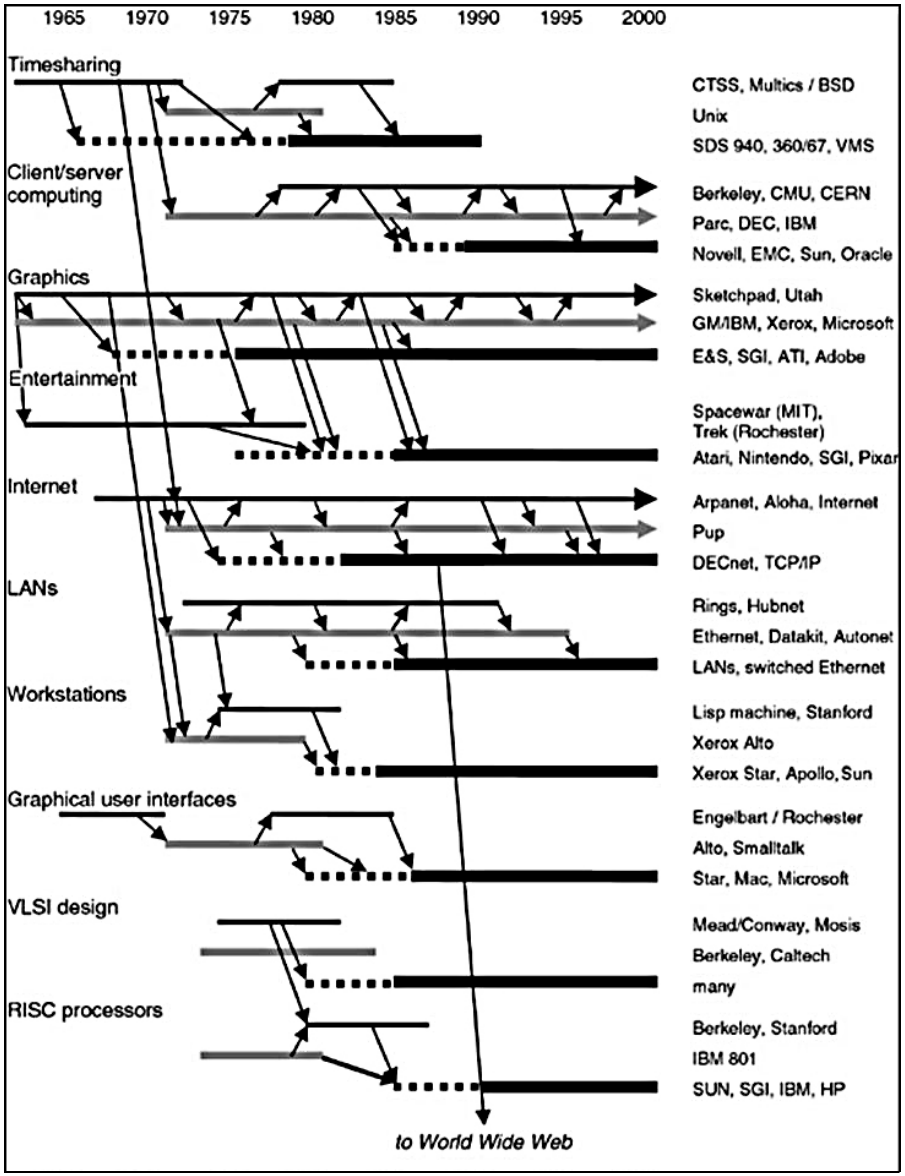
Credit: Intel Corporation

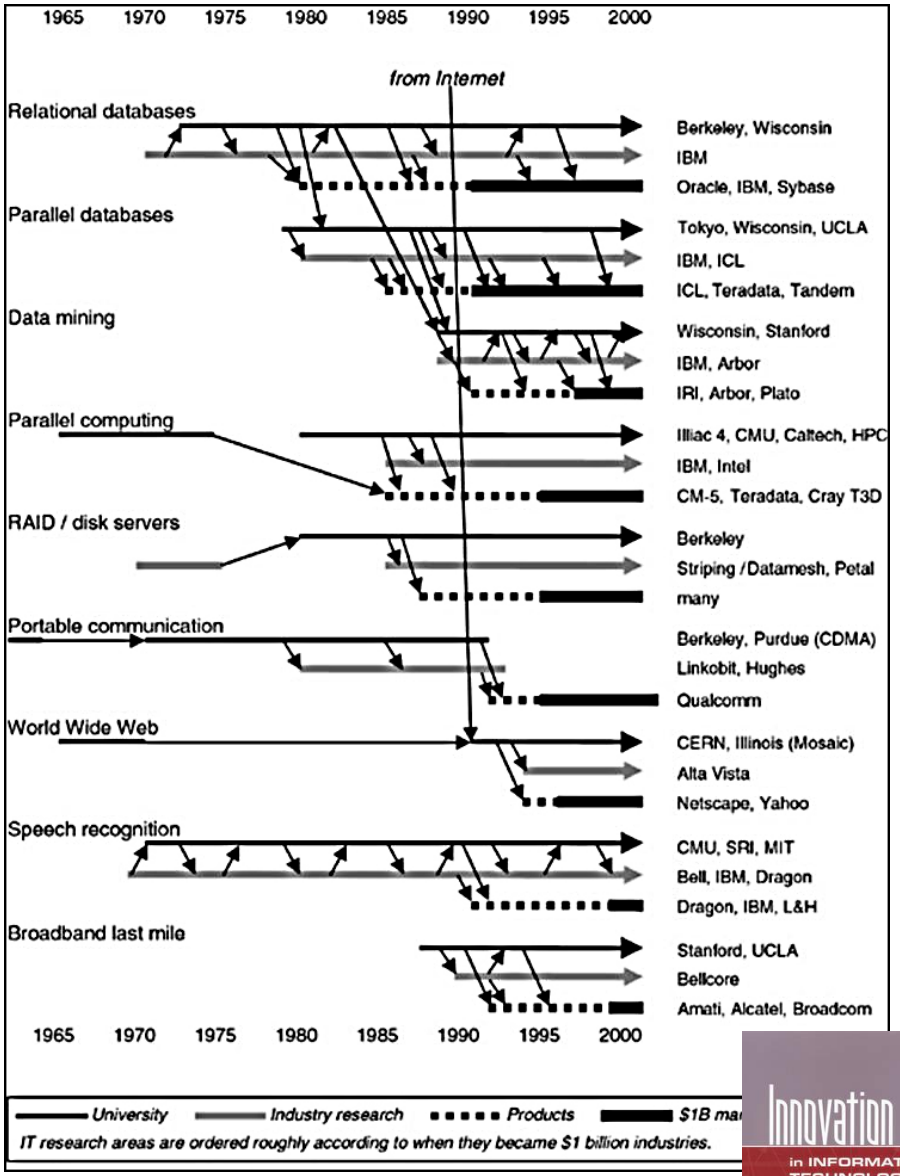
How did all this come to pass?





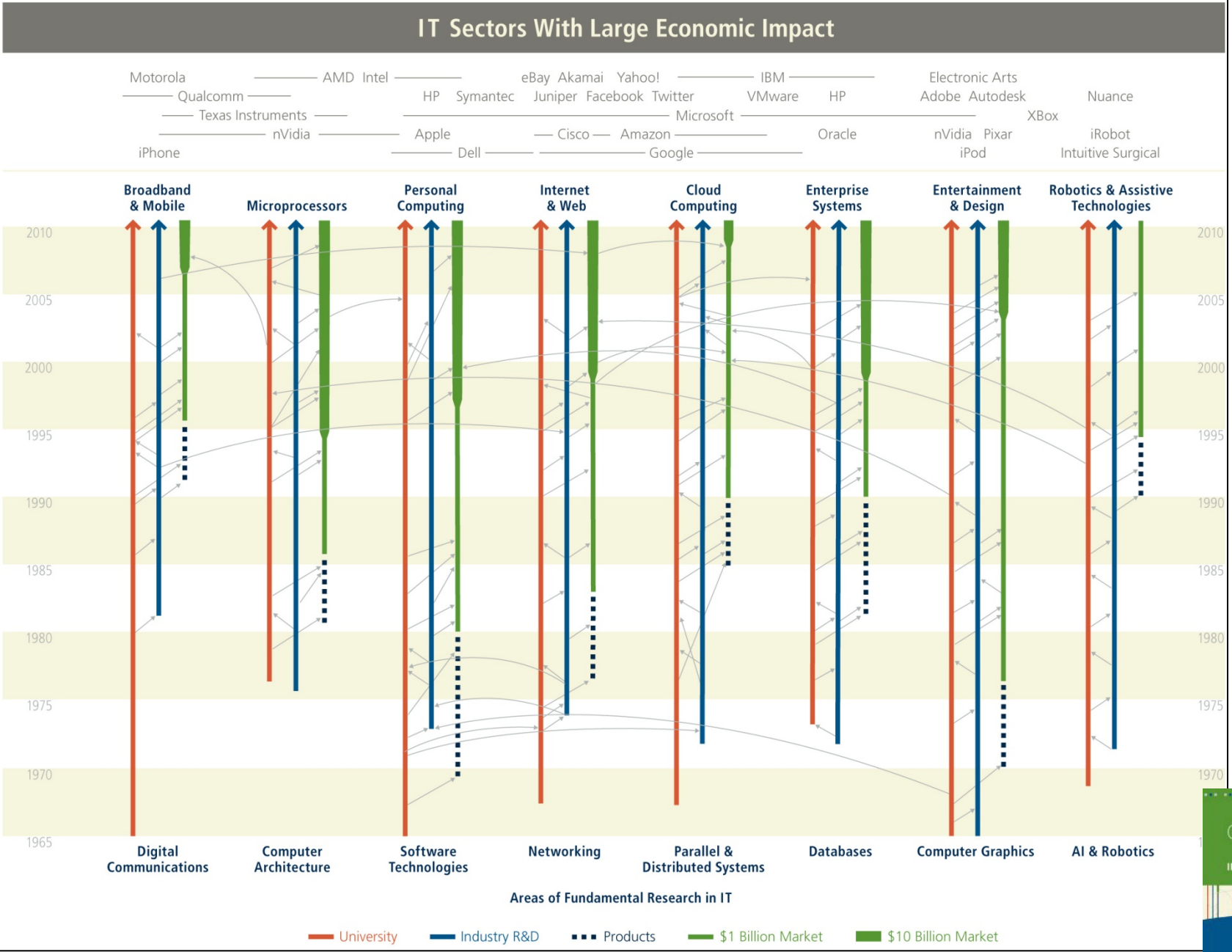
1995


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


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


Innovation
in INFORMATION TECHNOLOGY
NATIONAL RESEARCH COUNCIL

2003


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


Continuing
Innovation
IN INFORMATION TECHNOLOGY

2012

Lessons

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

The next ten years …

Exponential improvements in technology and algorithms are enabling the "big data" revolution

- A proliferation of sensors
  - Think about the sensors on your phone
- More generally, the creation of almost all information in digital form
  - It doesn't need to be transcribed in order to be processed
- Dramatic cost reductions in storage
  - You can afford to keep all the data
- Dramatic increases in network bandwidth
  - You can move the data to where it's needed

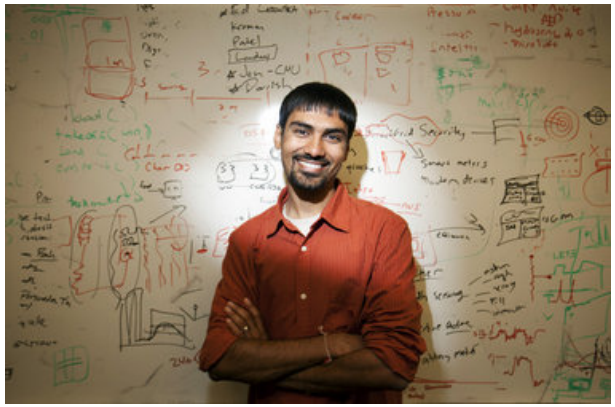
- Dramatic cost reductions and scalability improvements in computation
  - With Amazon Web Services, or Google App Engine, or Microsoft Azure, 1000 computers for 1 day costs the same as 1 computer for 1000 days
- Dramatic algorithmic breakthroughs
  - Machine learning, data mining – fundamental advances in computer science and statistics

"Big data" will allow us to put the "smarts" into everything …

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

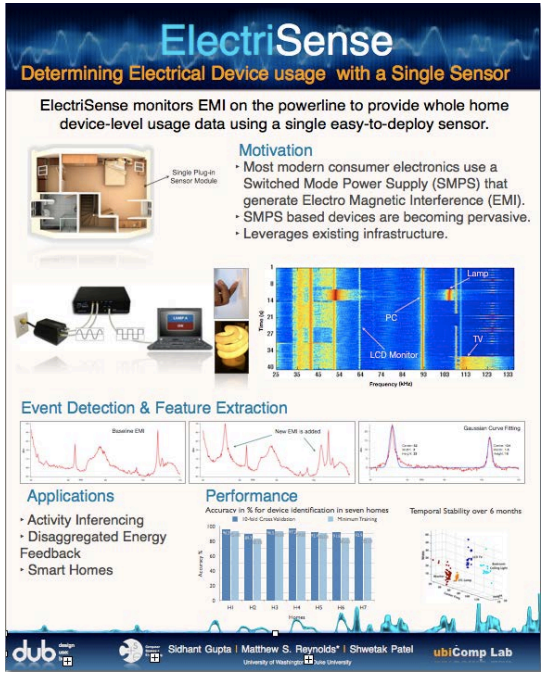
xconomy
Business + Technology in the Exponential Economy

