

eScience: Techniques and Technologies for 21st Century Discovery

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University of Washington

WICHE Commission Meeting

May 2009

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

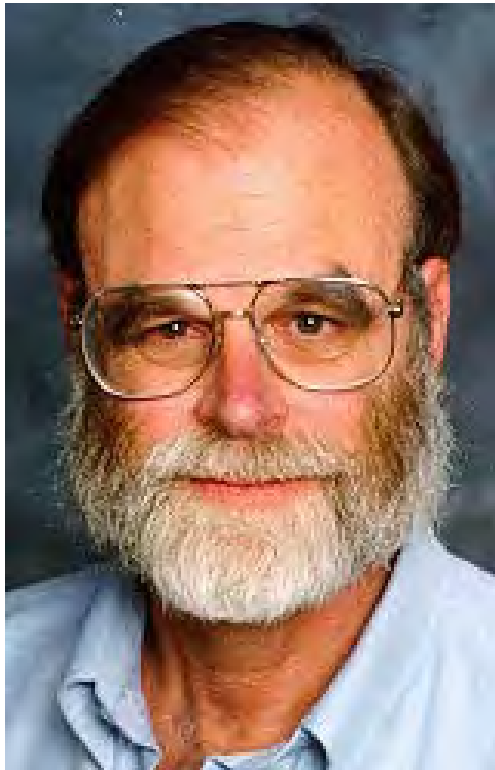


This morning

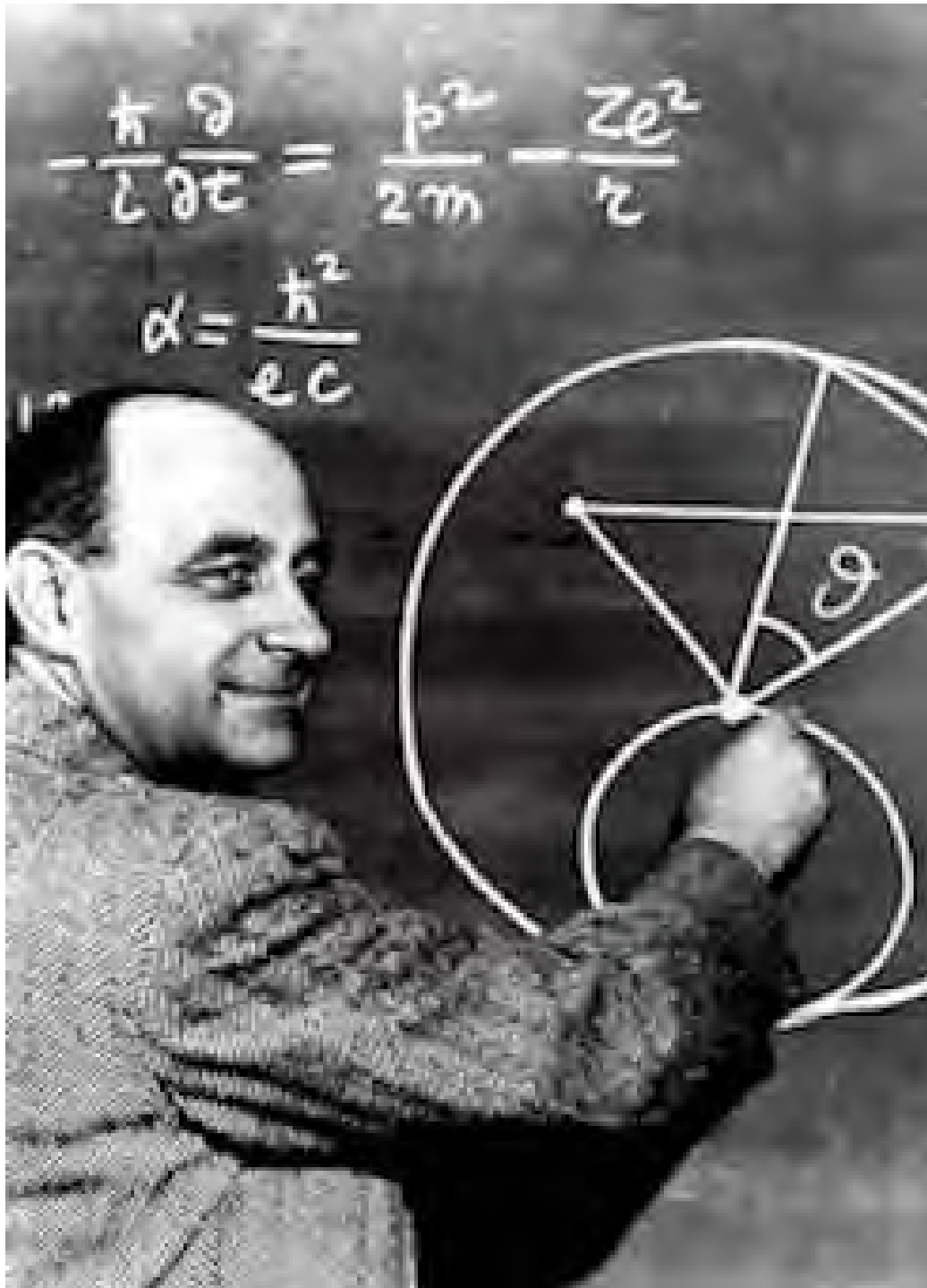


- The nature of eScience
- The advances that enable it
- Scalable computing for everyone
- Networking in the West, and the broadband stimulus
- Computer science & engineering: Changing the world
- The changing nature of our economy, and of educational requirements

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



Transforming science (again!)