Smart homes



Shwetak Patel,
University of Washington
2011 MacArthur Fellow

MACARTHUR
The John D. and Catherine T. MacArthur Foundation



belkin echo

Smart cars

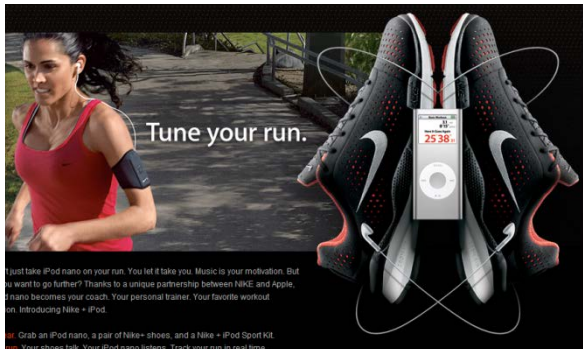
DARPA Grand Challenge

DARPA Urban Challenge

Google Self-Driving Car

Smart health: The "quantified self"

Omron pedometer



Nike + iPod

Bodymedia multi-function

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

Glucowatch: measuring body chemistry

Larry Smarr – "quantified self"

Smart health: Evidence-based medicine

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

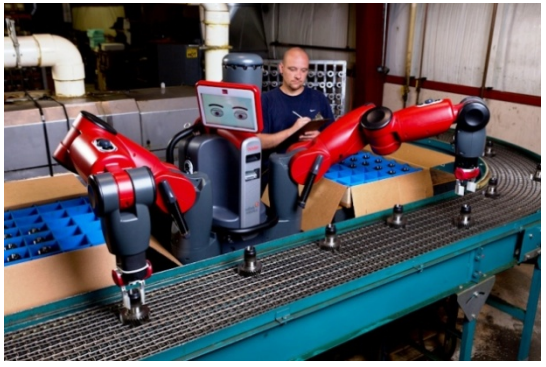
Smart health: P4 medicine

INSTITUTE FOR Systems Biology

Smart robots

iRobot®

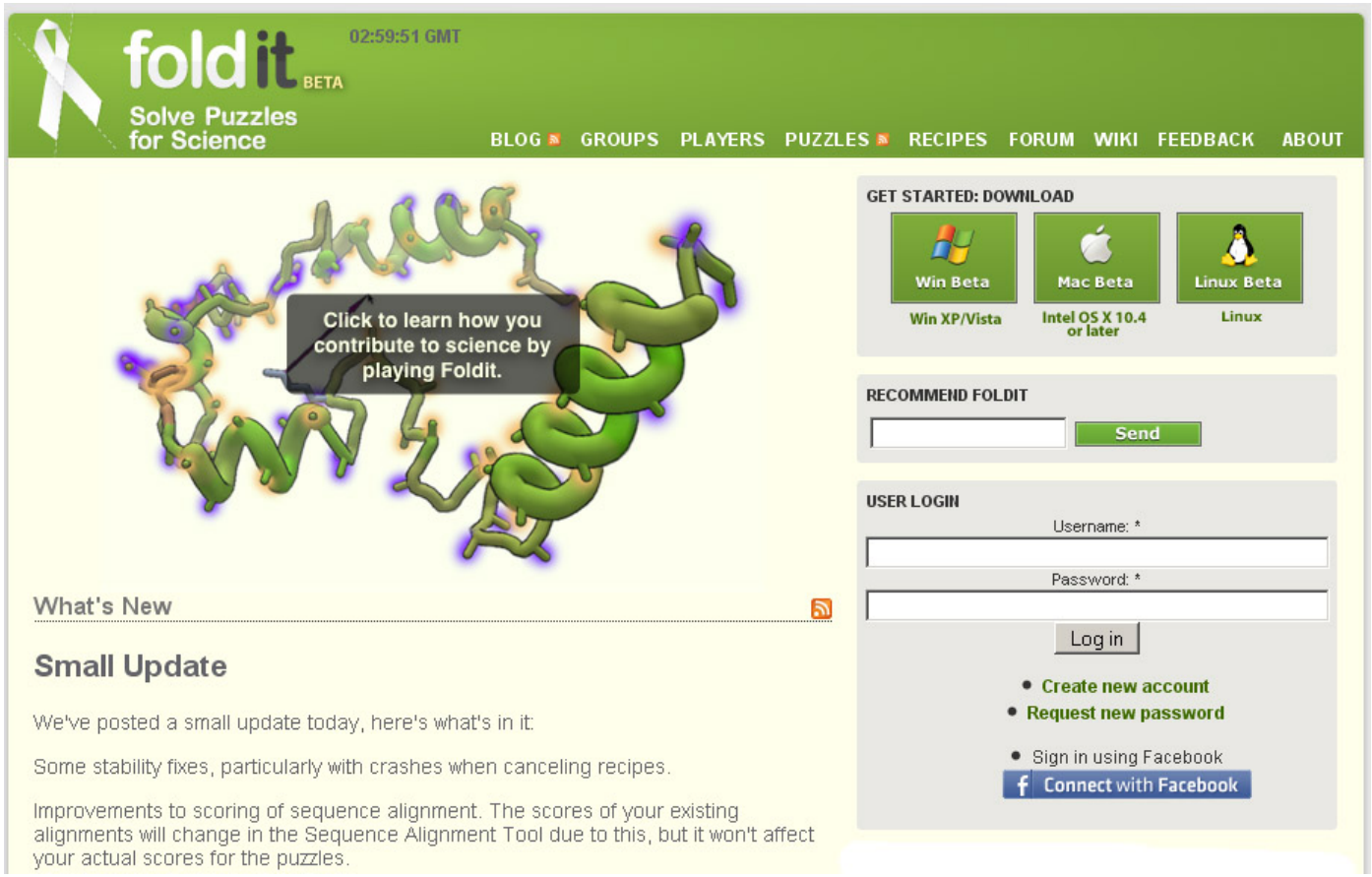
rethink robotics



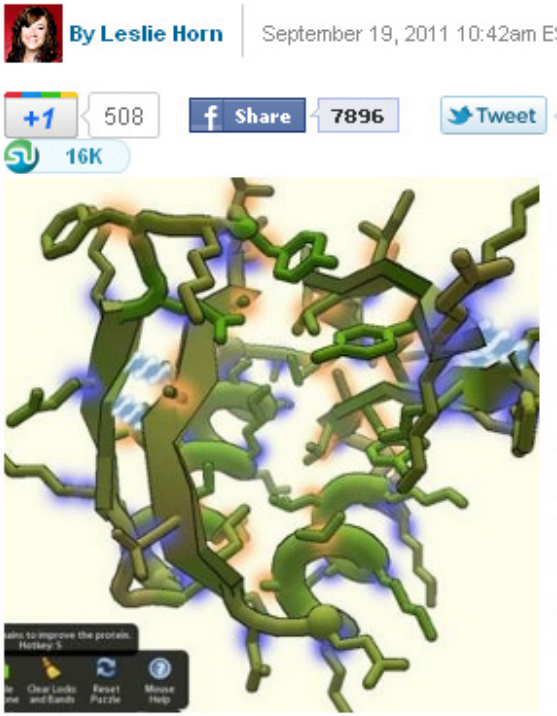
Smart crowds and human-computer systems

David Baker,
UW Biochemistry

Zoran Popovic,
UW Computer Science & Engineering



Gamers Unlock Protein Mystery That Baffled AIDS Researchers For Years



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

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

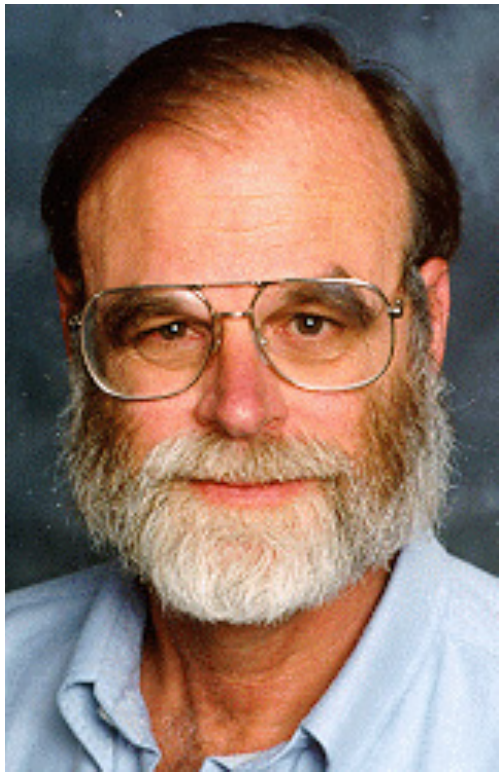
"Following the failure of a wide range of attempts to solve the crystal structure of M-PMV retroviral protease by molecular replacement, we challenged players of the protein folding game Foldit to produce accurate models of the protein," the study reads. "Remarkably, Foldit players were able to generate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

Smart interaction

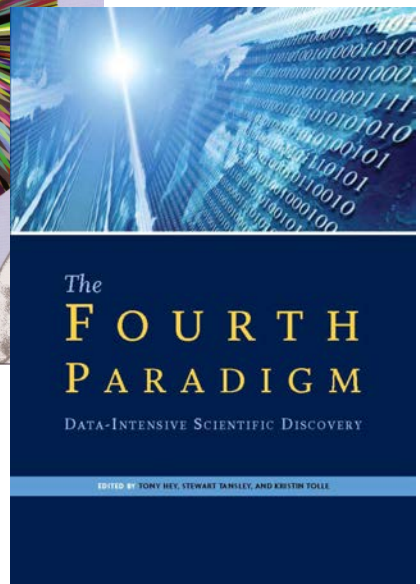
KINECT™
for XBOX 360

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

Smart (data-intensive) discovery: *eScience*



Jim Gray,
Microsoft Research



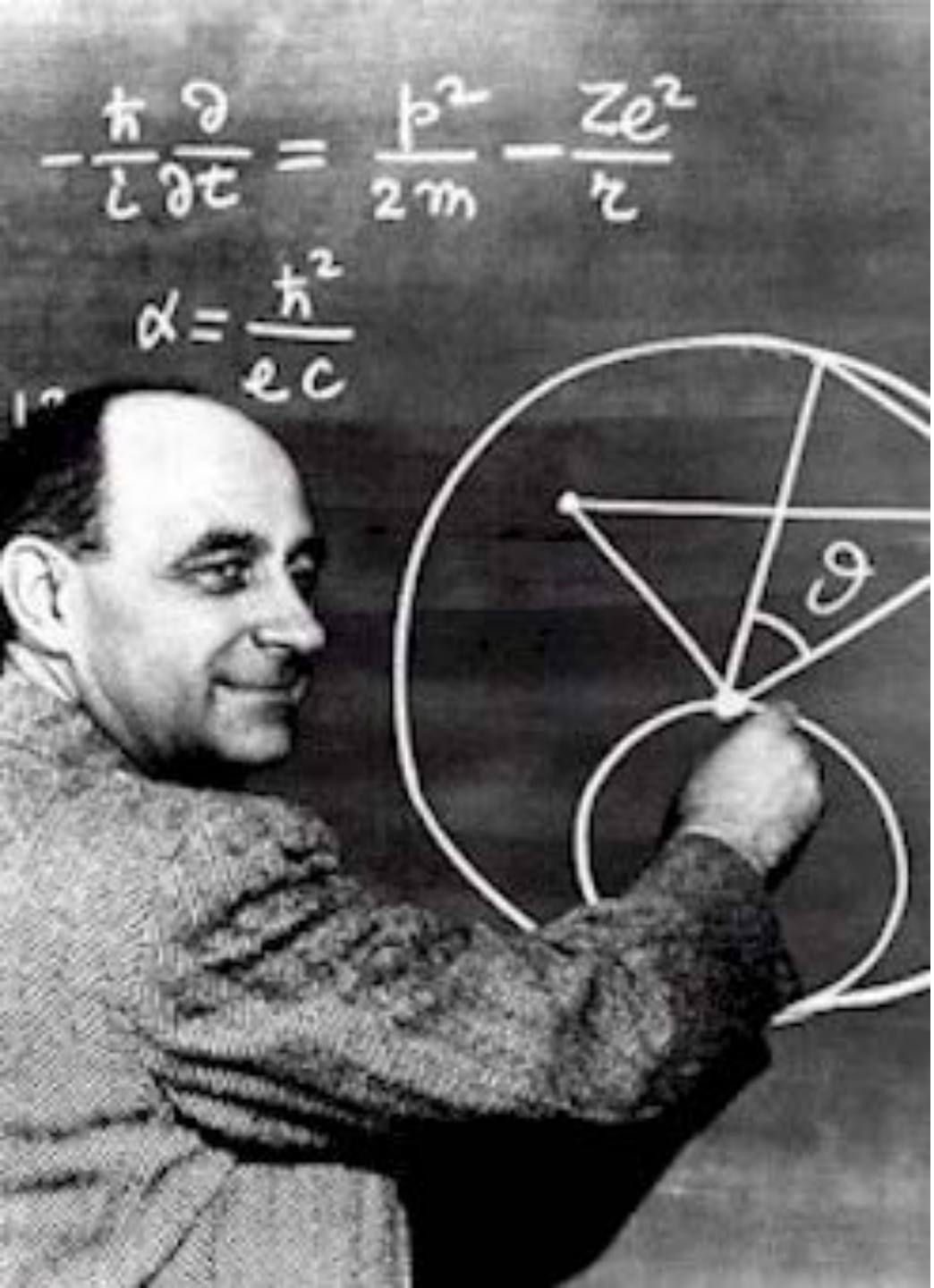
Transforming science (again!)