Theory
Experiment
Observation



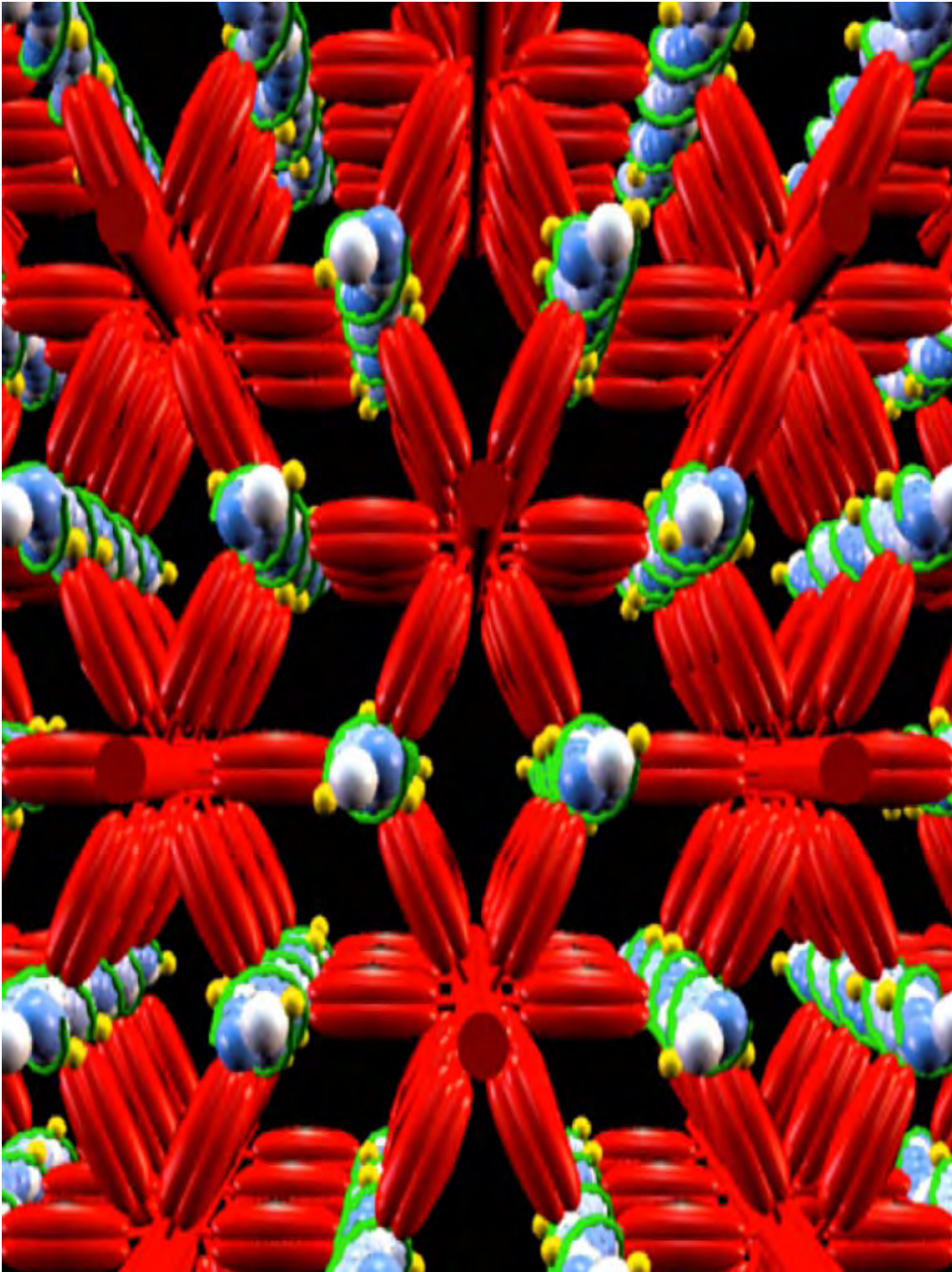
Theory
Experiment
Observation

Theory
Experiment
Observation



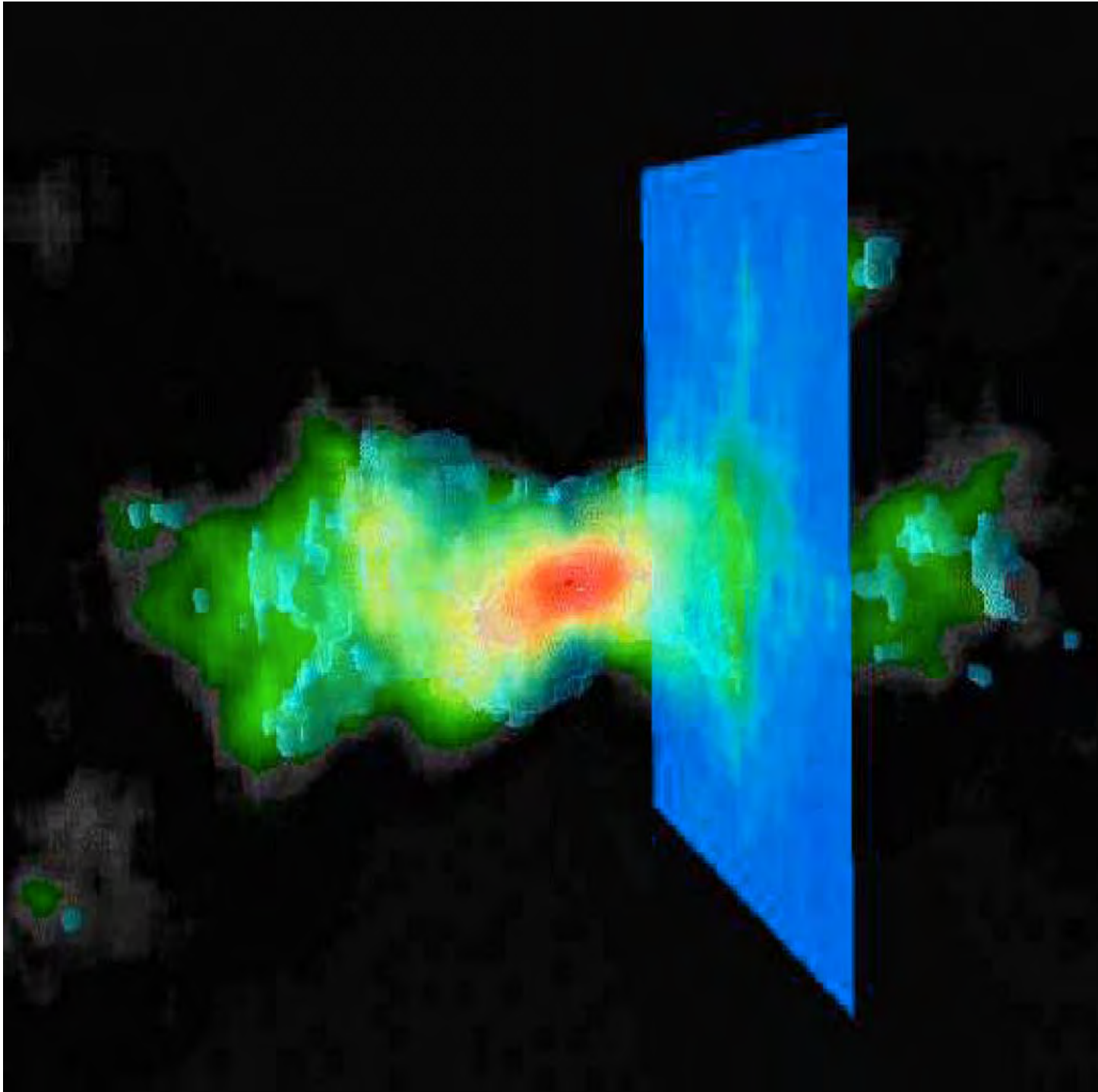


Theory
Experiment
Observation
**Computational
Science**



**Protein interactions
in striated muscles**

Tom Daniel lab



**QCD to study
interactions of
nuclei**

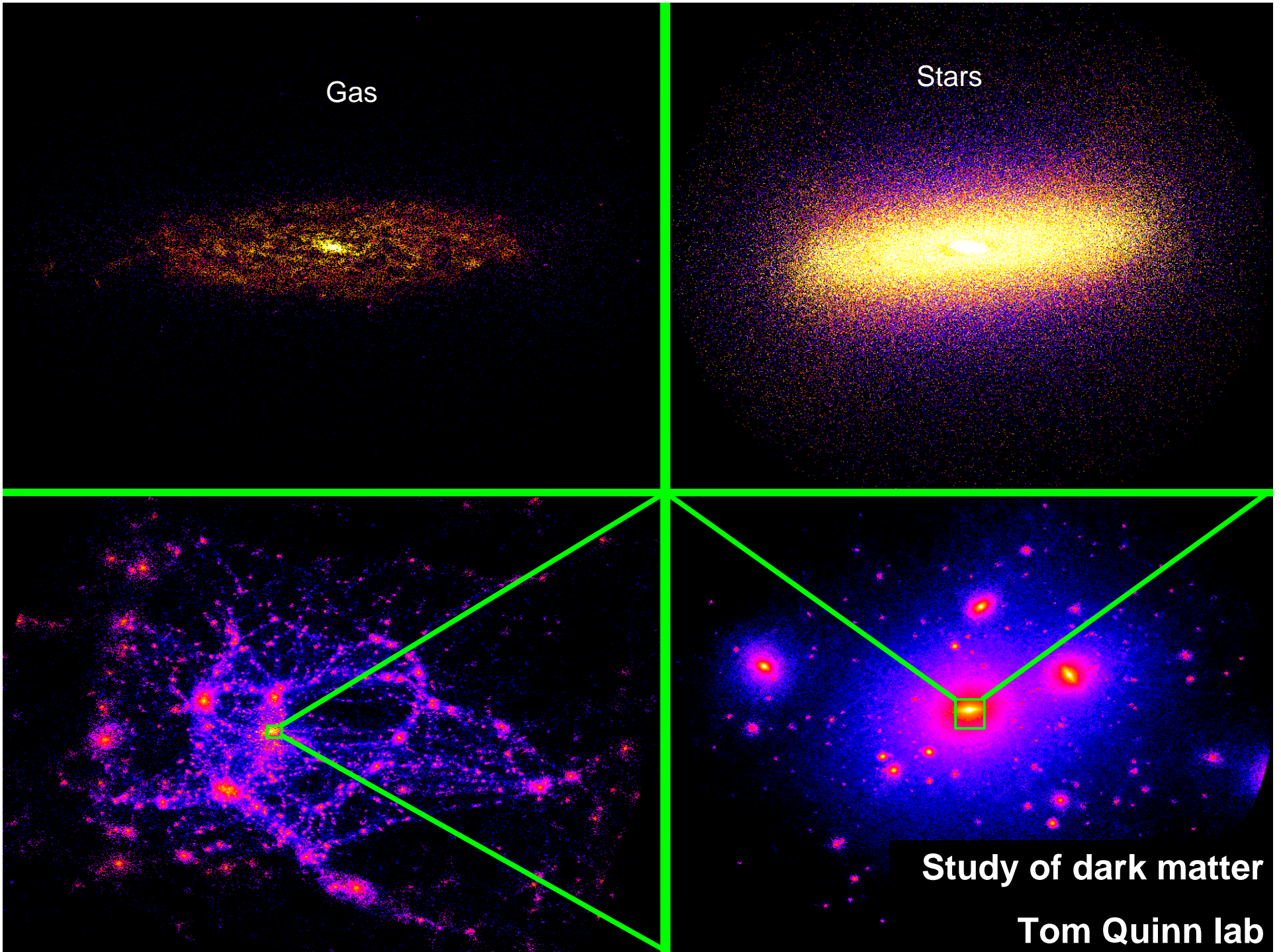
David Kaplan lab

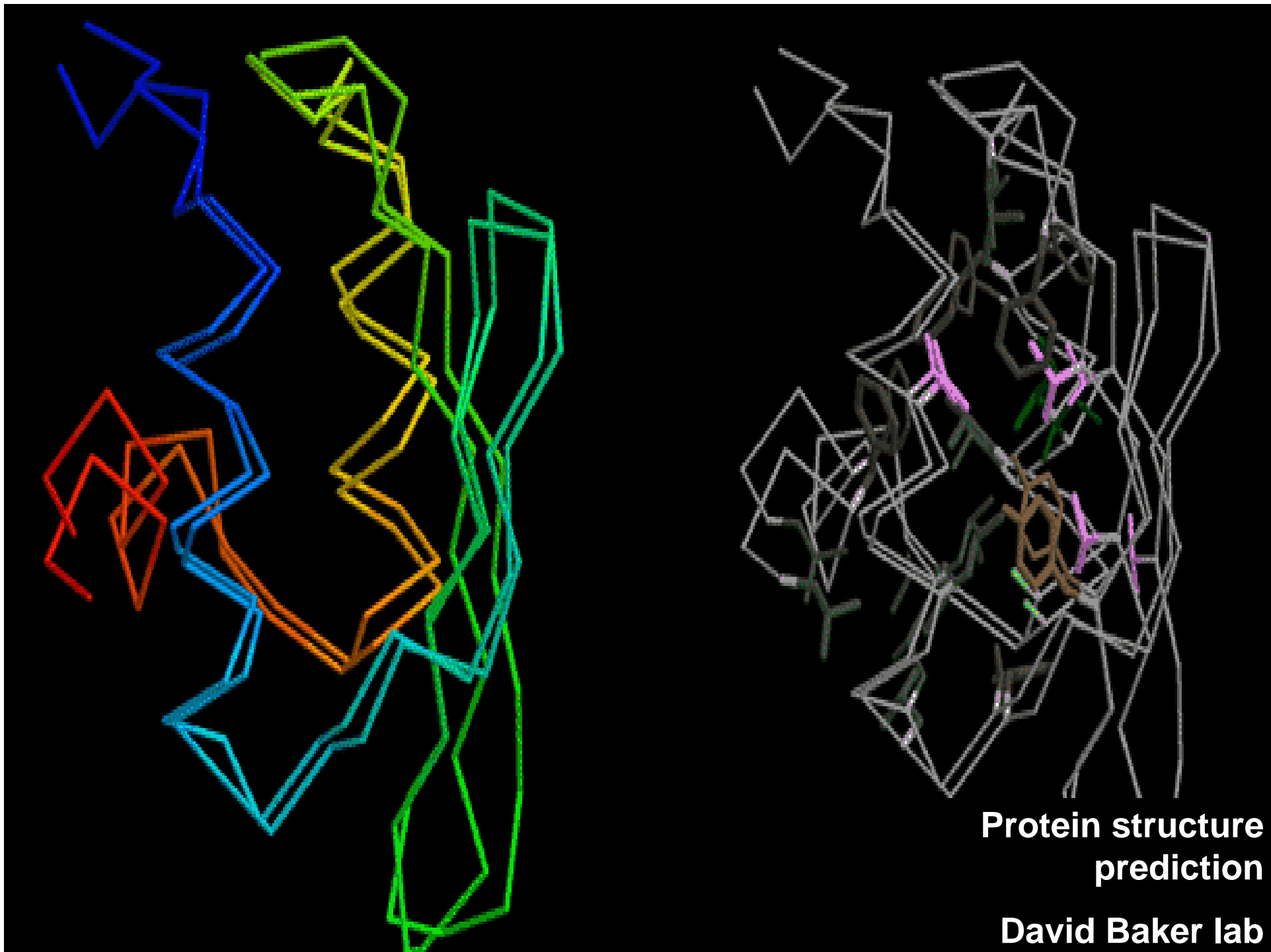
Gas

Stars

Study of dark matter

Tom Quinn lab





Theory
Experiment
Observation
Computational
Science
eScience

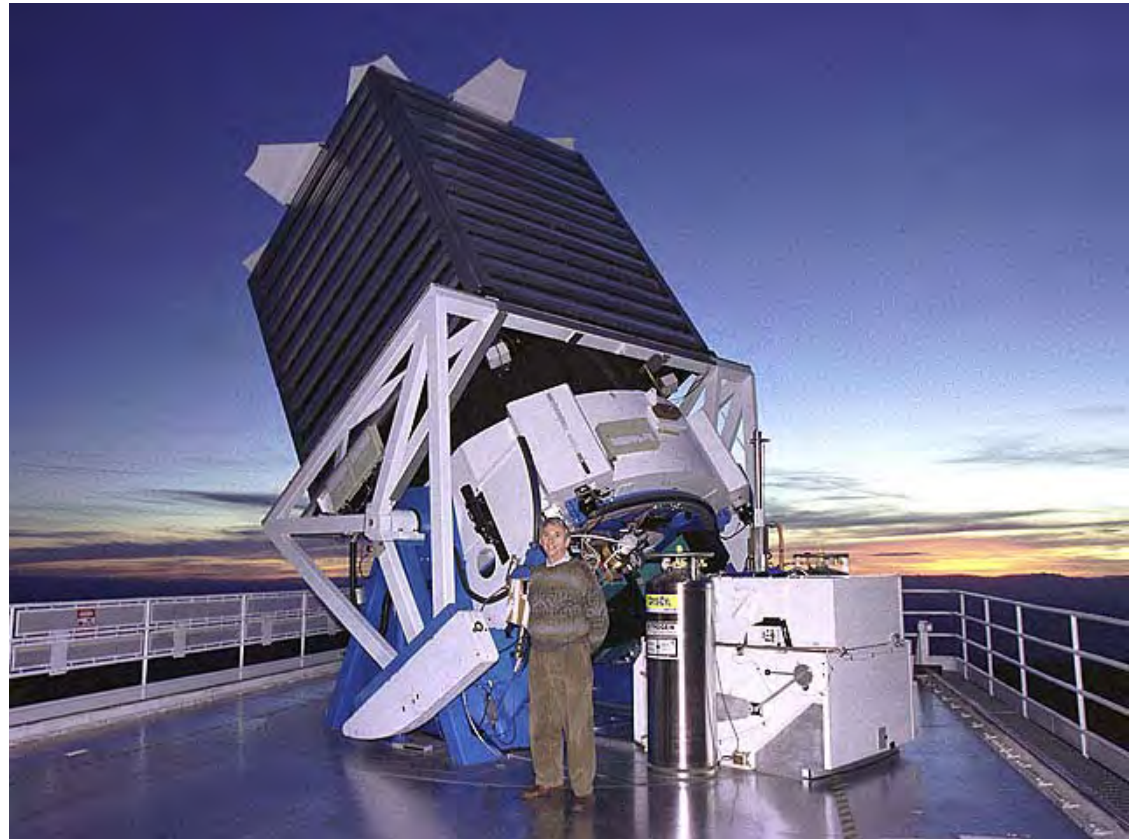


eScience is driven by *data*

- Massive volumes of data from sensors and networks of sensors

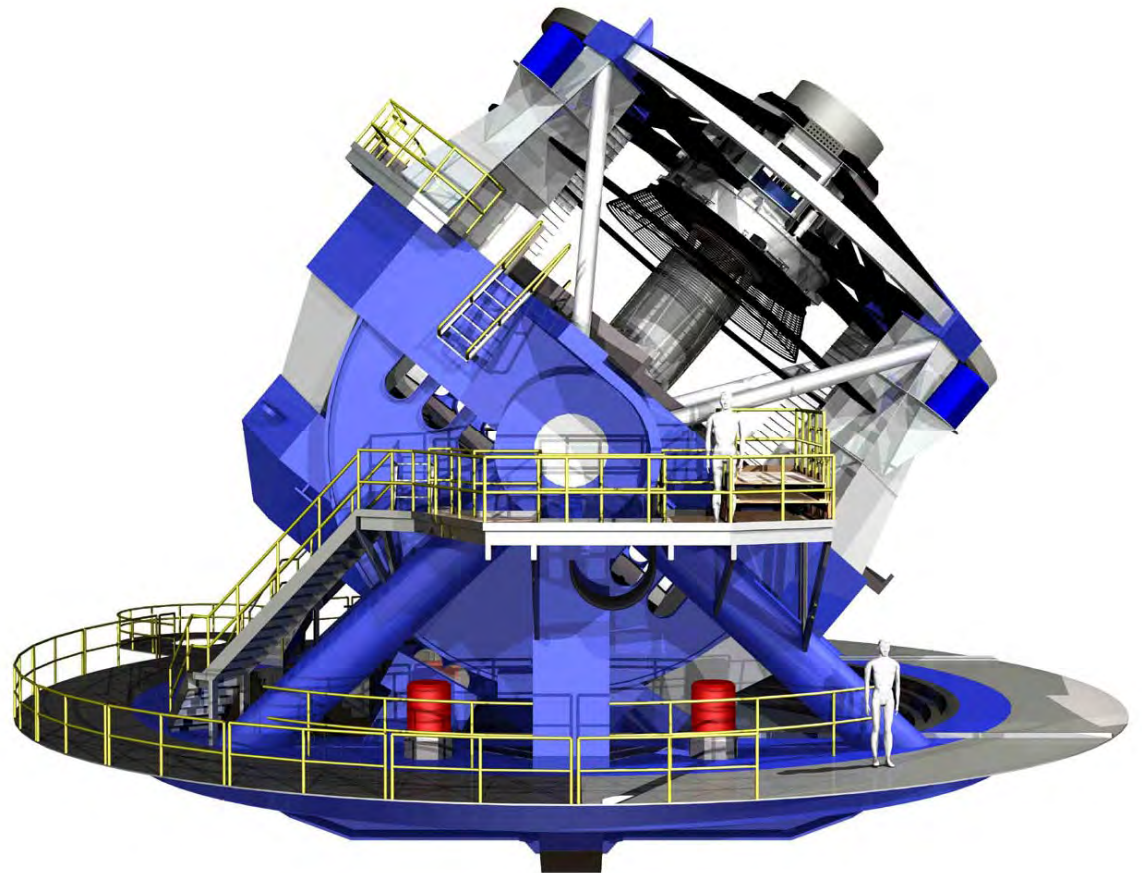
Apache Point telescope,
SDSS

15TB of data
(15,000,000,000,000 bytes)