Credit: John Delaney, University of Washington

Observation

Experiment

Theory

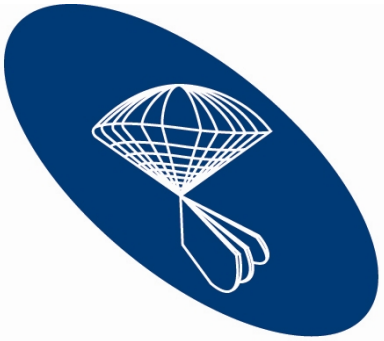


Observation

Experiment

Theory

Observation
Experiment
Theory
Computational Science



SLOAN DIGITAL SKY SURVEY

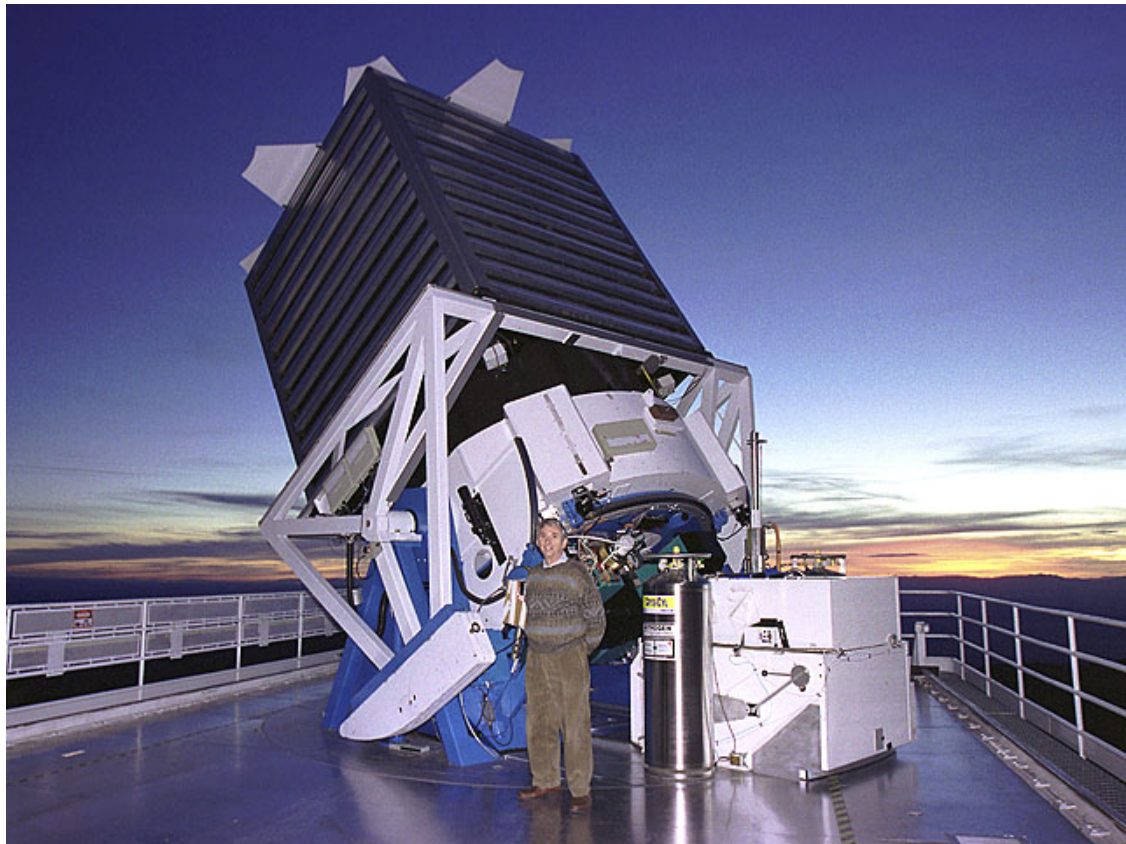
Observation
Experiment
Theory
Computational Science
eScience

eScience is driven by *data* more than by cycles

- Massive volumes of data from sensors and networks of sensors

Apache Point telescope, SDSS

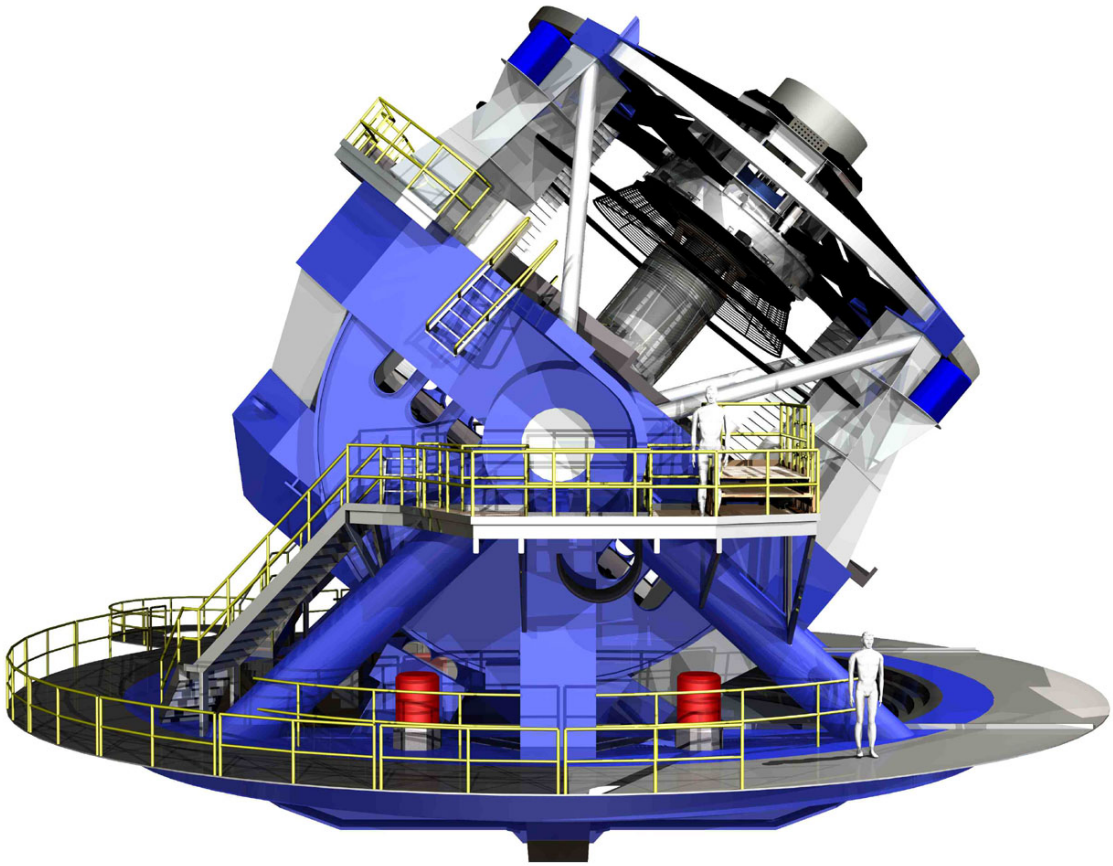
80TB of raw image data (80,000,000,000,000 bytes) over a 7 year period



Large Synoptic Survey Telescope (LSST)