**Large Synoptic Survey
Telescope (LSST)**

**30TB/day,
60PB in its 10-year
lifetime**

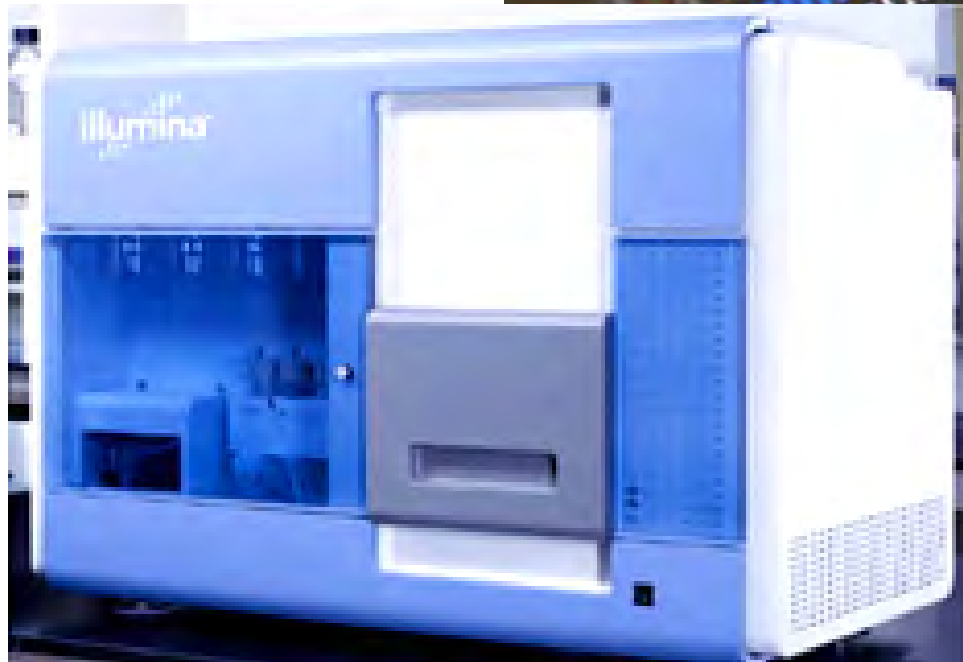




Large Hadron Collider

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

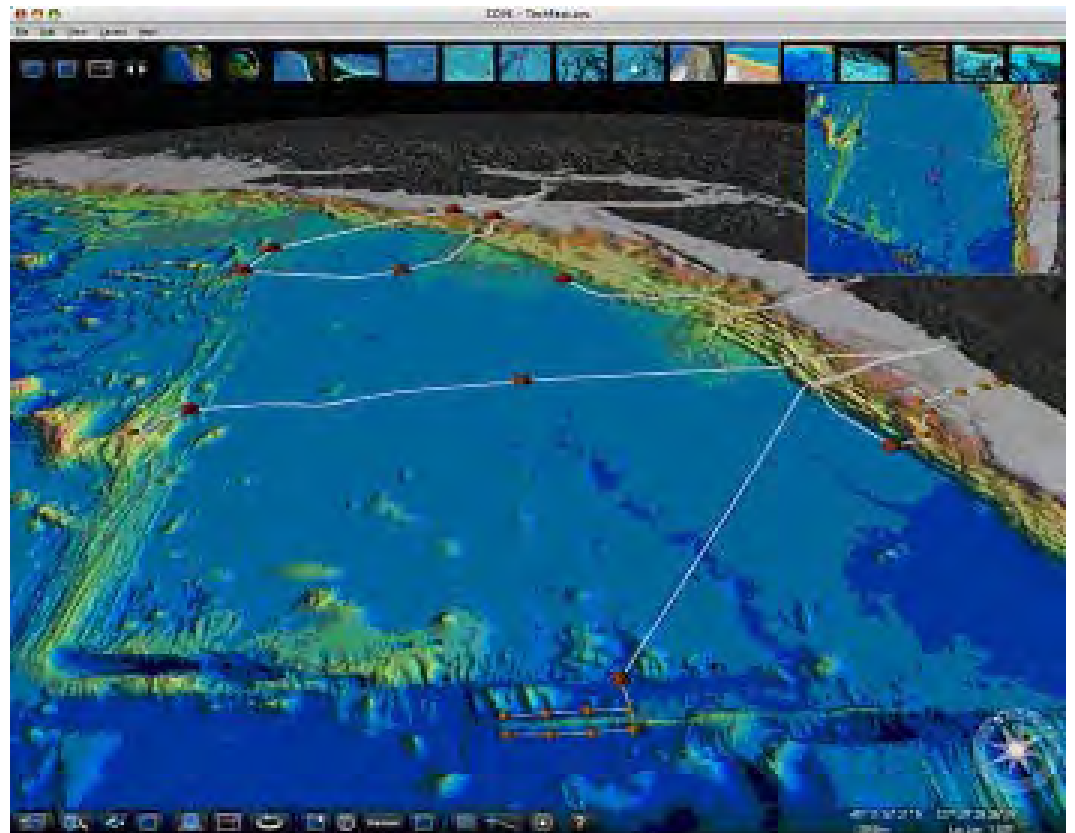




**Illumina Genome
Analyzer
~1TB/day**

**Regional Scale Nodes of the
NSF Ocean Observatories
Initiative**

**2000 km of fiber optic cable
on the seafloor, connecting
thousands of chemical,
physical, and biological
sensors**

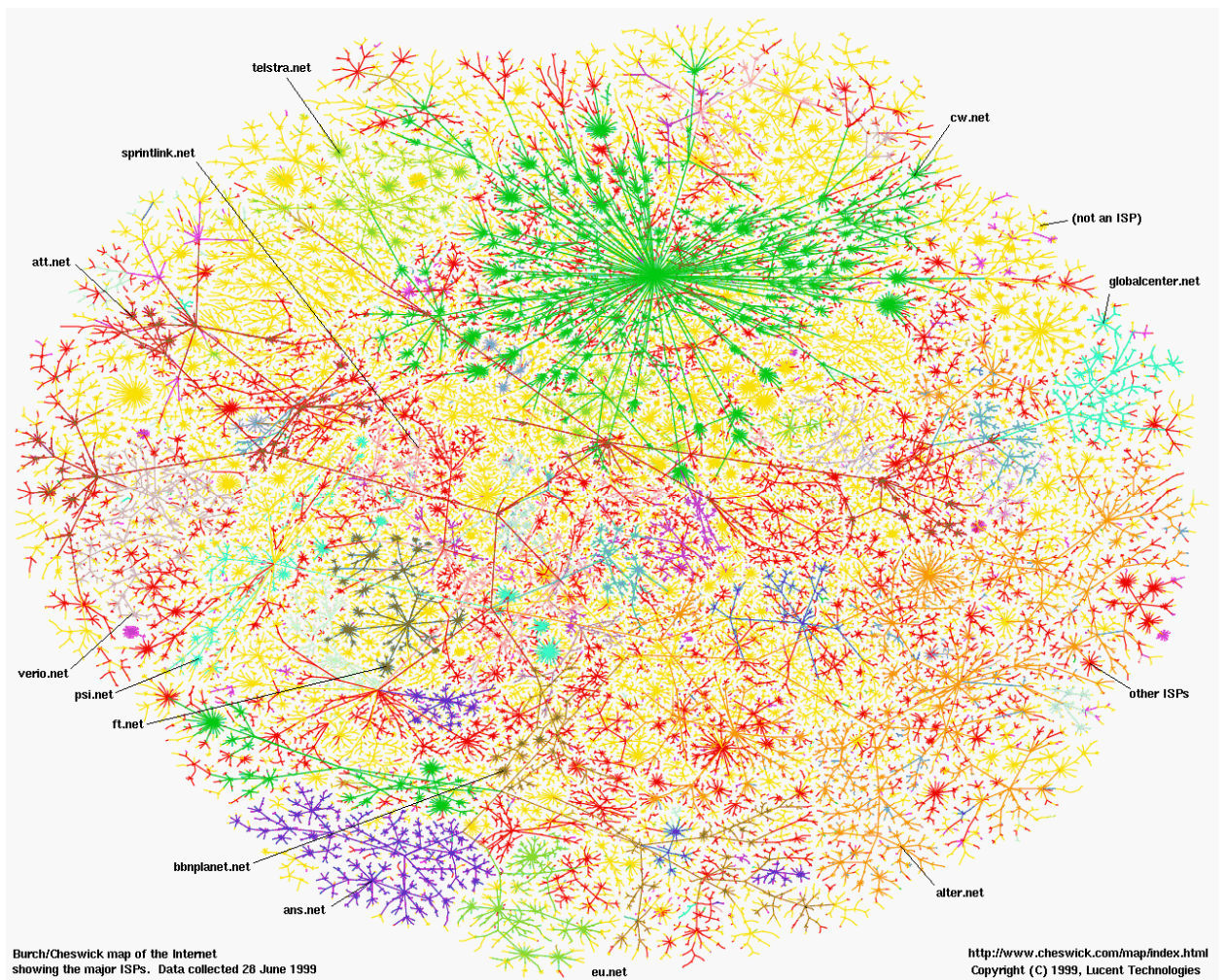




The Web

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

The technologies of eScience

- Sensors and sensor networks
- Databases
- Data mining
- Machine learning
- Data visualization

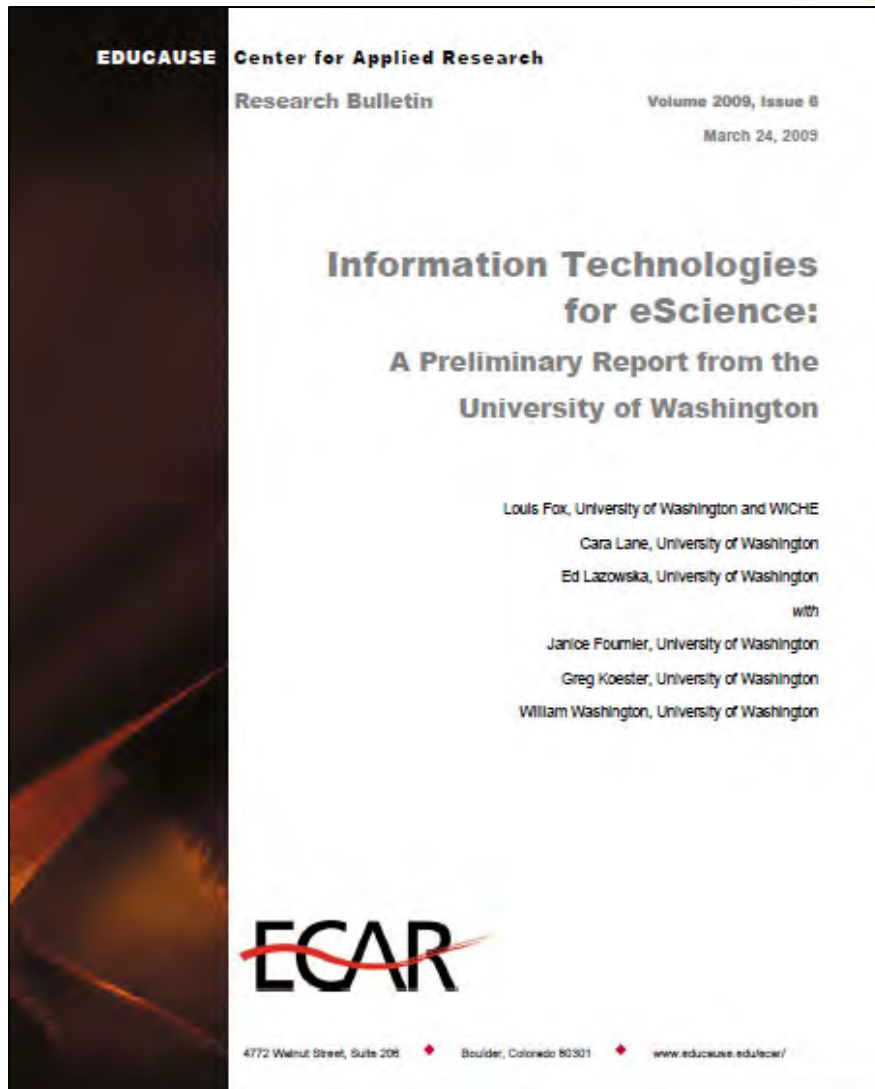


eScience will be pervasive



- Computational science was 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 organization
 - If not, the organization will simply cease to be competitive

Top faculty across all disciplines understand the coming data tsunami



Questions for you ...



- How does your institution track the IT needs - present and future - of its leading researchers?
- To what extent are you meeting these needs, and in what critical areas are you falling short?
- How well does your technology staff understand the institution's research and disciplinary directions and their IT implications?
- What potential resources, other than those currently in place, can be used to provide broad-based IT support for eScience and eScholarship?

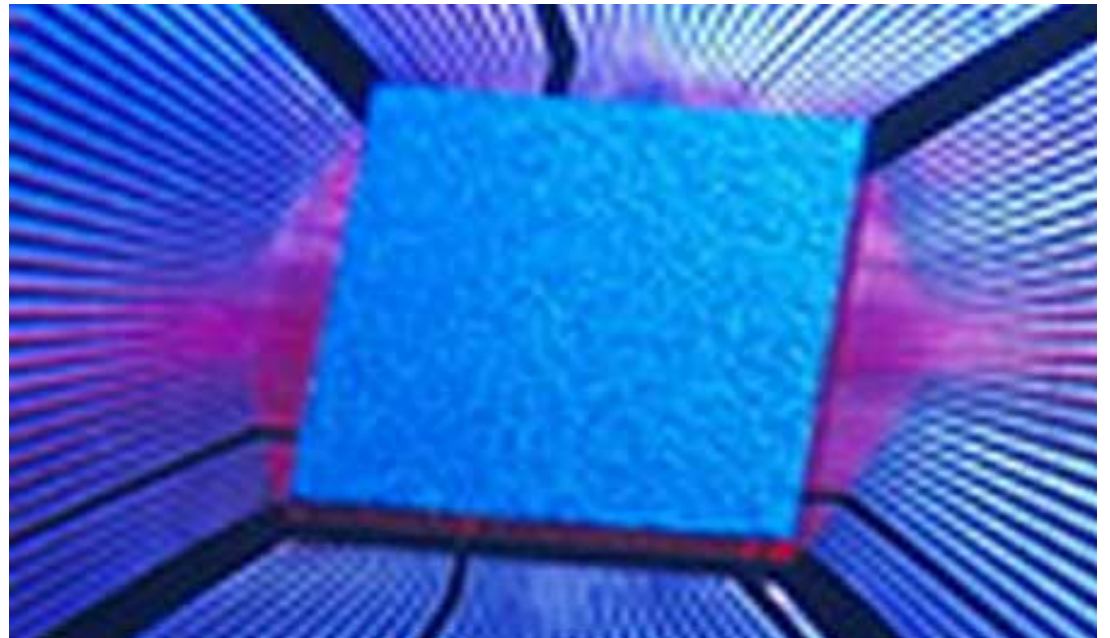
More on the enablement of eScience

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



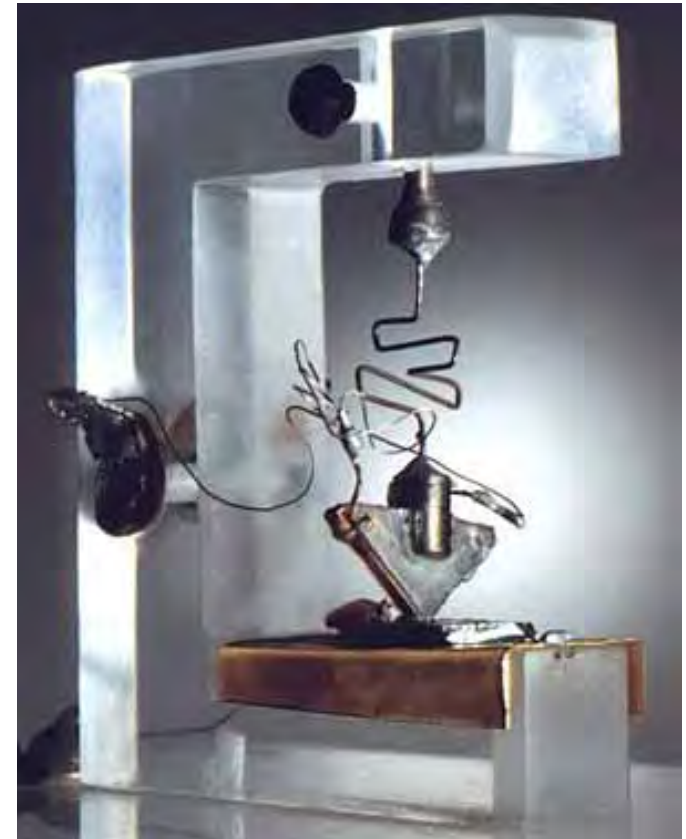
■ Ten quintillion: 10^{18}

- 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

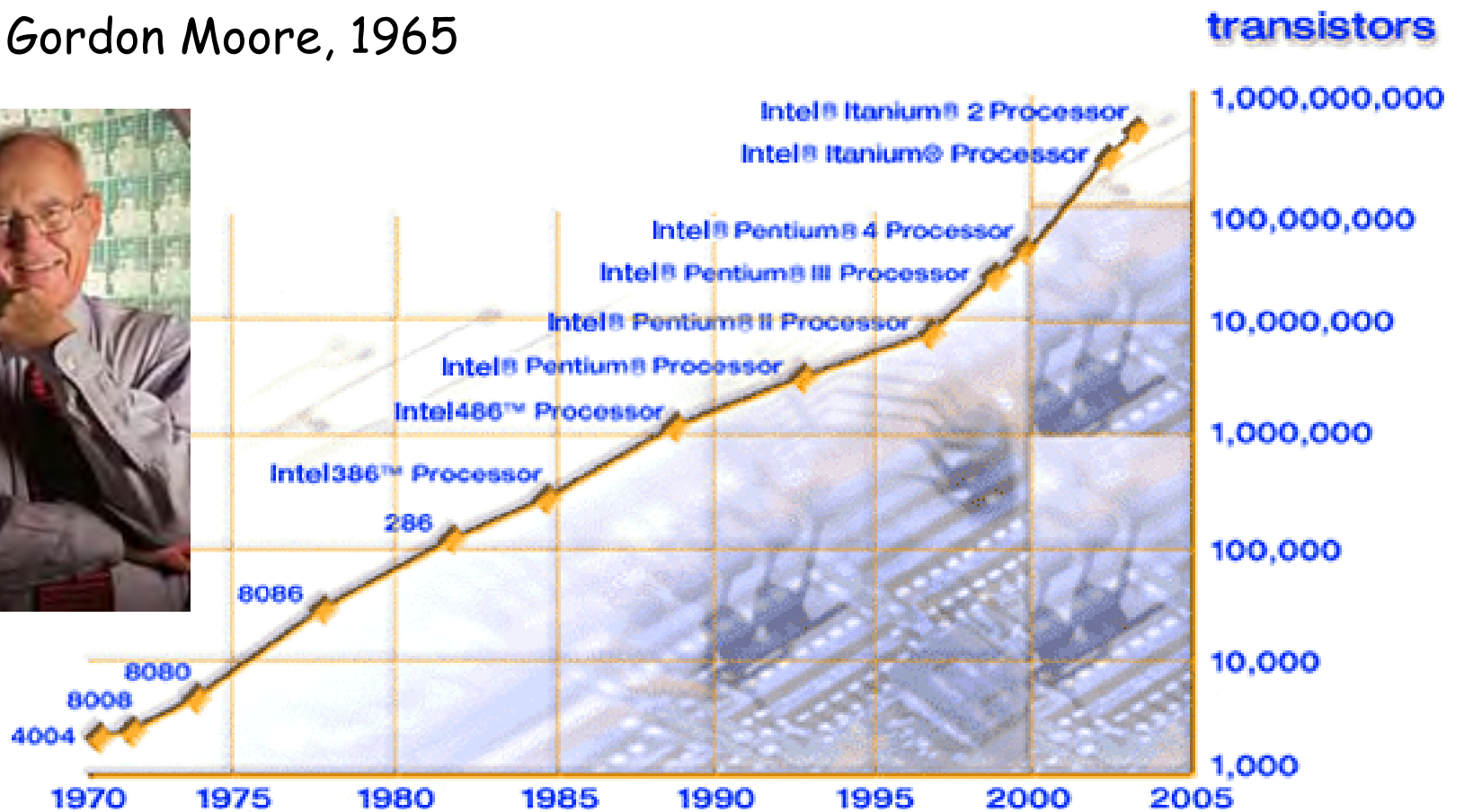
- Jack Kilby, Texas Instruments, and Bob Noyce, Fairchild Semiconductor Corporation, 1958





■ Moore's Law

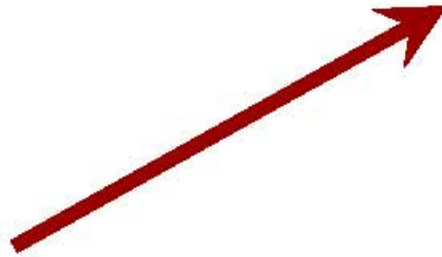
■ Gordon Moore, 1965











■ Processing power, historically

- 1980: 1 MHz Apple II+, \$2,000
 - | 1980 also 1 MIPS VAX-11/780, \$120,000
- 2006: 2.4 GHz Pentium D, \$800
 - | A factor of 6000



■ Processing power, recently

- Additional transistors => more cores of the same speed, rather than higher speed
- 2008: Intel Core 2 Quad-Core 2.4 GHz, \$800 (4x the capability, same price)
- 2009: Intel Core 2 Quad-Core 2.5 GHz, \$183 (same capability, 1/4 the price)



■ Primary memory - same story, same reason (but no multicore fiasco)

- 1972: 1MB, \$1,000,000
- 1982: 1MB, \$60,000
- 2005: \$400/GB (1MB, \$0.40)

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Memory [Learn More](#)

Standard Microsoft Windows XP and Windows 2000 operating systems can not address more than 4GB of memory. Large memory configurations for the Dell Precision 470 and 670 are only supported with Red Hat Enterprise VWS v3 for Intel EM64T.

- 512MB, DDR2 SDRAM Memory, 400MHz, ECC (2 DIMMS)
- 1GB, DDR2 SDRAM Memory, 400MHz, ECC (2 DIMMS) [Add \$124.10]
- 1.5GB, DDR2 SDRAM Memory, 400MHz, ECC (4 DIMMS) [Add \$313.10]
- 2GB, DDR2 SDRAM Memory, 400MHz, ECC (4 DIMMS) [Add \$466.10]
- 2GB, DDR2 SDRAM Memory, 400MHz, ECC (2 DIMMS) [Add \$700.10]
- 3GB, DDR2 SDRAM Memory, 400MHz, ECC (4 DIMMS) [Add \$952.10]
- 4GB, DDR2 SDRAM Memory, 400MHz, ECC (6 DIMMS) [Add \$1,267.10]
- 4GB, DDR2 SDRAM Memory, 400MHz, ECC (4 DIMMS) [Add \$1,537.10]
- 1GB, DDR2 SDRAM Memory, 400MHz, ECC (4 DIMMS) [Add \$124.10]

**4GB vs. 2GB
(@400MHz) = \$800
(\$400/GB)**

2007: \$145/GB (1MB, \$0.15)

1 Build My Dell 2 Add My Accessories 3 Choose My Software 4 Protect My Investment 5 Confirm & Add to Cart

SWITCH TO LIST VIEW

SELECT MY MEMORY

[? Help Me Choose](#) [Video Learn More](#)

- 2GB Dual Channel DDR2 SDRAM at 667MHz - 2 DIMMs
[Included in Price]
Dell Recommended for an enhanced Windows Vista experience
- 4GB Dual Channel DDR2 SDRAM at 667MHz - 4 DIMMs
[add \$290 or \$9/month*]

MEMORY

Dell Recommends **2 GB RAM**
For the best Windows Vista experience, especially if multi-tasking with several applications.

Windows Vista

[Previous Component](#) [Go to Next Component](#)

**4GB vs. 2GB
(@667MHz) = \$290
(\$145/GB)**

2008: \$49/GB (1MB, \$0.05)



Chat with us or call: 1-888-799-3355

Dell recommends Windows Vista® Home Premium.