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

400mbps sustained data rate between Chile and NCSA



Large Hadron Collider

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

Illumina HiSeq 2000 Sequencer

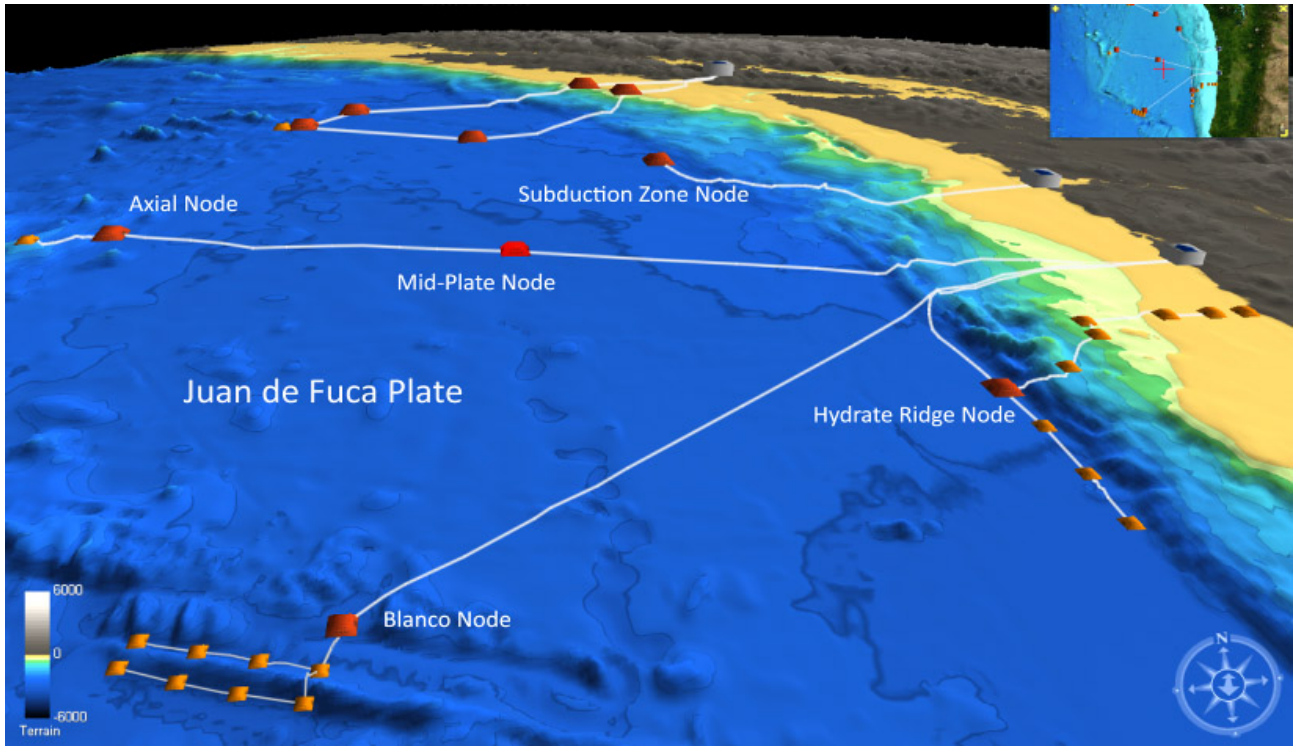
~1TB/day

Major labs have 25-100 of these machines

OCEAN OBSERVATORIES INITIATIVE

Regional Scale Nodes of the NSF Ocean Observatories Initiative

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

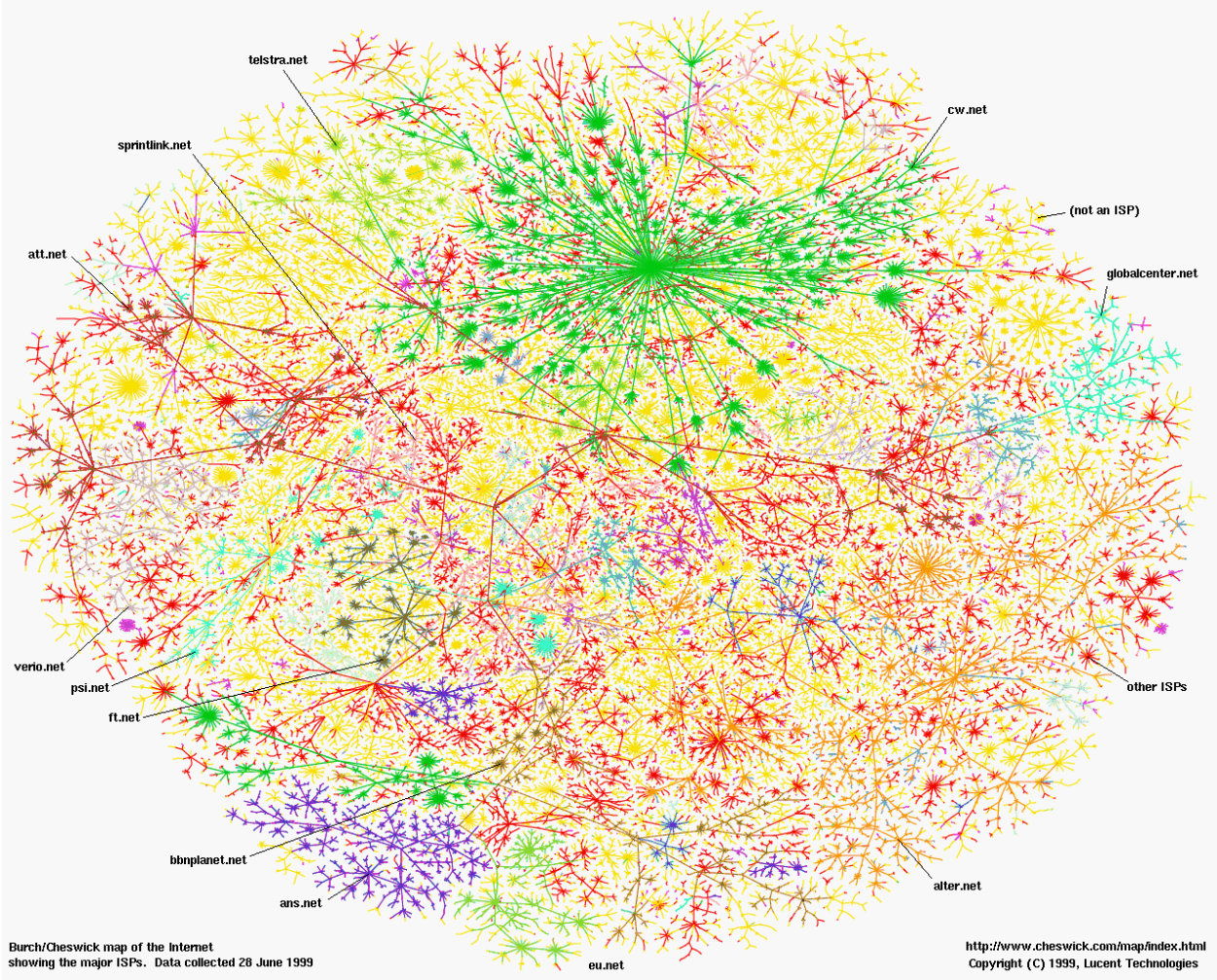


The Web

~1.2B Facebook users

~~750M websites

~~~200B web pages



Point-of-sale terminals

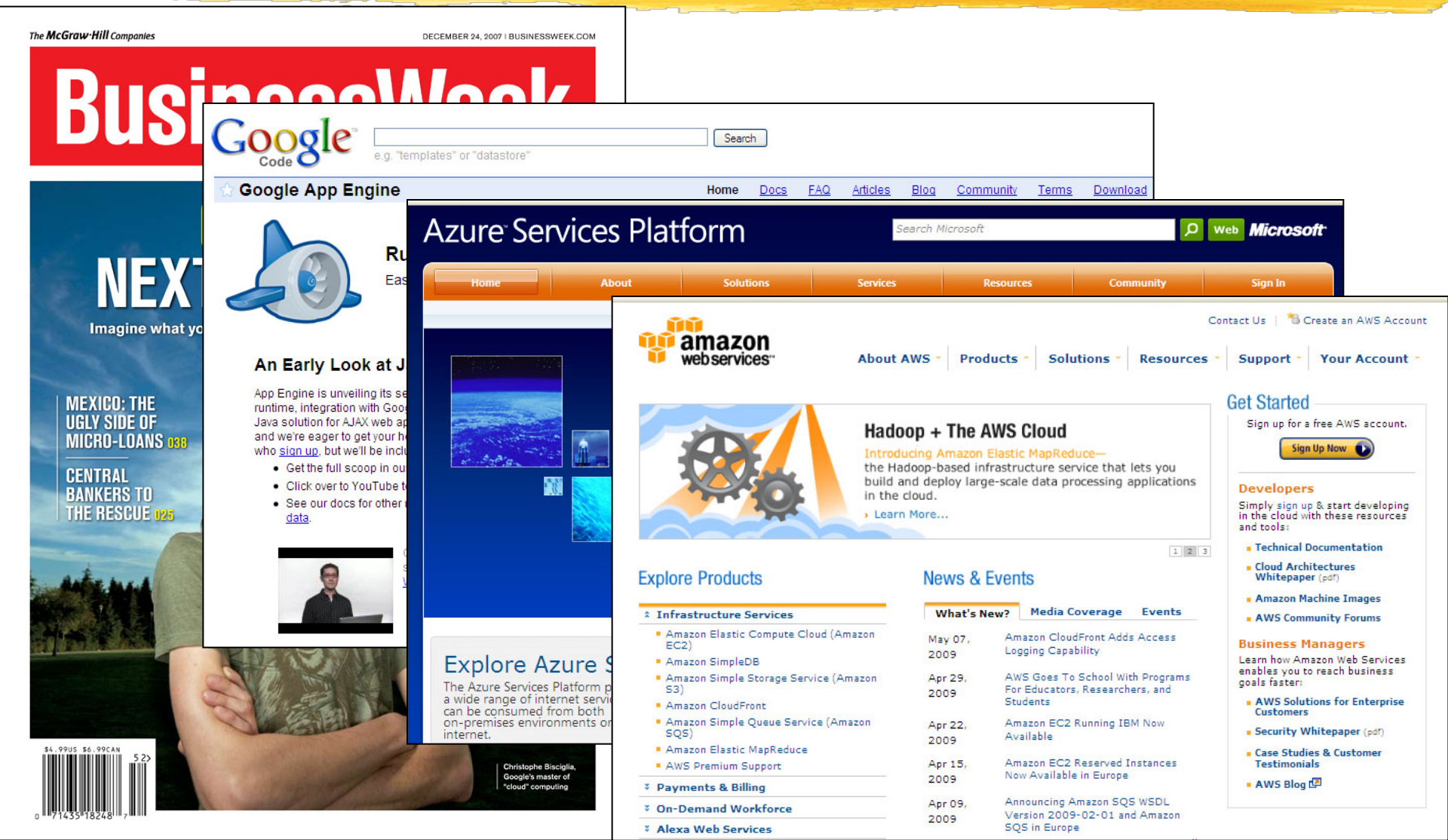
eScience is about the *analysis* of data

- 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 – it's "the 3 V's":
  - Volume
  - Velocity (rate)
  - Variety (dimensionality / complexity)

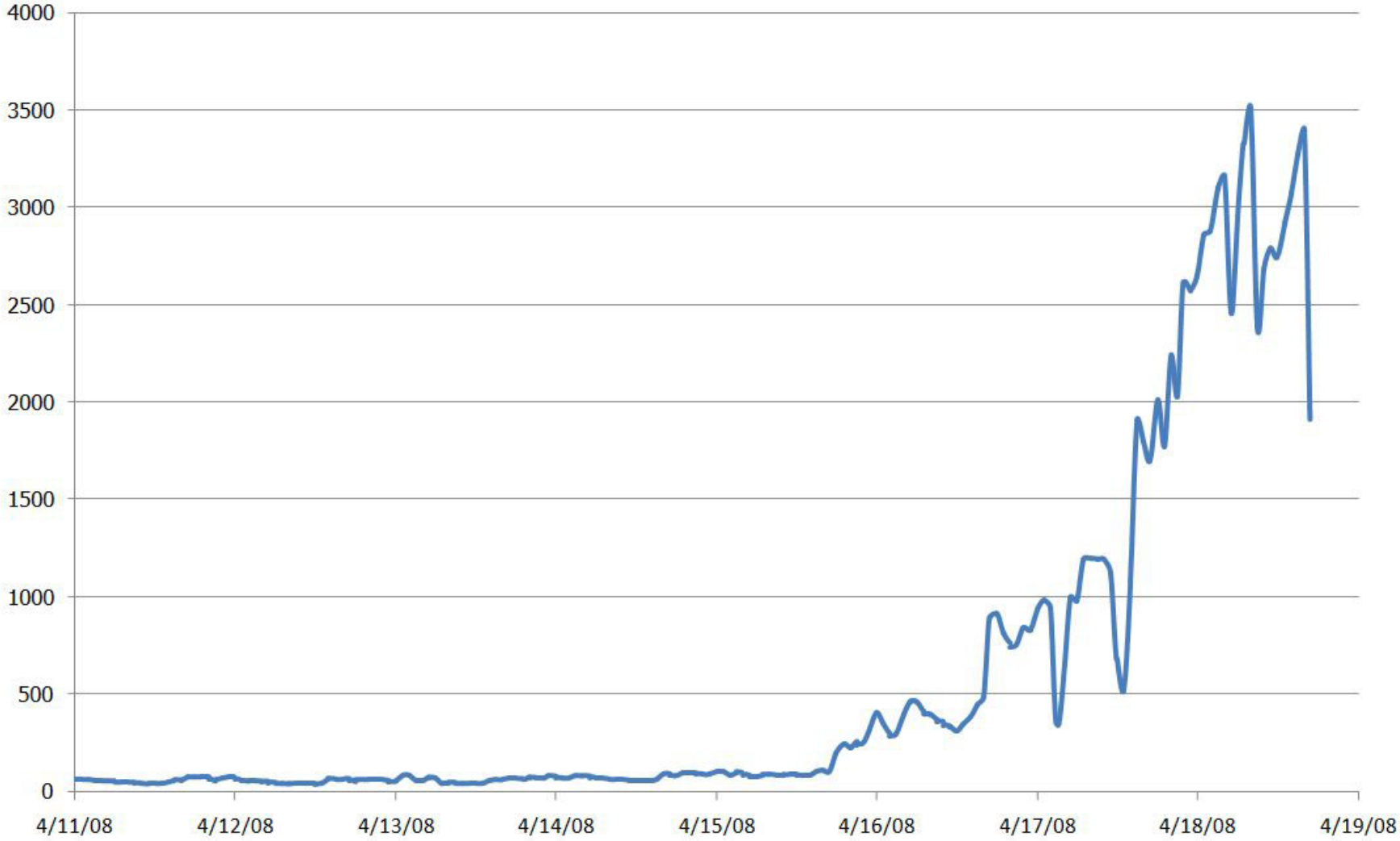
eScience utilizes a spectrum of computer science techniques and technologies

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

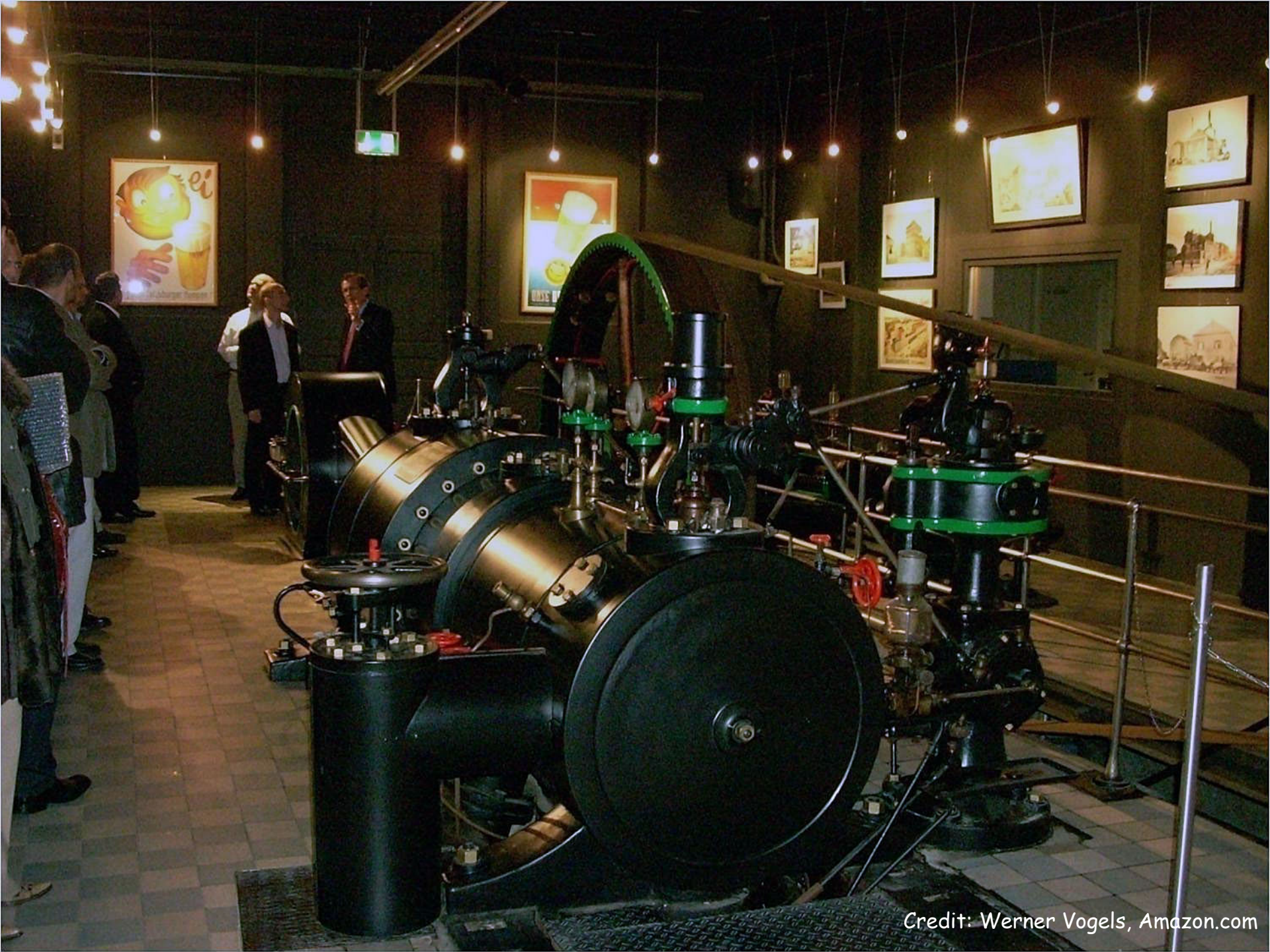
eScience is married to the cloud: Scalable computing and storage for everyone



Animoto: EC2 Instance Usage



Credit: Werner Vogels, Amazon.com

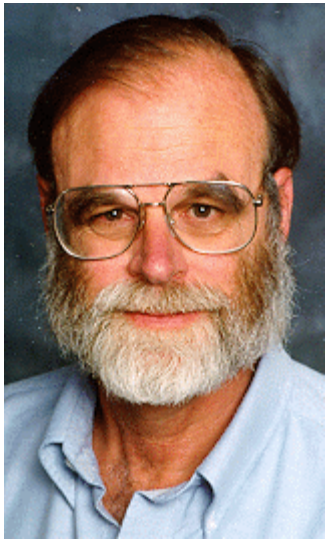


Credit: Werner Vogels, Amazon.com

eScience will be pervasive

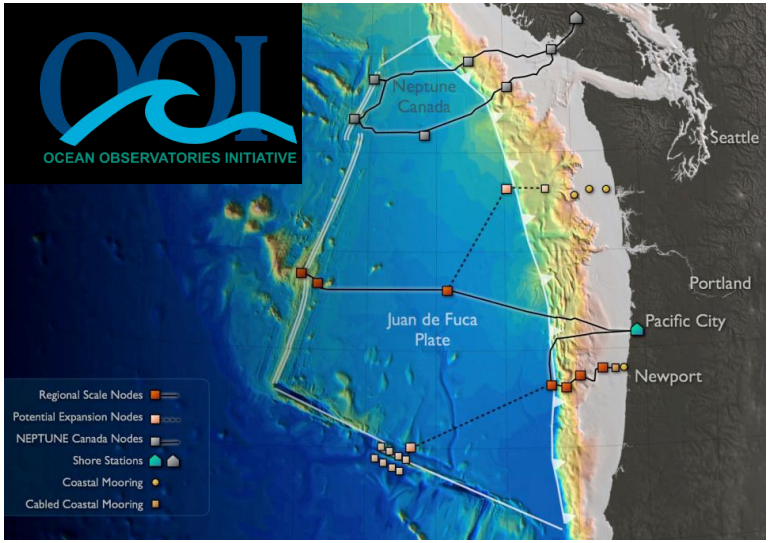
- Simulation-oriented computational science has been transformational, but it has been a niche
  - As an institution (e.g., a university), you didn't need to excel in order to be competitive
- eScience capabilities must be broadly available in any institution
  - If not, the institution will simply cease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

My personal story, and the story of the UW eScience Institute

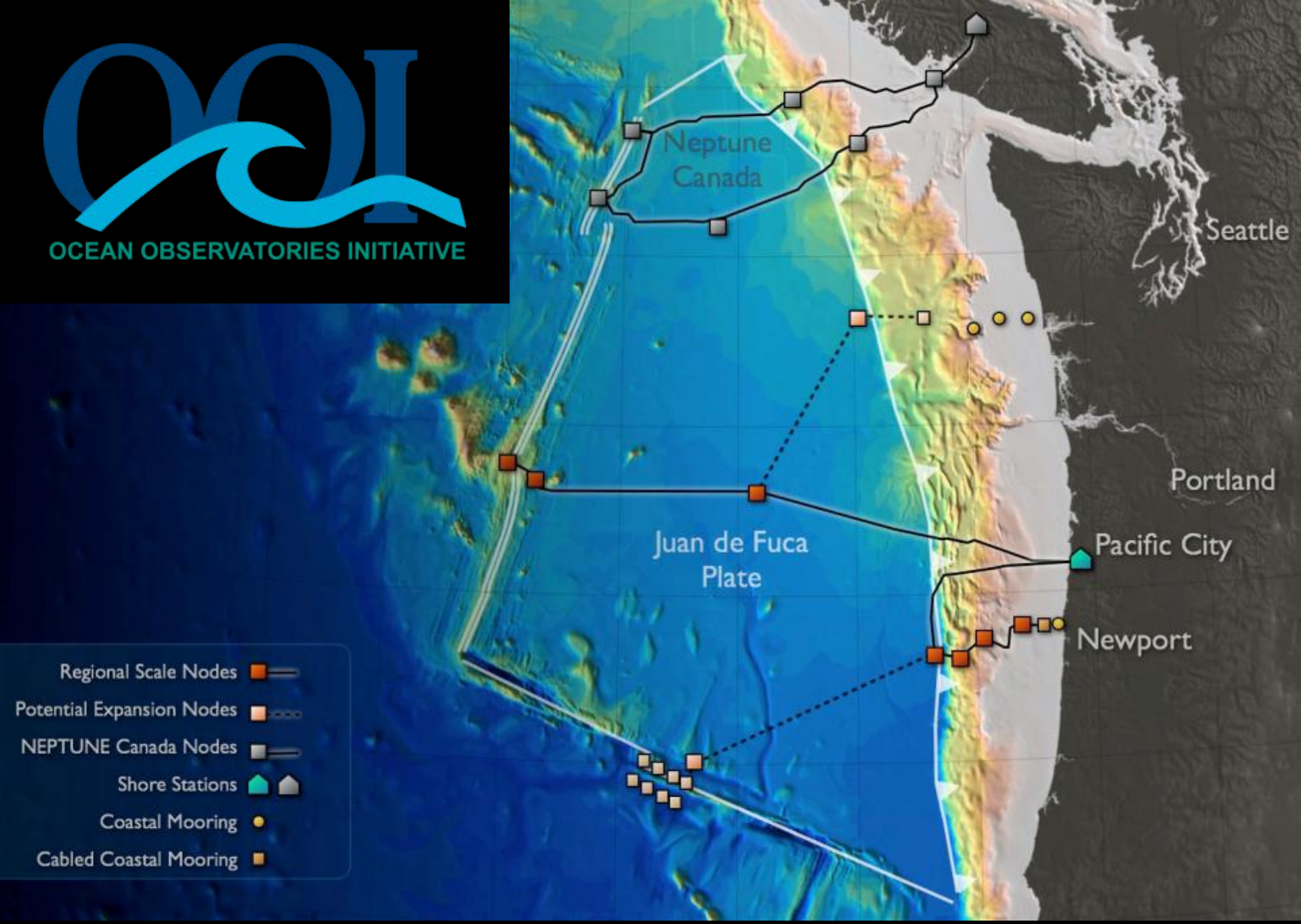


Early 1980s

Late 1990s



Credit: John Delaney, University of Washington



Credit: John Delaney, University of Washington

Mark Emmert

LSU

2004

UNIVERSITY OF WASHINGTON 1861 LVX SIT

Ed Lazowska
Computer Science & Engineering

Tom Daniel
Biology

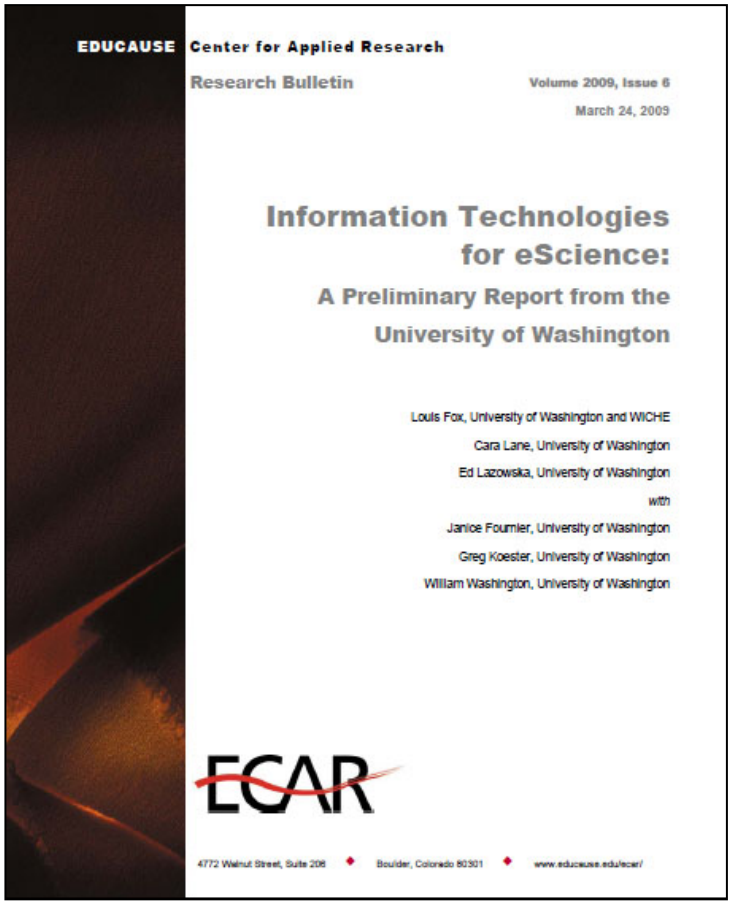
Werner Stuetzle
Statistics

UW eScience Institute

- *"All across our campus, the process of discovery will increasingly rely on researchers' ability to extract knowledge from vast amounts of data... In order to remain at the forefront, UW must be a leader in advancing these techniques and technologies, and in making [them] accessible to researchers in the broadest imaginable range of fields."*
- In other words:
  - Data-driven discovery will be ubiquitous
  - We must be a leader in inventing the capabilities
  - We must be a leader in translational activities – in putting these capabilities to work
  - It's about *intellectual infrastructure* (human capital) and *software infrastructure* (shared tools and services – digital capital)

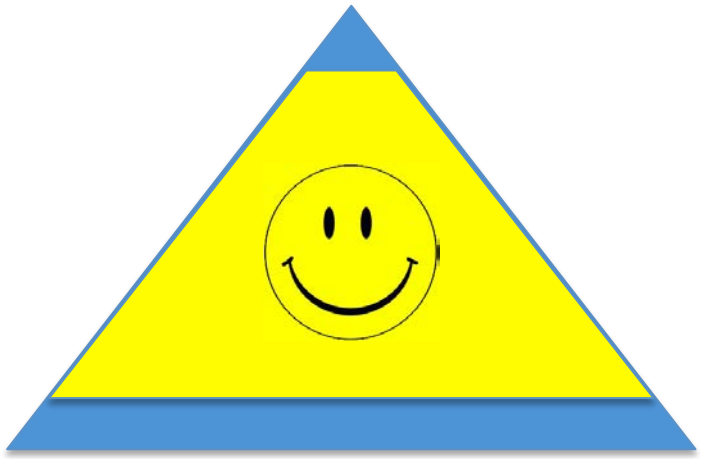
This was not as broadly obvious in 2005 as it is today

- But we asked UW's leading faculty, and they confirmed our intuition!
  - *From the get-go, this has been a bottom-up, needs-based, driven-by-the-scientists effort!*



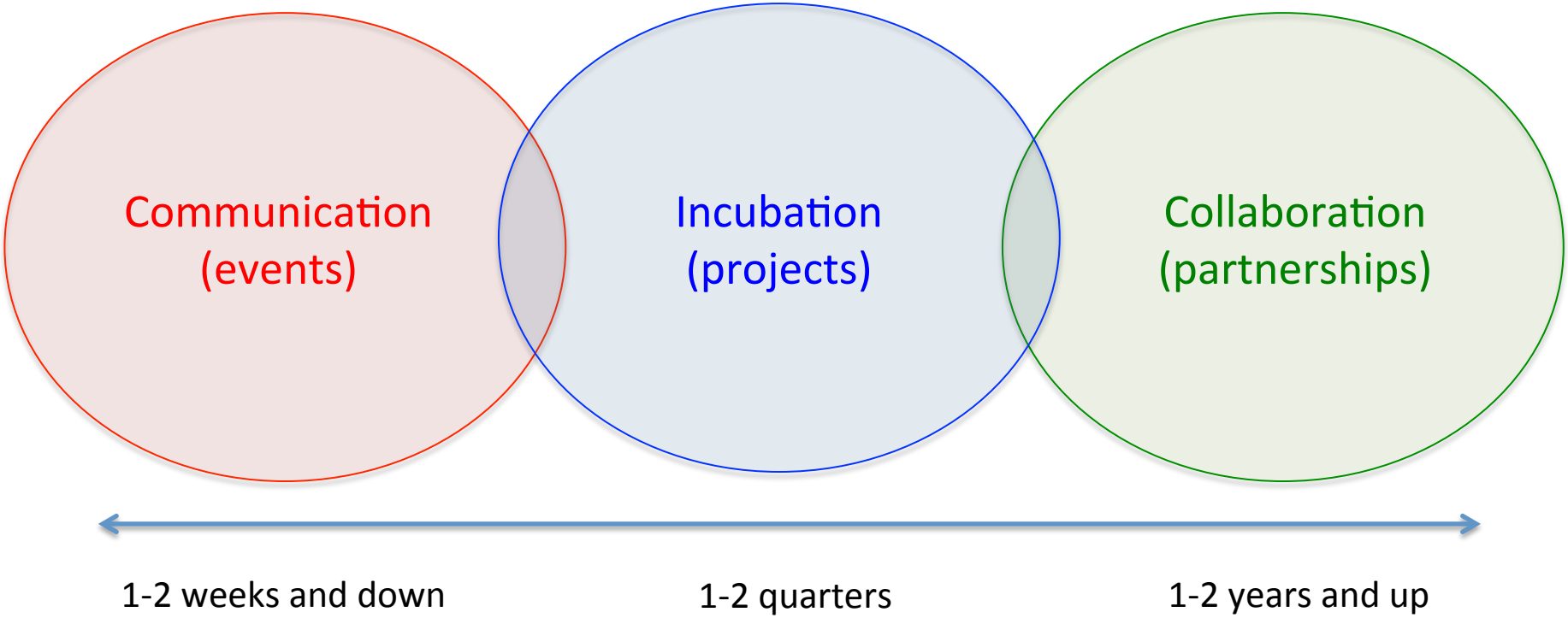
Strategies

- "Long tail"

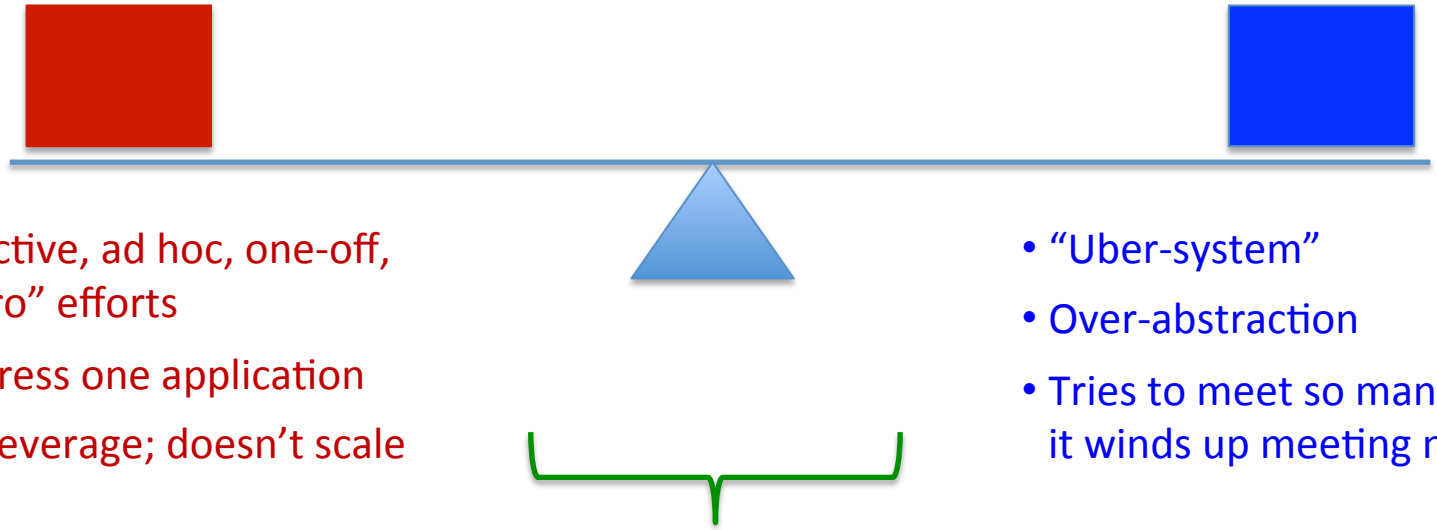


- "Flip the influentials"

- Multiple modes of interaction, multiple time scales



- Focus on tools, but recognize and avoid the common failure modes of cyberinfrastructure projects



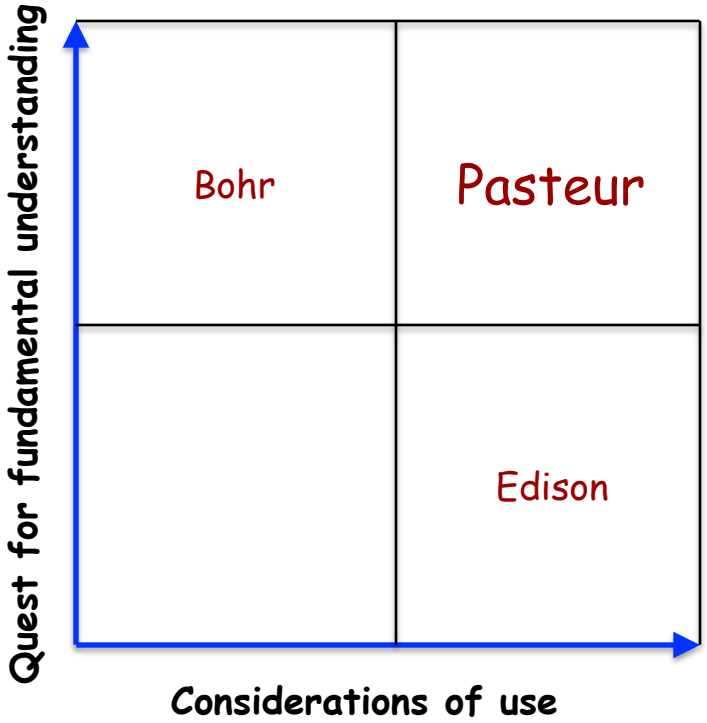
- Reactive, ad hoc, one-off, "hero" efforts
- Address one application
- No leverage; doesn't scale

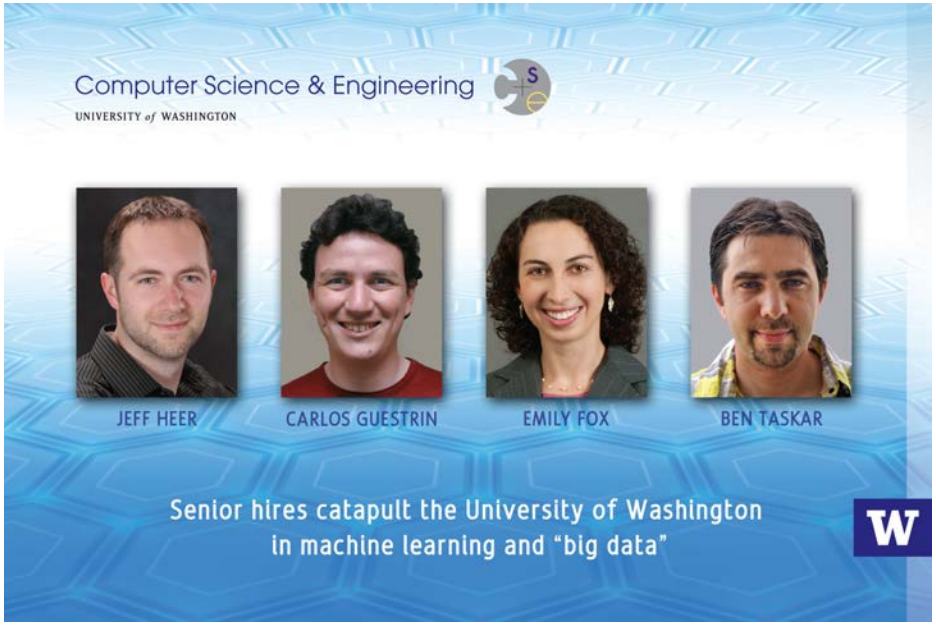
- "Uber-system"
- Over-abstraction
- Tries to meet so many needs, it winds up meeting none well

The sweet spot: bottom-up, needs-based, driven-by-the-scientists … and "just general enough" to achieve leverage

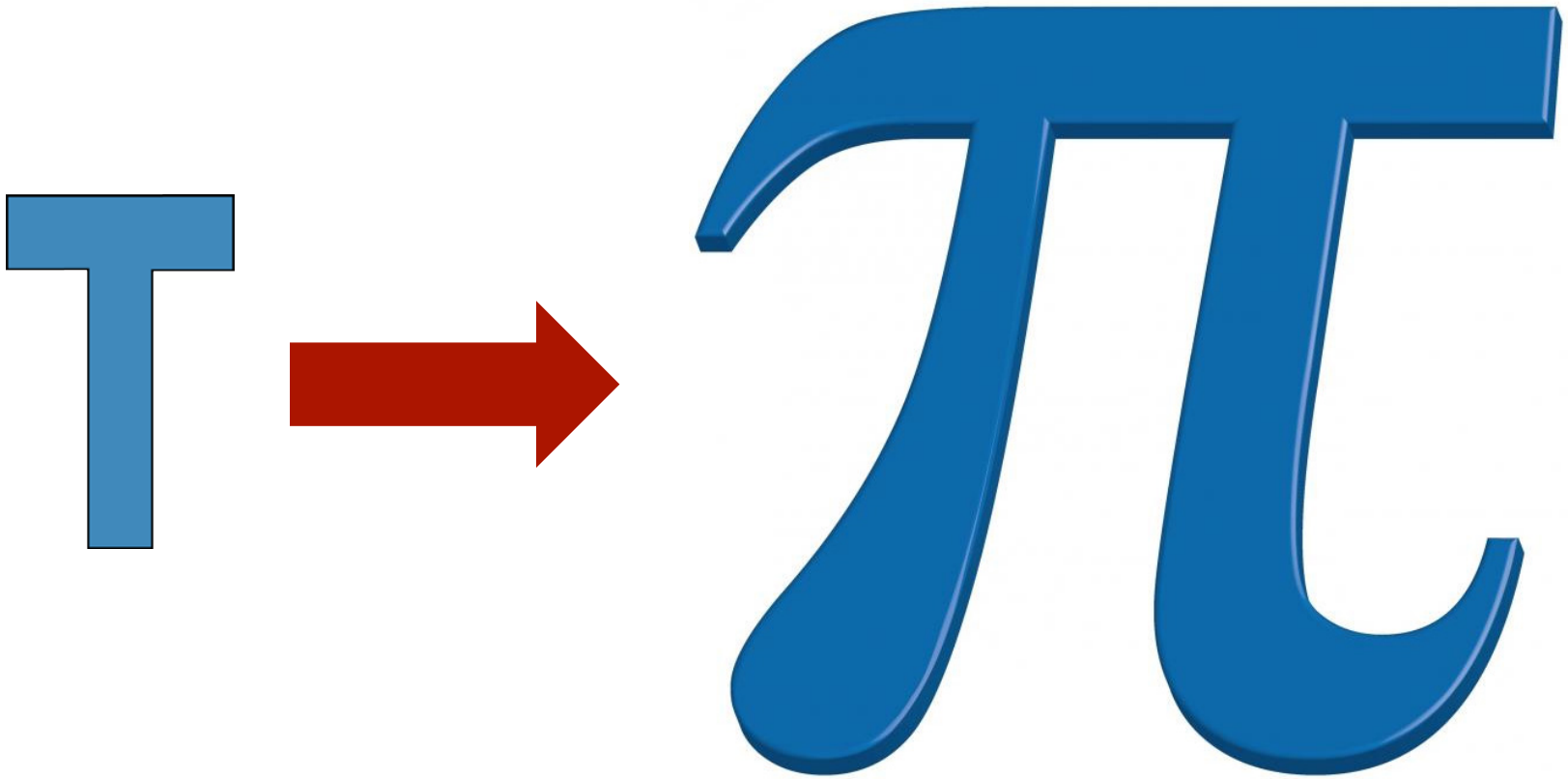
- A full spectrum of individuals … a full spectrum of careers and career paths
  - Faculty
  - Research Scientists ← translation
  - Software Professionals ← robustness
  - Postdocs ← the next generation – the real agents of cultural change
  - Graduate and Undergraduate Students

- On the methodology side, seek faculty in "Pasteur's Quadrant"



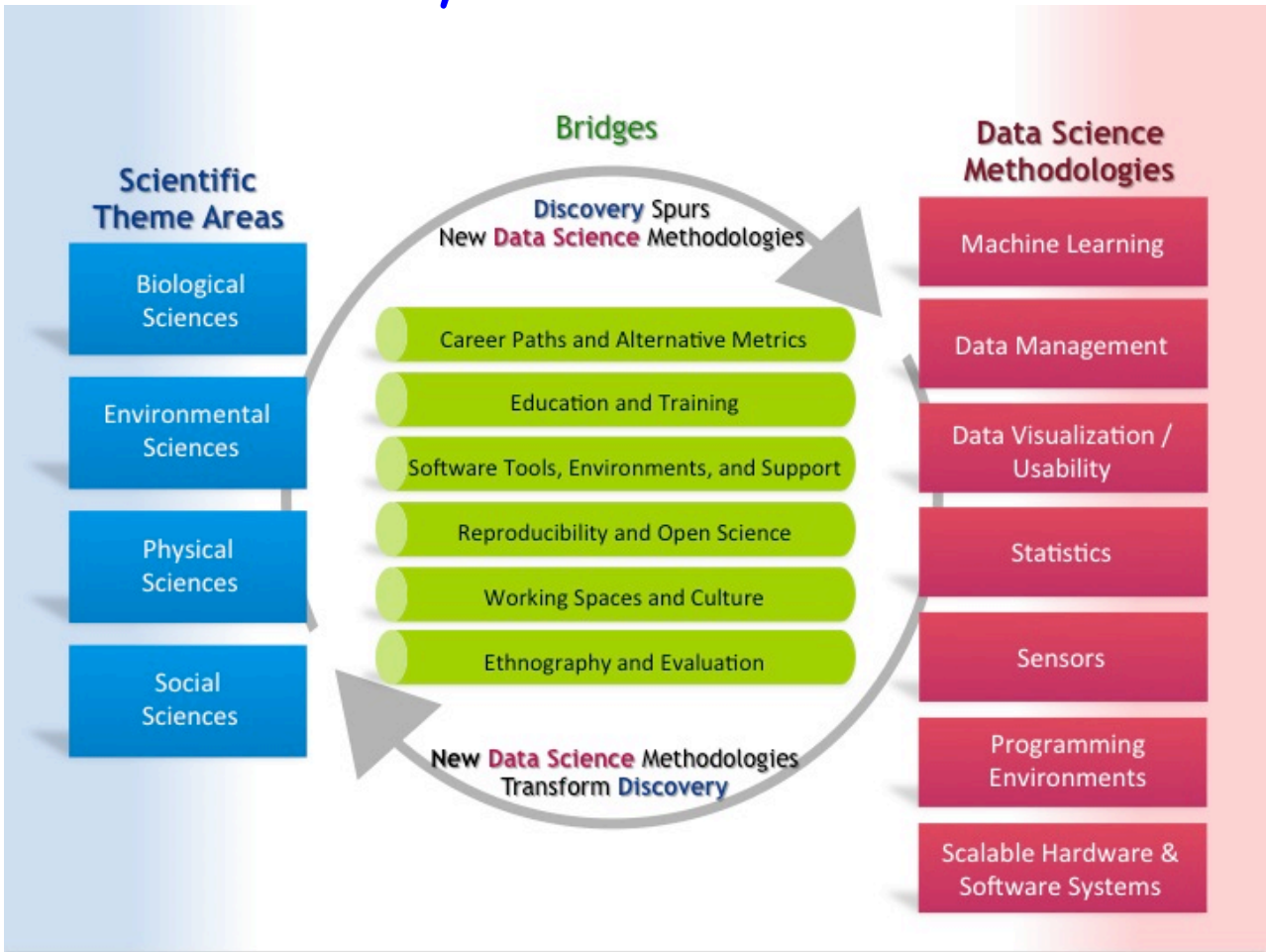


- Across-the-board, strive to create "Pi-shaped" scholars



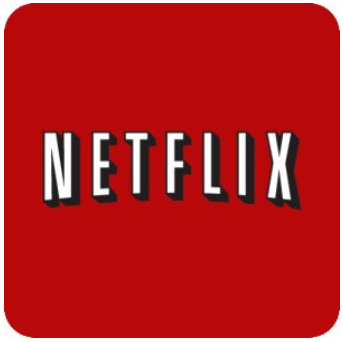
- Resurrect the water cooler! (Data is the unifier!)

- Create a "virtuous cycle"



Other examples of "big data in action" (beyond all of the preceding "smarts")

- Collaborative filtering



- Fraud detection

Secret government surveillance of American citizens

The New York Times

Drug Agents Use Vast Phone Trove, Eclipsing N.S.A.'s

By SCOTT SHANE and COLIN MOYNIHAN
Published: September 1, 2013 | 285 Comments

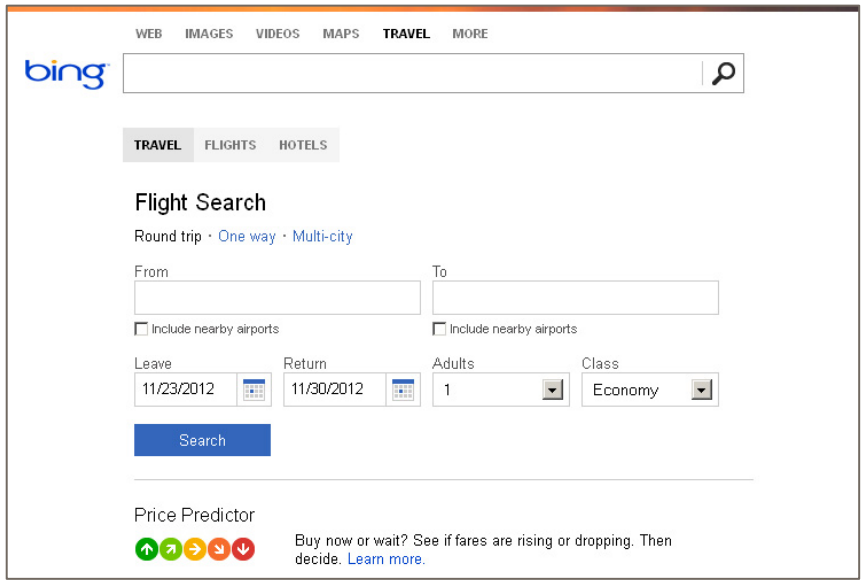
For at least six years, law enforcement officials working on a counternarcotics program have had routine access, using subpoenas, to an enormous AT&T database that contains the records of decades of Americans' phone calls — parallel to but covering a far longer time than the National Security Agency's hotly disputed collection of phone call logs.

The Hemisphere Project, a partnership between federal and local drug officials and AT&T that has not previously been reported, involves an extremely close association between the government and the telecommunications giant.