You are here: USA > Home & Home Office

To compare multiple configurations, click the review and continue tab below then click 'Add to Wish List'.

- 1 Build My Dell
- 2 Add My Software & Accessories
- 3 Protect My Investment
- 4 Review & Continue

▶ SWITCH TO LIST VIEW



MEMORY

Help improve multi-tasking, speed up gaming, and take your PC's performance even higher with increased RAM.

SELECT MY MEMORY

- 3GB Dual Channel DDR2 SDRAM at 800MHz - 4 DIMMs
[Included in Price]
- 4GB Dual Channel DDR2 SDRAM at 800MHz - 4 DIMMs
[add \$49 or \$1/month¹]
Maximize Your Memory Performance

4GB vs. 3GB
(@800MHz) = \$49
(\$49/GB)

← Previous Component

Go to Next Component →

Buy Now

2009: \$31/GB (1MB, \$0.03)



Chat with us or call: 1-877-294-3355

Dell recommends Windows Vista® Home Premium.

You are here: USA > Home & Home Office

To compare multiple configurations, click the review and continue tab below then click 'Add to Wish List'.

- 1 Customize
- 2 Software & Accessories
- 3 Services
- 4 Review

▶ SWITCH TO LIST VIEW



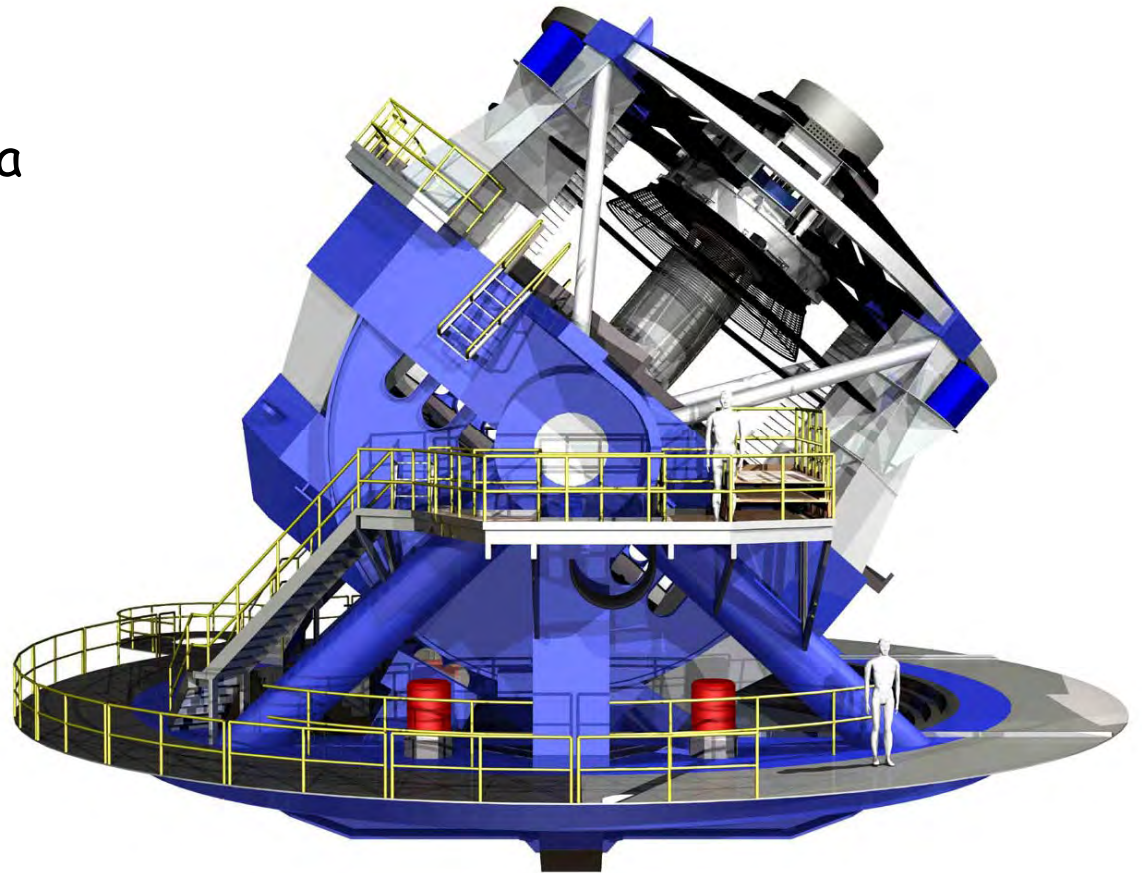
SELECT MY MEMORY

- 4GB Dual Channel DDR2 SDRAM at 800MHz - 4DIMMs [Included in Price]
- 6GB Dual Channel DDR2 SDRAM at 800MHz - 4 DIMMs [add \$75 or \$3/month¹]
- 8GB Dual Channel DDR2 SDRAM at 800MHz - 4 DIMMs [add \$125 or \$4/month¹]

8GB vs. 4GB
(@800MHz) = \$125
(\$31/GB)

■ Moore's Law drives sensors as well as processing and memory

- LSST will have a 3.2 Gigapixel camera






■ Disk capacity, 1975-1989

- doubled every 3+ years
- 25% improvement each year
- factor of 10 every decade
- Still exponential, but far less rapid than processor performance

■ Disk capacity since 1990

- doubling every 12 months
- 100% improvement each year
- factor of 1000 every decade
- 10x as fast as processor performance

- 
- Only a few years ago, we purchased disks by the megabyte (and it hurt!)
 - Current cost of 1 GB (a billion bytes) from Dell
 - 2005: \$1.00
 - 2006: \$0.50
 - 2008: \$0.25
 - Purchase increment
 - 2005: 40GB
 - 2006: 80GB
 - 2008: 250GB



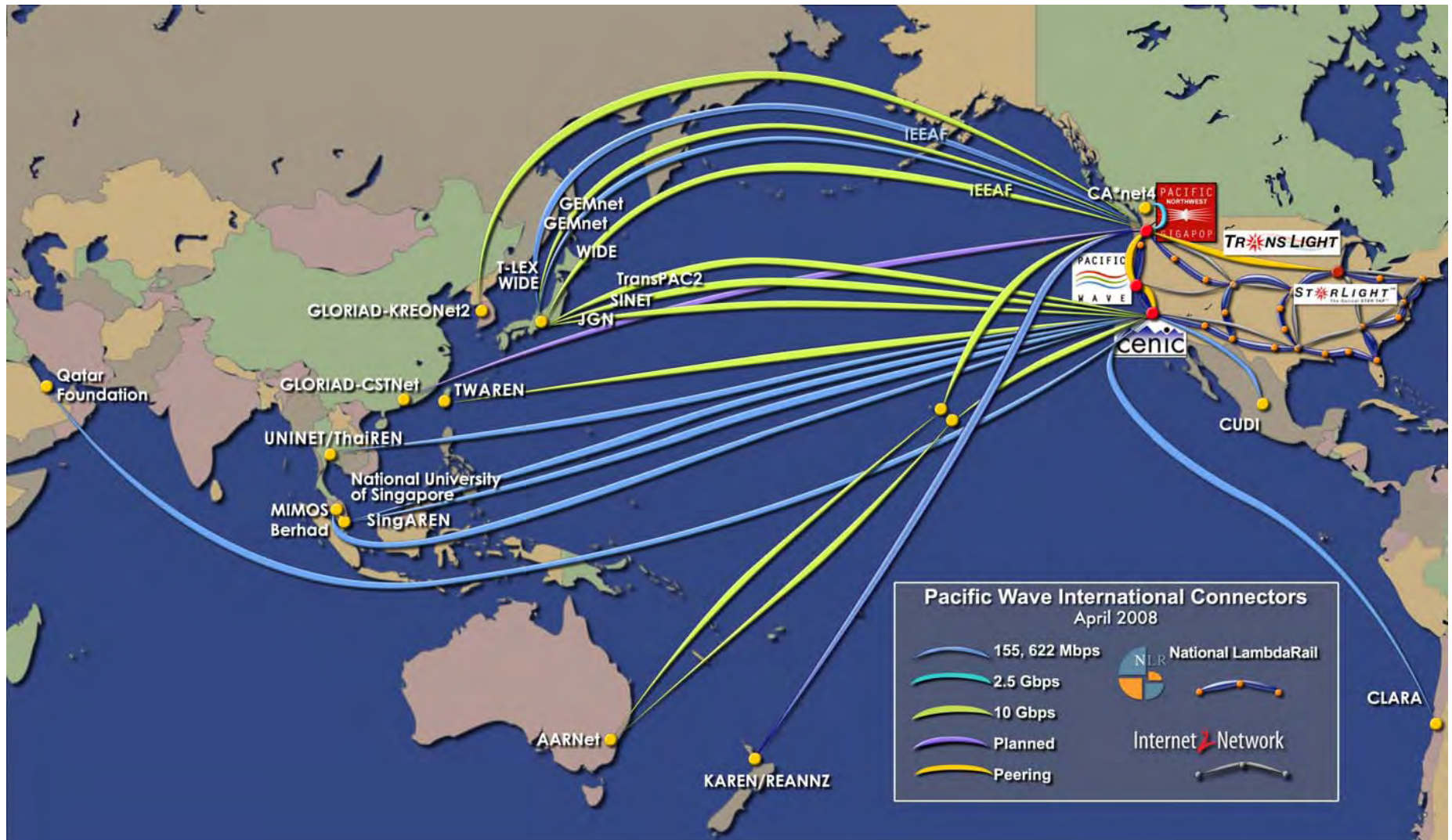
■ Optical bandwidth today

- Doubling every 9 months
- 150% improvement each year
- Factor of 10,000 every decade
- 10x as fast as disk capacity
- 100x as fast as processor performance

A connected region - then



A connected region - now



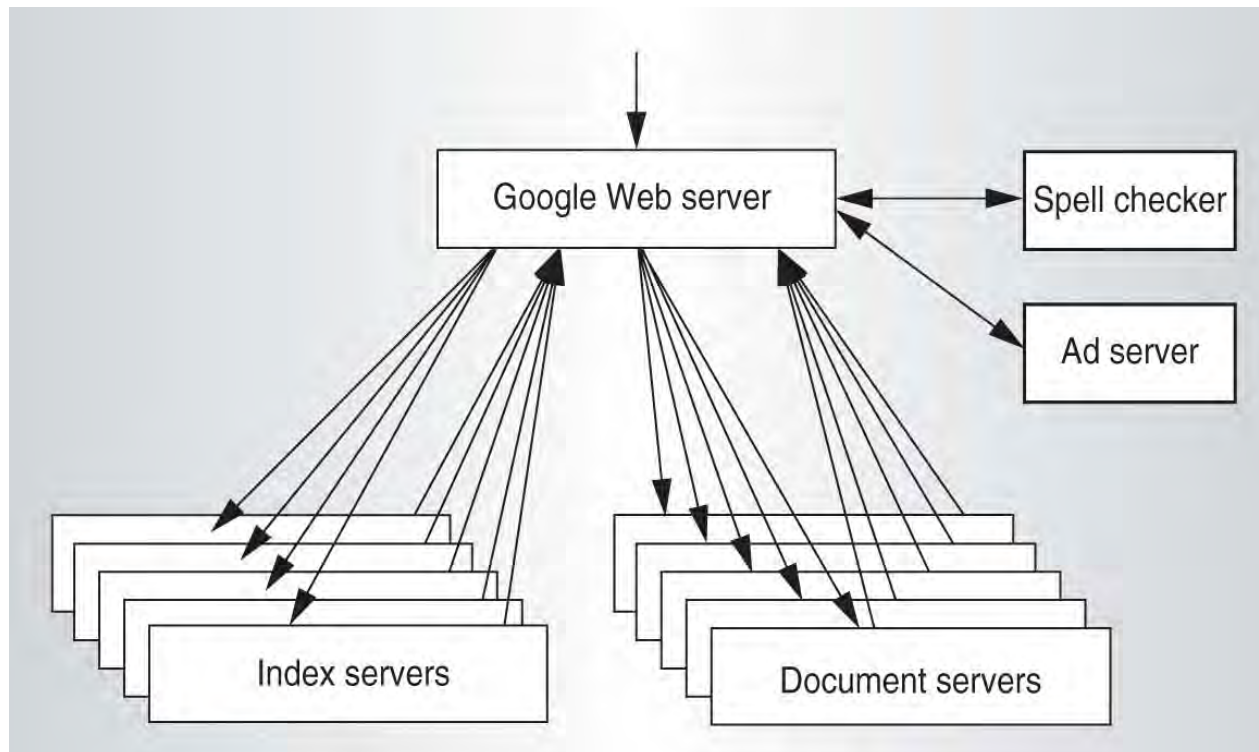
But eScience is equally enabled by *software for scalability and for discovery*