"Hemisphere Project"

- 26 years of records of every call that passed through an AT&T switch
- New records added at a rate of 4B/ day

Price prediction



Farecast

Hospital re-admission prediction

caradigm

a Microsoft | GE Healthcare company

Products | Partners | About

AMALGA - REDUCE READMISSIONS

Avoid preventable readmissions, reduce costs and deliver higher quality care

Service Offerings

- Improve Quality of Care
- Reduce Readmissions
- Ease Care Transitions
- Manage Chronic Disease

Background

With payers implementing penalties for readmissions, it's critical to start addressing readmissions risks today. Solutions that help healthcare enterprises count last month's readmissions are no longer sufficient. Enterprises need to know which patients in their hospitals today are at risk for being readmitted within 30 days of discharge, so they can take action and address those risks before the patient walks out the door.

Amalga helps healthcare organizations proactively identify inpatient and Emergency Department (ED) patients at risk for readmissions and helps them take action to avoid preventable readmissions, reduce costs and deliver higher quality care – today and tomorrow.

Overview

By using predictive modeling technologies, Amalga can help reduce preventable readmissions by enabling healthcare delivery organizations to:

- Effectively define and monitor patient groups across the enterprise
- Use data collected in Amalga to predict readmission probability based on a given hospital's historical data
- Proactively manage at-risk patients throughout their stay and at discharge
- Access patterns in key indicators to identify and address root causes of readmissions

Features and Benefits

With Amalga, organizations can:

- Actively identify and track patient groups
- Integrate disparate systems and identify patient cohorts based on key characteristics
- Use predictive modeling technologies to help identify patients at risk for readmission
- Analyze readmission patterns and monitor 30-day inpatient and 72-hour ED readmissions
- View simplified reports that support identification and addressing of root causes sooner

- Travel time prediction under specific circumstances

Microsoft Research

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Worldwide Labs | Research Areas | Research Groups

> Projects > Predictive Analytics for Traffic

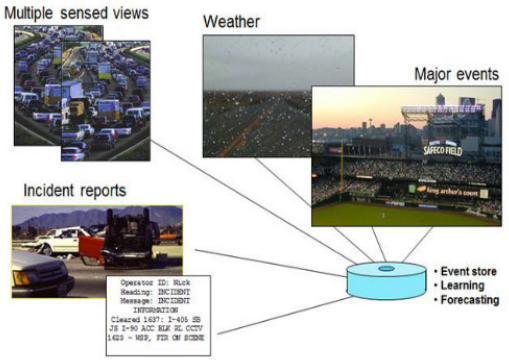
Predictive Analytics for Traffic

Machine learning and intelligence for sensing, inferring, and forecasting traffic flows

Machine learning and intelligence are being applied in multiple ways to addressing difficult challenges in multiple fields, including transportation, energy, and healthcare. Research scientists at Microsoft Research have been engaged in efforts in all of these areas. We focus on multiyear efforts at Microsoft Research to infer and forecast the flows of traffic. The work leverages machine learning to build services that make use of both live streams of sensed information and large amounts of heterogeneous historical data. This has led to multiple prototypes and real-world services such as traffic-sensitive directions in Bing Maps. Focused work in this realm also stimulated new efforts in related areas, such as privacy and routing.

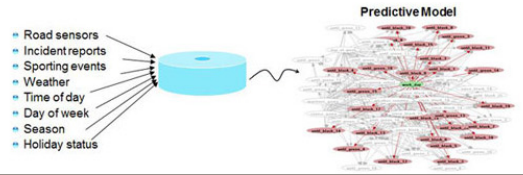
Predicting Traffic Jams and Flows: JamBayes

Machine learning methods have been applied to create methods that provide estimates of flows inferences about current and future traffic flows. Research on the JamBayes project, started in 2002, was framed by the frustrations encountered with navigating through Seattle traffic, a region that has seen great growth amidst slower changes to the highway infrastructure.



JamBayes focused on learning to forecast flows from multiple streams of information.

The challenge was to predict the future of traffic flow: How long would it be until a current traffic jam on the highway system of Seattle would melt? How long until open flows on different segments of the highway system of Seattle would become clogged? The idea was to combine heterogeneous streams and histories of information to make these predictions. These streams included multiple years of different types of data, including sensed highway data, reports of accidents throughout the highway system, weather, and major regional events such as Mariners and Supersonics games.



- Coaching / play calling in all sports

Speech recognition

Siri. Beta

Your wish is its command.

Siri lets you use your voice to send messages, schedule meetings, place phone calls, and more.* Ask Siri to do things just by talking the way you talk. Siri is so easy to use and does so much, you'll keep finding more and more ways to use it.

Machine translation

- Speech -> text
- Text -> text translation
- Text -> speech in speaker's voice

http://www.youtube.com/watch?v=Nu-nlQqFCKg&t=7m30s
7:30 – 8:40

Presidential campaigning

2012 ELECTION

Inside the Secret World of the Data Crunchers Who Helped Obama Win

By Michael Scherer | Nov. 07, 2012 | 268 Comments

Like 16k Tweet 6,662 +1 656 Share 1,479

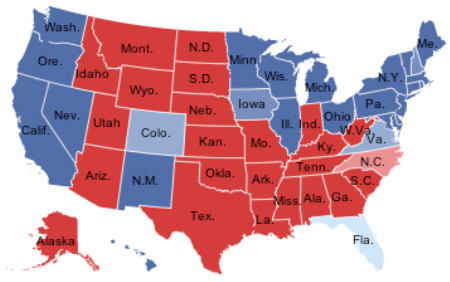