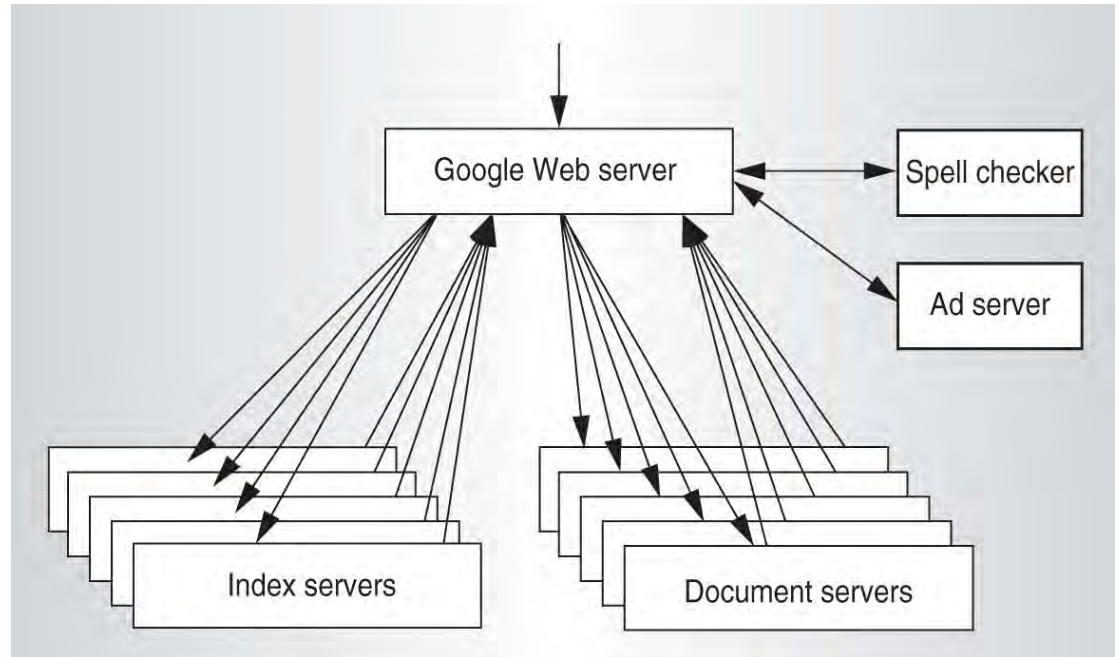
- It's likely that Google has several million machines
 - But let's be conservative - 1,000,000 machines
 - A rack holds 176 CPUs (88 1U dual-processor boards), so that's about 6,000 racks
 - A rack requires about 50 square feet (given datacenter cooling capabilities), so that's about 300,000 square feet of machine room space (more than 6 football fields of real estate - although of course Google divides its machines among dozens of datacenters all over the world)
 - A rack requires about 10kw to power, and about the same to cool, so that's about 120,000 kw of power, or nearly 100,000,000 kwh per month (\$10 million at \$0.10/kwh)
 - Equivalent to about 20% of Seattle City Light's generating capacity

- Many hundreds of machines are involved in a single Google search request (remember, the web is 400+TB)
 - There are multiple clusters (of thousands of computers each) all over the world
 - DNS routes your search to a nearby cluster

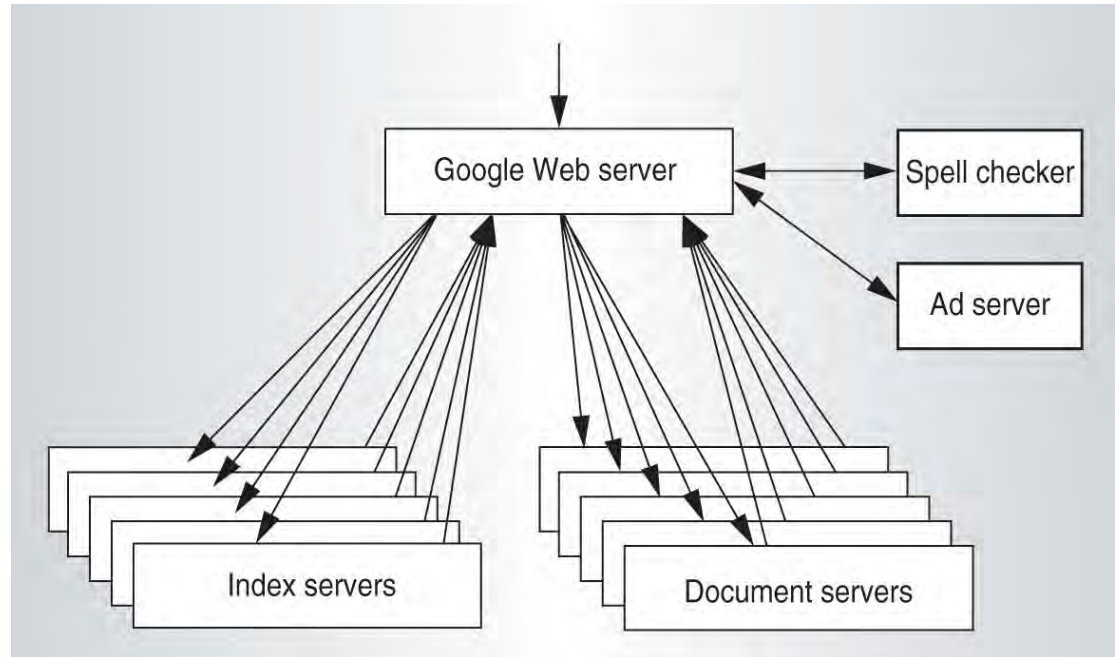


- A cluster consists of Google Web Servers, Index Servers, Doc Servers, and various other servers (ads, spell checking, etc.)
- These are cheap standalone computers, rack-mounted, connected by commodity networking gear

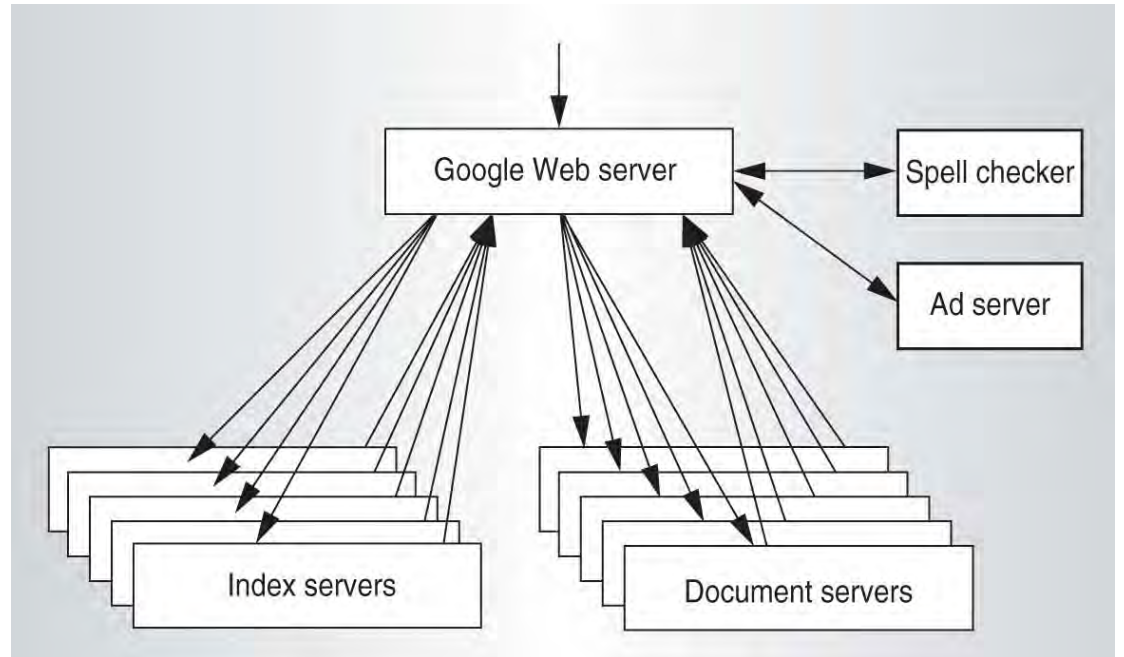





- Within the cluster, load-balancing routes your search to a lightly-loaded Google Web Server (GWS), which will coordinate the search and response
- The index is partitioned into "shards." Each shard indexes a subset of the docs (web pages). Each shard is replicated, and can be searched by multiple computers - "index servers"
- The GWS routes your search to one index server associated with each shard, through another load-balancer
- When the dust has settled, the result is an ID for every doc satisfying your search, rank-ordered by relevance



- The docs, too, are partitioned into "shards" - the partitioning is a hash on the doc ID. Each shard contains the full text of a subset of the docs. Each shard can be searched by multiple computers - "doc servers"
- The *GWS* sends appropriate doc IDs to one doc server associated with each relevant shard
- When the dust has settled, the result is a URL, a title, and a summary for every relevant doc




- Meanwhile, the ad server has done its thing, the spell checker has done its thing, etc.
- The *GWS* builds an HTTP response to your search and ships it off
- Many hundreds of computers have enabled you to search 400+TB of web in ~100 ms.

- 
- Enormous volumes of data
 - Extreme parallelism
 - 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

How on earth would you enable mere mortals write hairy applications such as this?



- Recognize that many Google applications have the same structure
 - Apply a "map" operation to each logical record in order to compute a set of intermediate key/value pairs
 - Apply a "reduce" operation to all the values that share the same key in order to combine the derived data appropriately
- Example: Count the number of occurrences of each word in a large collection of documents
 - Map: Emit <word, 1> each time you encounter a word
 - Reduce: Sum the values for each word

- 
- Build a runtime library that handles all the details, accepting a couple of customization functions from the user - a Map function and a Reduce function
 - That's what MapReduce is
 - Supported by the Google File System and the Chubby lock manager
 - Augmented by the BigTable not-quite-a-database system

Scalable computing for everyone

The image shows three overlapping web pages. The top-left page is Google App Engine, featuring the Google Code logo and a search bar. The middle page is the Azure Services Platform, with a dark blue header and navigation menu. The bottom-right page is Amazon Web Services, displaying a 'Hadoop + The AWS Cloud' banner and a list of infrastructure services.

Google App Engine

Code
e.g. "templates" or "datastore"

Search

Google App Engine Home Docs FAQ Articles Blog Community Terms Download

Run your code
Easy to use

An Early Look at Java

App Engine is unveiling its second runtime, integration with Google's Java solution for AJAX web applications, and we're eager to get your help as you who [sign up](#), but we'll be including:

- Get the full scoop in our [blog](#).
- Click over to YouTube to watch our [video](#).
- See our docs for other new [data](#).

Get a sample
[Watch](#)

Azure Services Platform

Search Microsoft

Home About Solutions Services Resources Community Sign In

Explore Azure Services

The Azure Services Platform provides a wide range of internet services that can be consumed from both on-premises environments or the internet.

amazon web services

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Get Started

Sign up for a free AWS account.

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Simply sign up & start developing in the cloud with these resources and tools:

- [Technical Documentation](#)
- [Cloud Architectures Whitepaper](#) (pdf)
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- [AWS Community Forums](#)

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Learn how Amazon Web Services enables you to reach business goals faster:

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Explore Products

- **Infrastructure Services**
 - Amazon Elastic Compute Cloud (Amazon EC2)
 - Amazon SimpleDB
 - Amazon Simple Storage Service (Amazon S3)
 - Amazon CloudFront
 - Amazon Simple Queue Service (Amazon SQS)
 - Amazon Elastic MapReduce
 - AWS Premium Support
- **Payments & Billing**
- **On-Demand Workforce**
- **Alexa Web Services**

News & Events

What's New?	Media Coverage	Events
May 07, 2009	Amazon CloudFront Adds Access Logging Capability	
Apr 29, 2009	AWS Goes To School With Programs For Educators, Researchers, and Students	
Apr 22, 2009	Amazon EC2 Running IBM Now Available	
Apr 15, 2009	Amazon EC2 Reserved Instances Now Available in Europe	
Apr 09, 2009	Announcing Amazon SQS WSDL Version 2009-02-01 and Amazon SQS in Europe	

Amazon Elastic Compute Cloud (EC2)



- \$0.80 per hour for
 - 8 cores of 3 GHz 64-bit Intel or AMD
 - 7 GB memory
 - 1.69 TB scratch storage
- Need it 24x7 for a year?
 - \$4800