Electoral forecasting

DATA MINING

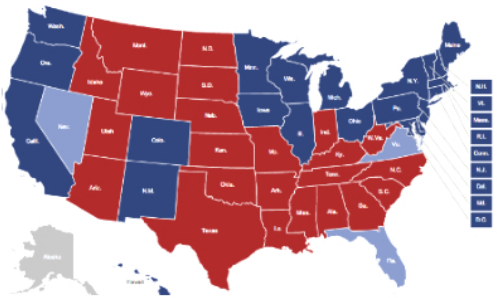
Nate Silver's Sweep Is a Huge Win for 'Big Data'

The data utopia awaits.

By **Nitasha Tiku** 11/07 11:10am

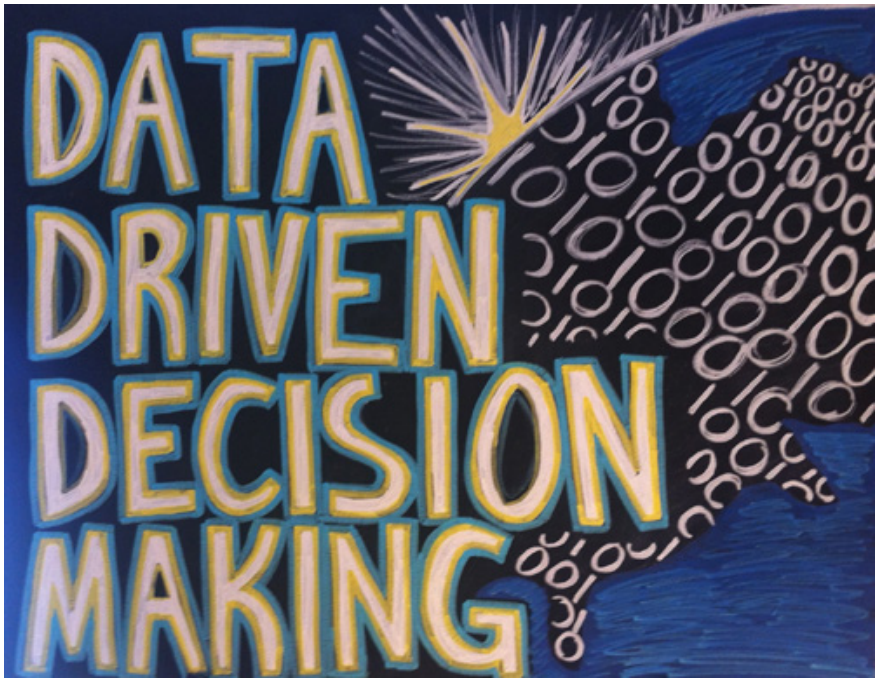


Nate Silver's Map

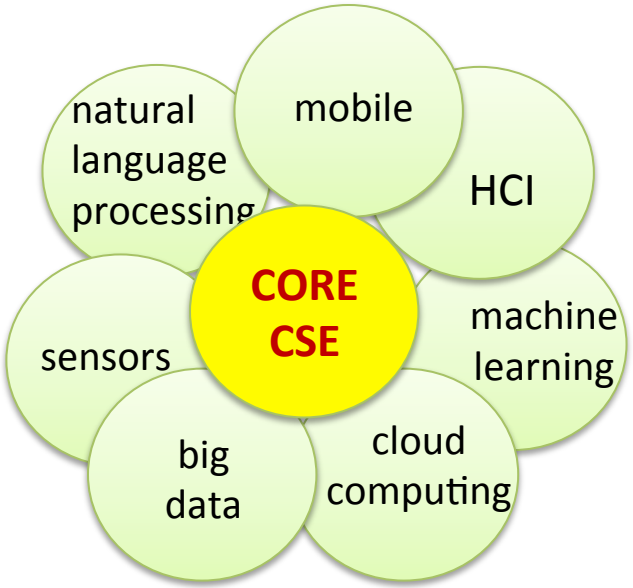


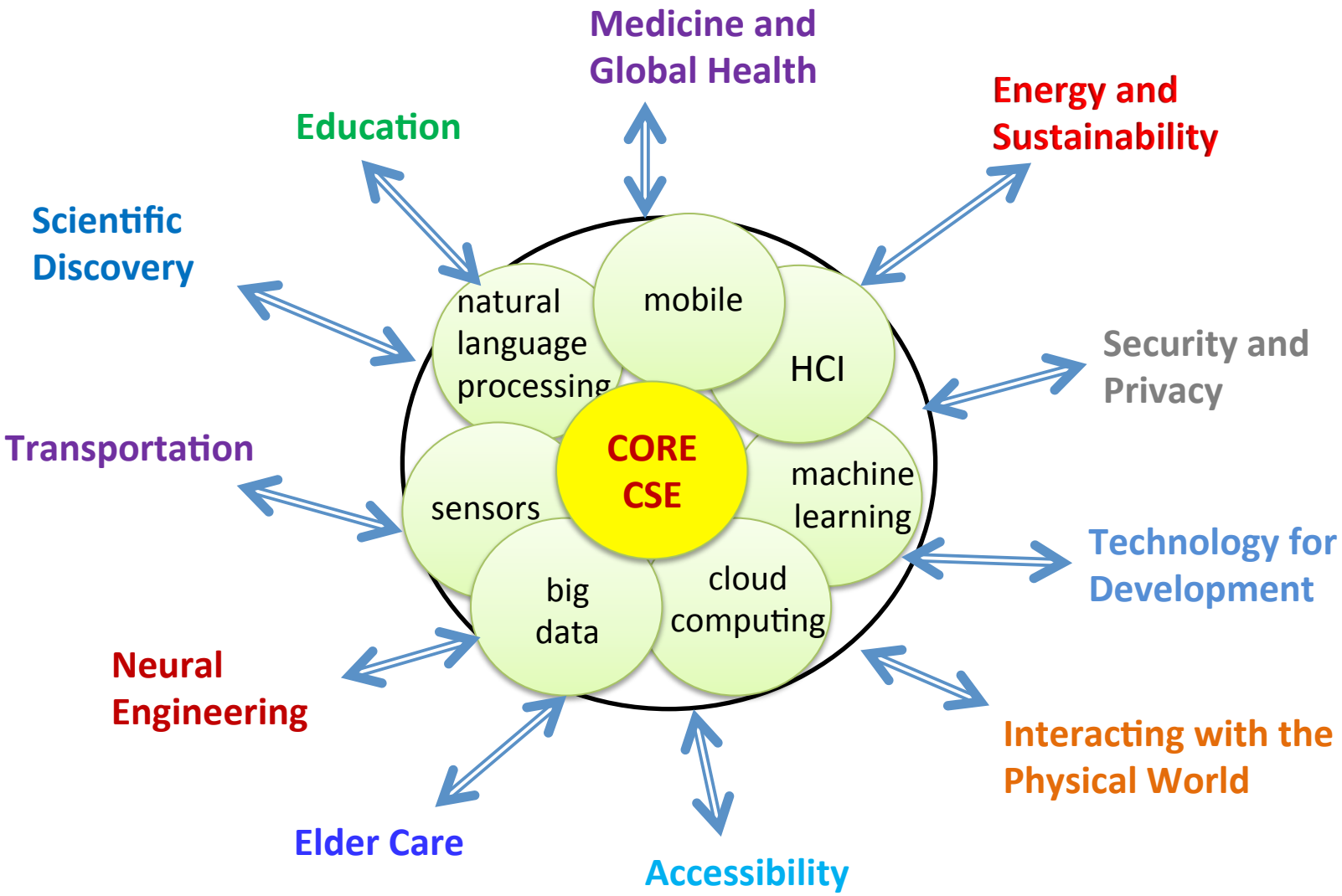
The Actual Map

- *Real* data-driven decision-making (vs. the traditional MBA hoo-hah) for every sector!

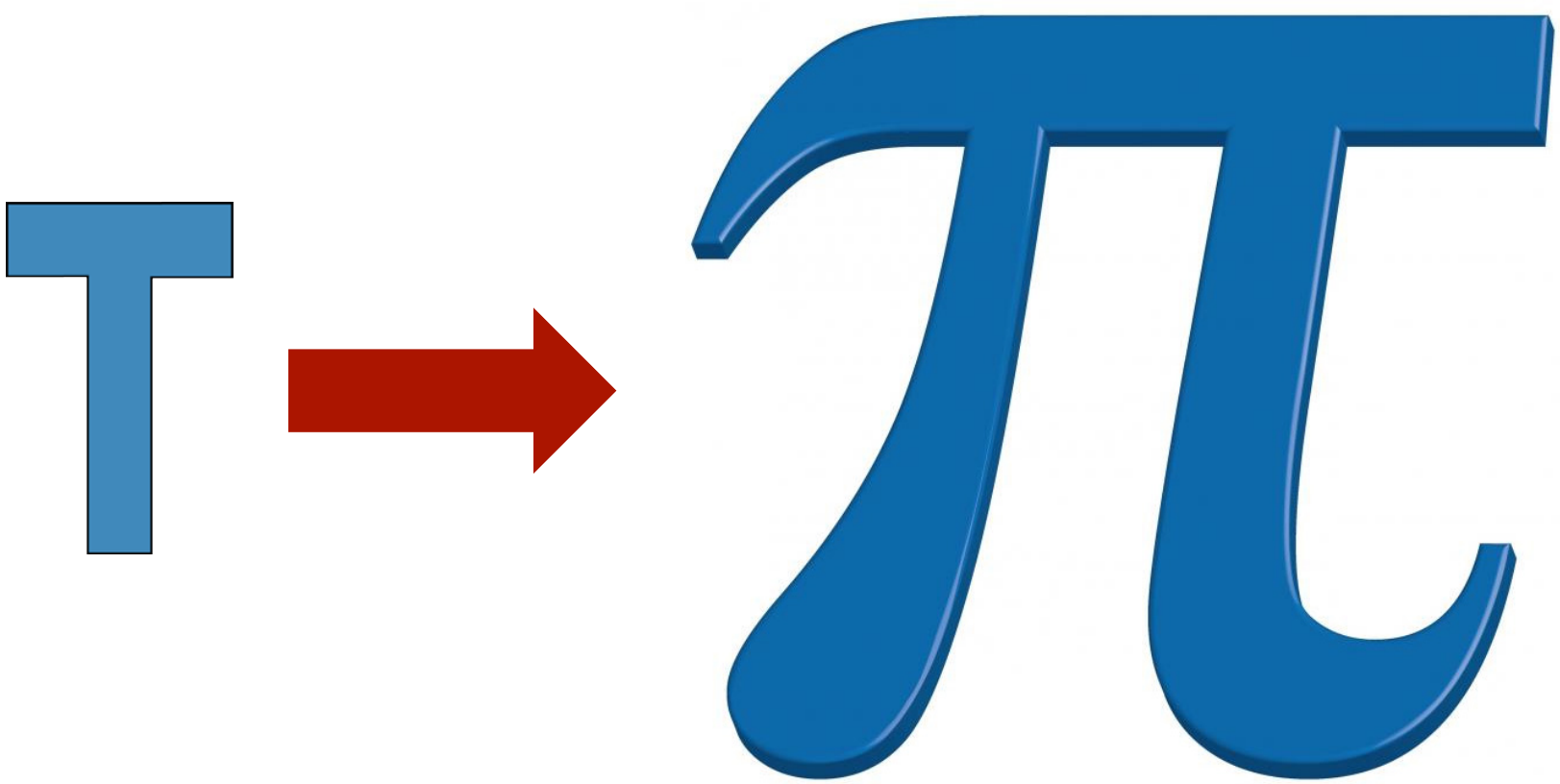


All of this leads to a different, expansive view of computer science


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


Medicine and Global Health
Education
Energy and Sustainability
Scientific Discovery
natural language processing
mobile
HCI
Security and Privacy
Transportation
CORE CSE
sensors
machine learning
Technology for Development
big data
cloud computing
Neural Engineering
Interacting with the Physical World
Elder Care
Accessibility

And to the need for a cultural shift in universities



And to some changes in K-12 education
Computer Science in K-12: 1983

A Nation At Risk

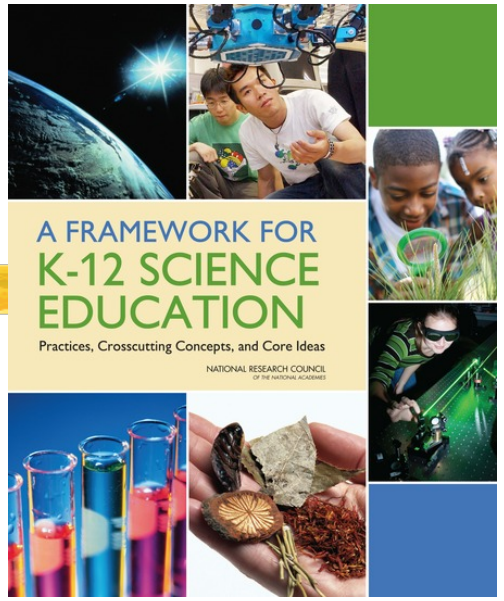
Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American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

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

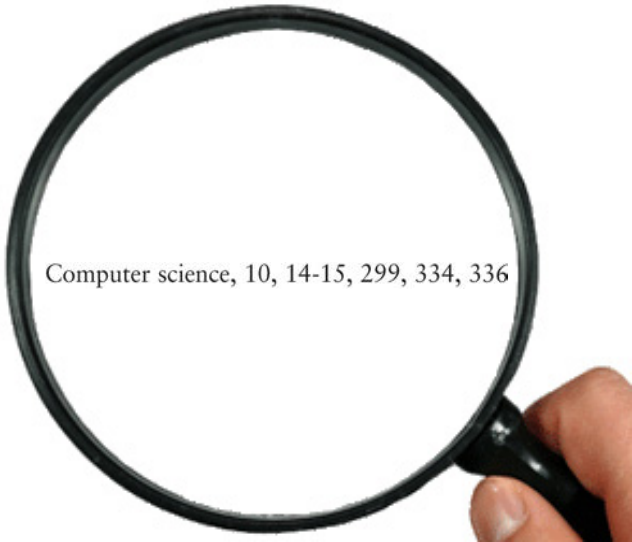
Recommendation A: Content

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

Computer Science in K-12: 2013



401 page report
15 page index



Computer Science in K-12: 2013

Elementary (K–5)

Storylines: K–2 3–5 PDFs: K 1 2 3 4 5

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

PS: Physical Sciences

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

LS: Life Sciences

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

ESS: Earth and Space Sciences

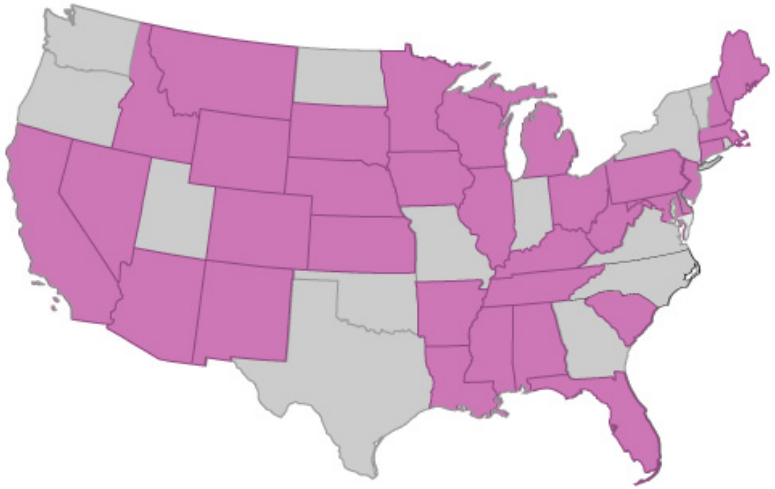
Middle School (6–8) Storyline PDF	High School (9–12) Storyline PDF
MS. Space Systems	**HS.** Space Systems
MS. History of Earth	**HS.** History of Earth
MS. Earth's Systems	**HS.** Earth's Systems
MS. Weather and Climate	**HS.** Weather and Climate
MS. Human Impacts	**HS.** Human Sustainability

ETS: Engineering, Technology, and Applications of Science

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

Computer Science in K-12: 2013

- In 9 out of 10 high schools nationwide, computer science is not offered
- In 36 of the 50 states, computer science does not count towards the math or science graduation requirement



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

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

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