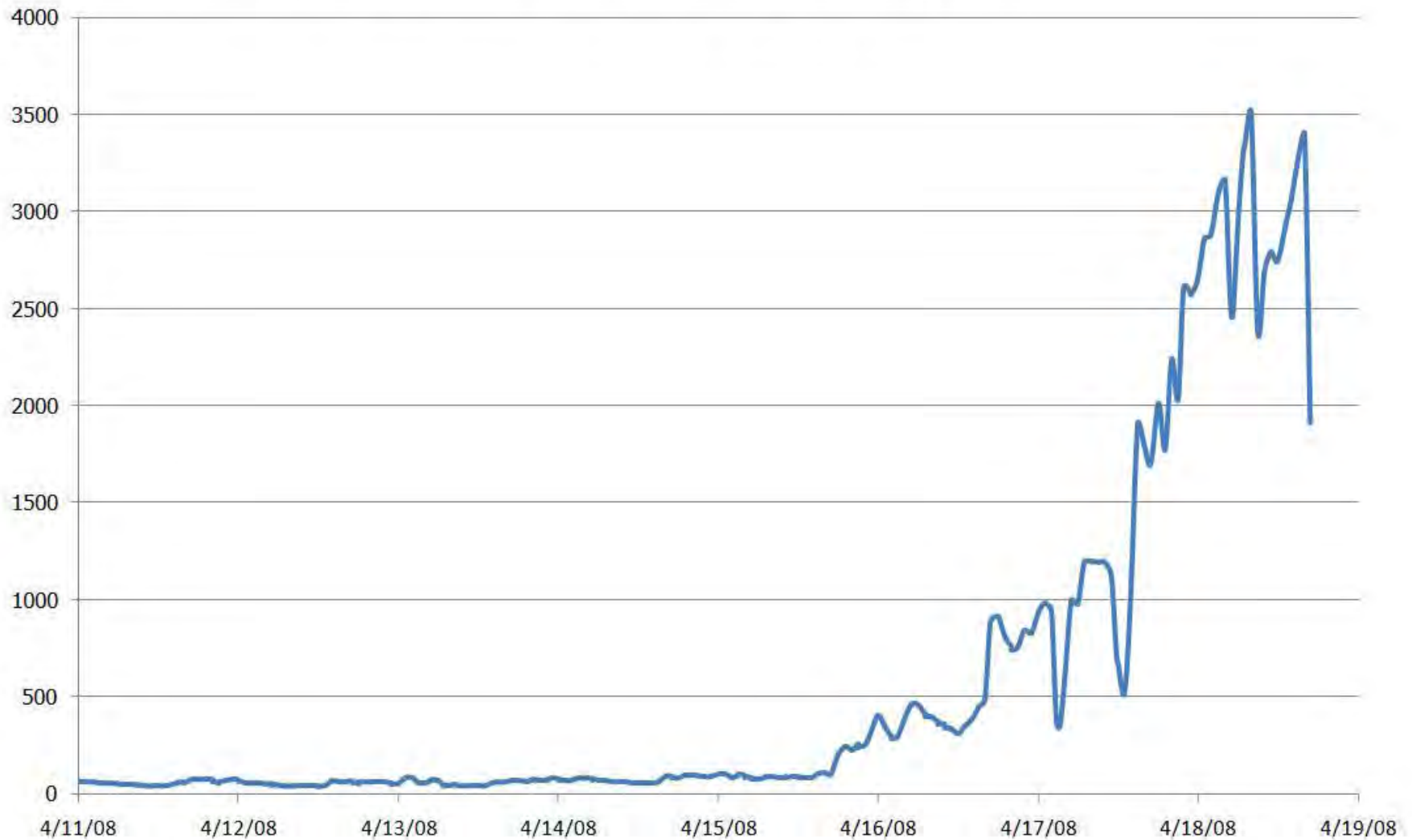
- \$0.10 per hour for
 - 1 core of 1.2 GHz 32-bit Intel or AMD (1/20th the above)
 - 1.7 GB memory
 - 160 GB scratch storage
- Need it 24x7 for a year?
 - \$590




■ This includes

- Purchase + replacement
- Housing
- Power
- Operation
- Reliability
- Security
- Instantaneous expansion and contraction

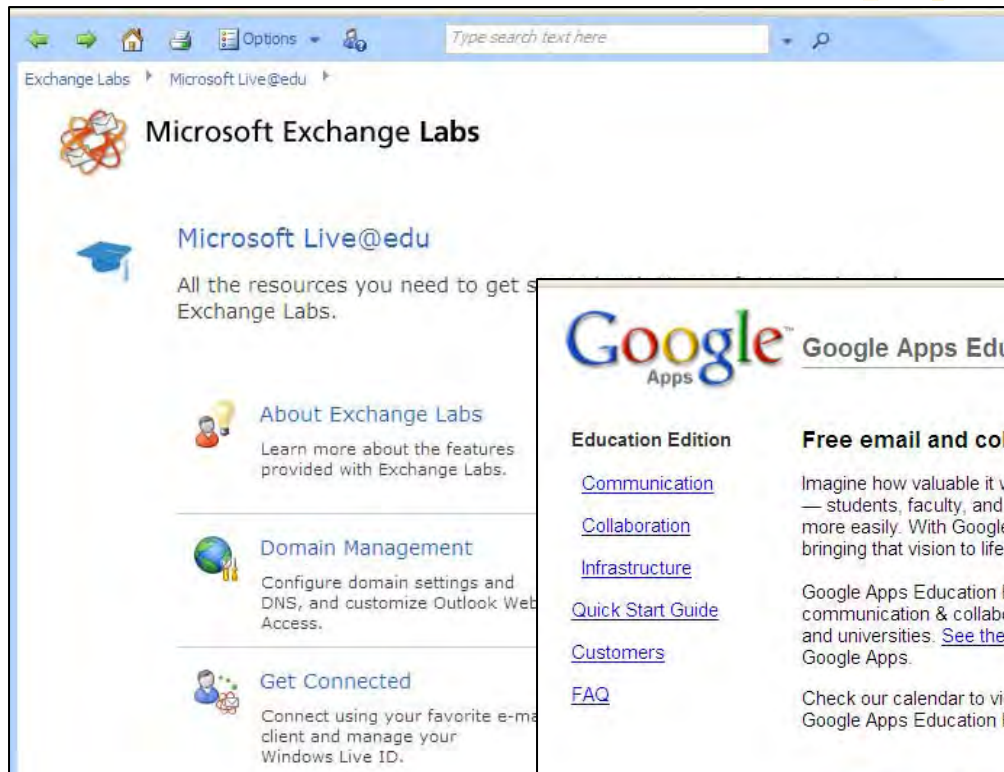
Animoto: EC2 Instance Usage



Slide courtesy of Werner Vogels

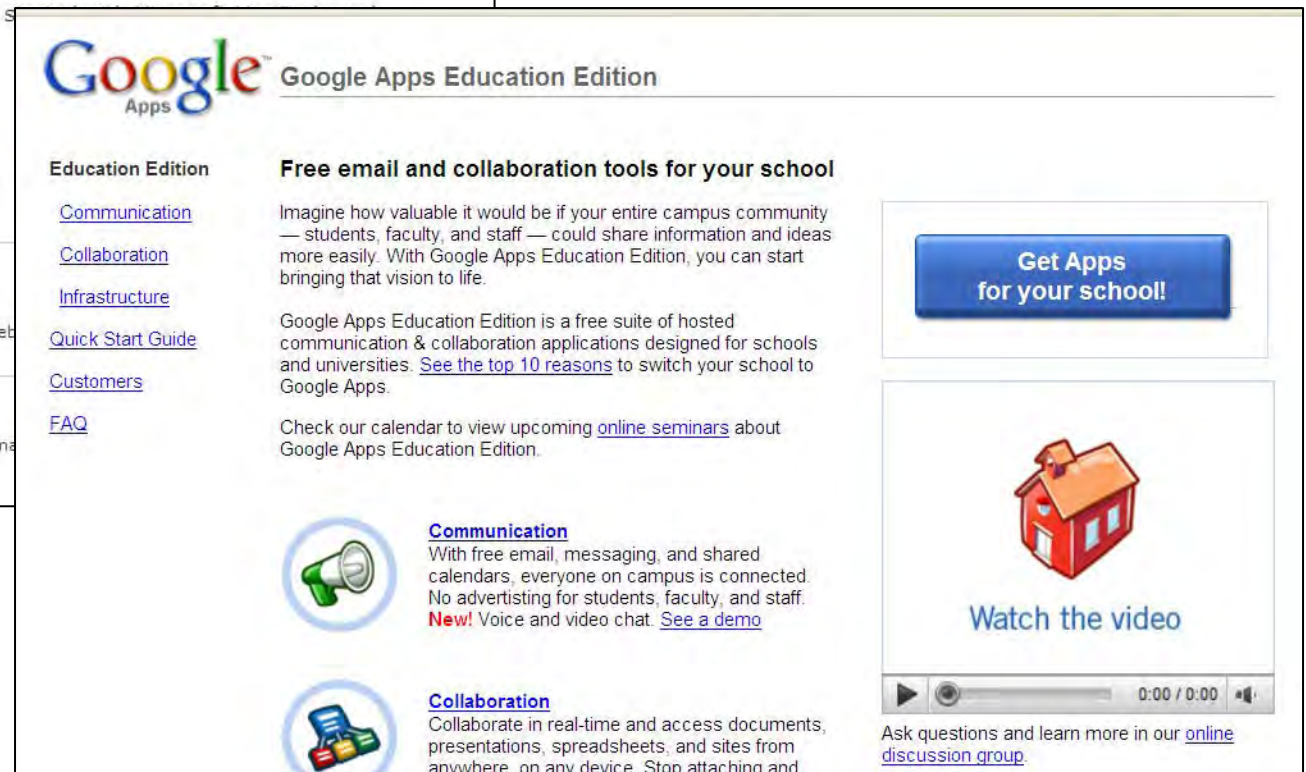
- 
- 1000 processors for 1 hour costs the same as 1 processor for 1000 hours
 - Revolutionary!
 - Your application doesn't run decently on this environment?
 - Start figuring out how to change that!

Still running your own email servers?



A screenshot of a web browser displaying the Microsoft Exchange Labs website. The browser's address bar shows "Exchange Labs" and "Microsoft Live@edu". The page features the Microsoft Exchange Labs logo and a navigation menu with the following items:

- About Exchange Labs**: Learn more about the features provided with Exchange Labs.
- Domain Management**: Configure domain settings and DNS, and customize Outlook Web Access.
- Get Connected**: Connect using your favorite e-mail client and manage your Windows Live ID.

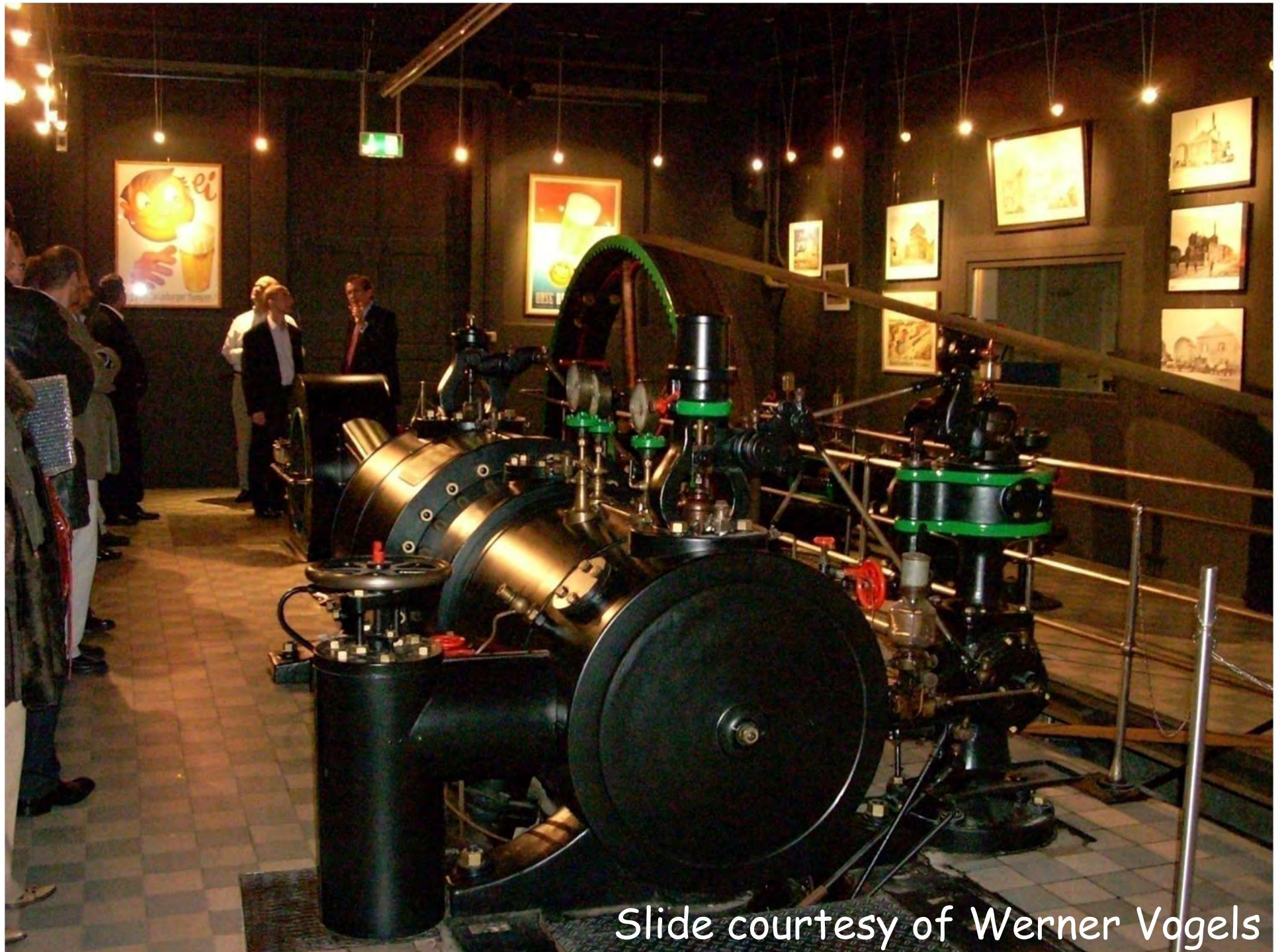


A screenshot of the Google Apps Education Edition website. The page features the Google Apps logo and the text "Google Apps Education Edition". The main heading is "Free email and collaboration tools for your school". Below this, there is a list of links: "Communication", "Collaboration", "Infrastructure", "Quick Start Guide", "Customers", and "FAQ".

The page also includes a "Get Apps for your school!" button and a "Watch the video" section with a video player showing a red schoolhouse icon. The video player has a progress bar at 0:00 / 0:00. Below the video player, there is a link to "Ask questions and learn more in our [online discussion group](#)."

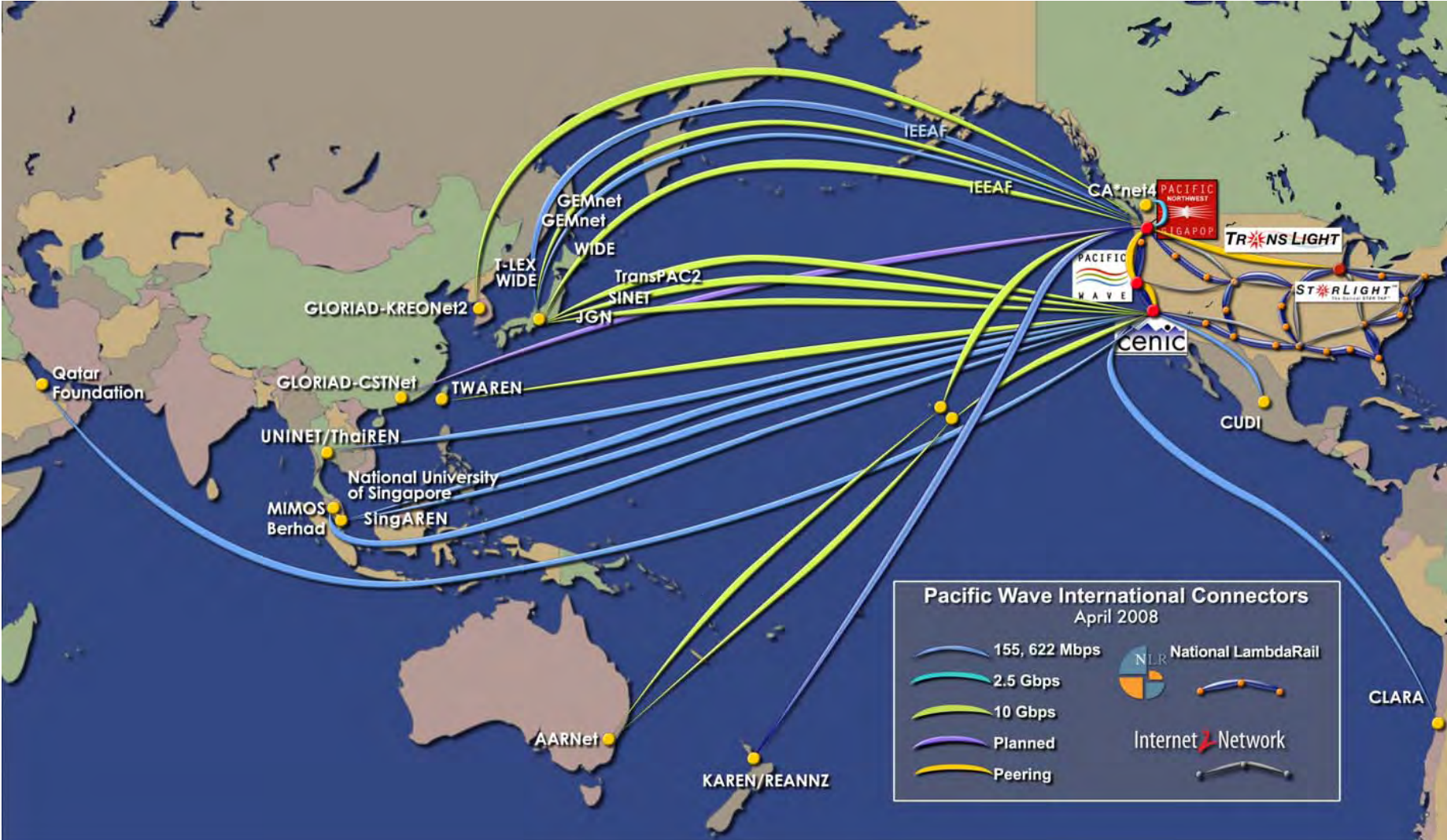
Communication
With free email, messaging, and shared calendars, everyone on campus is connected. No advertising for students, faculty, and staff. **New!** Voice and video chat. [See a demo](#)

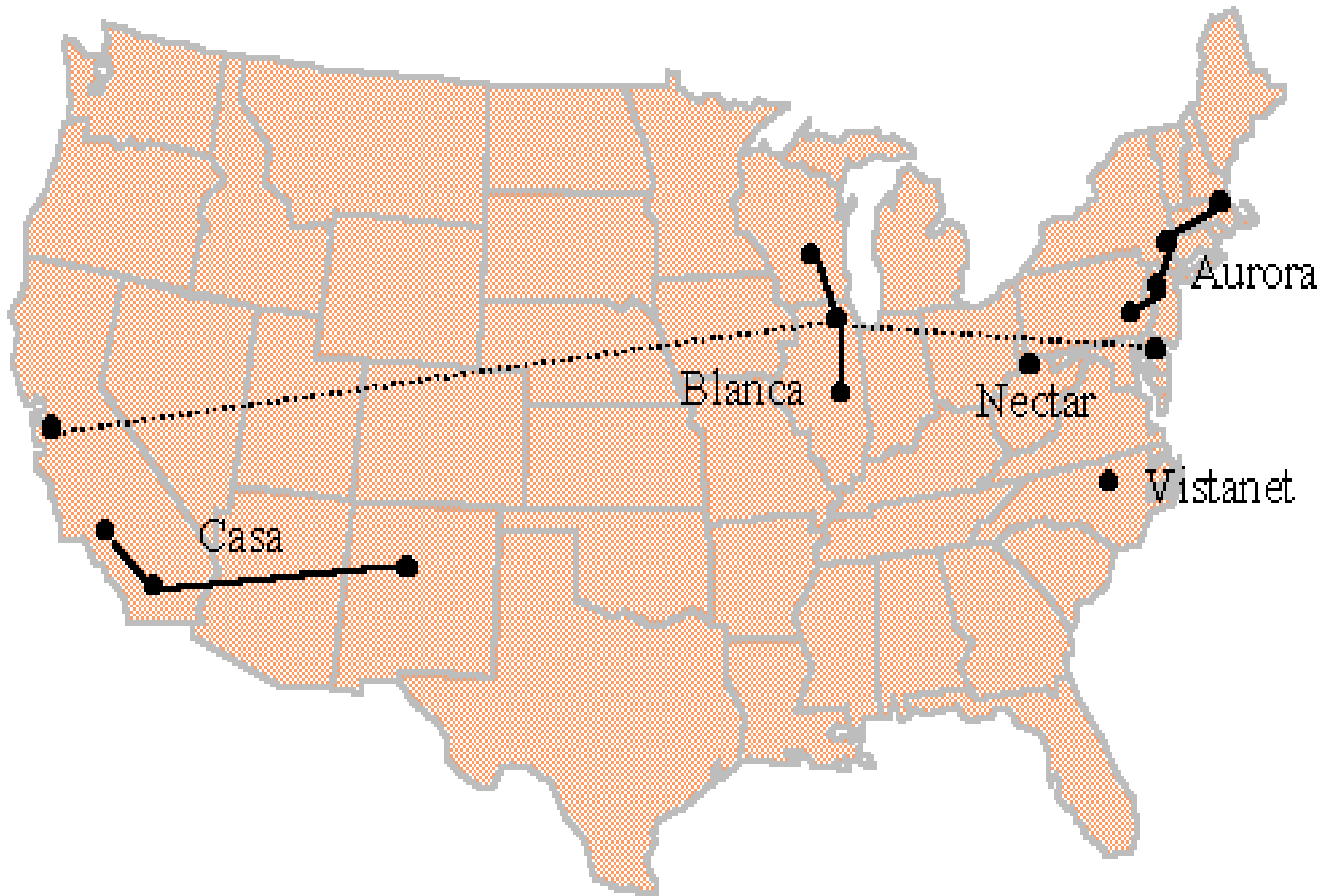
Collaboration
Collaborate in real-time and access documents, presentations, spreadsheets, and sites from anywhere, on any device. Stop attaching and



Slide courtesy of Werner Vogels

Networking in the West





DARPA Gigabit Testbeds, mid-1990's

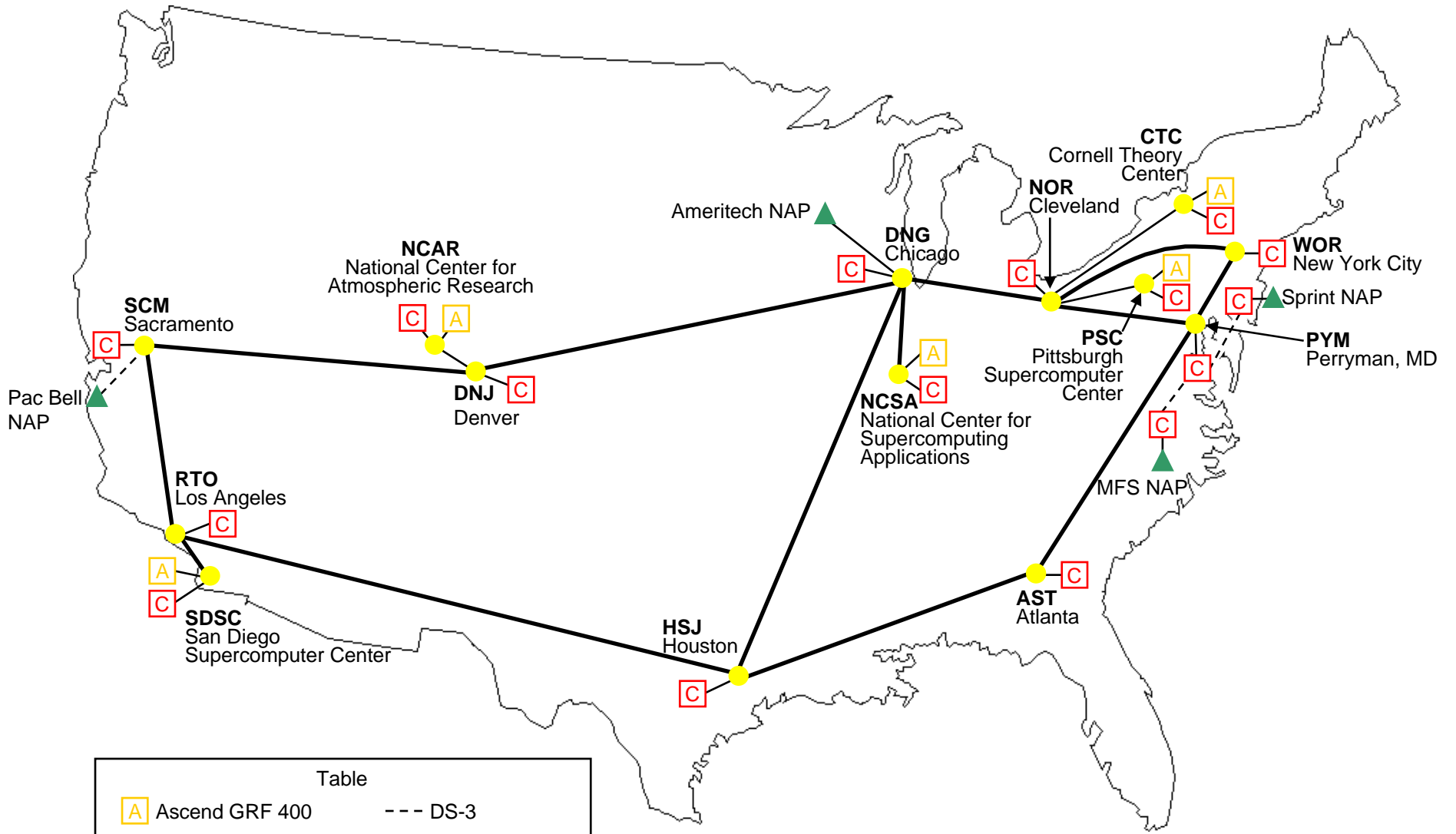
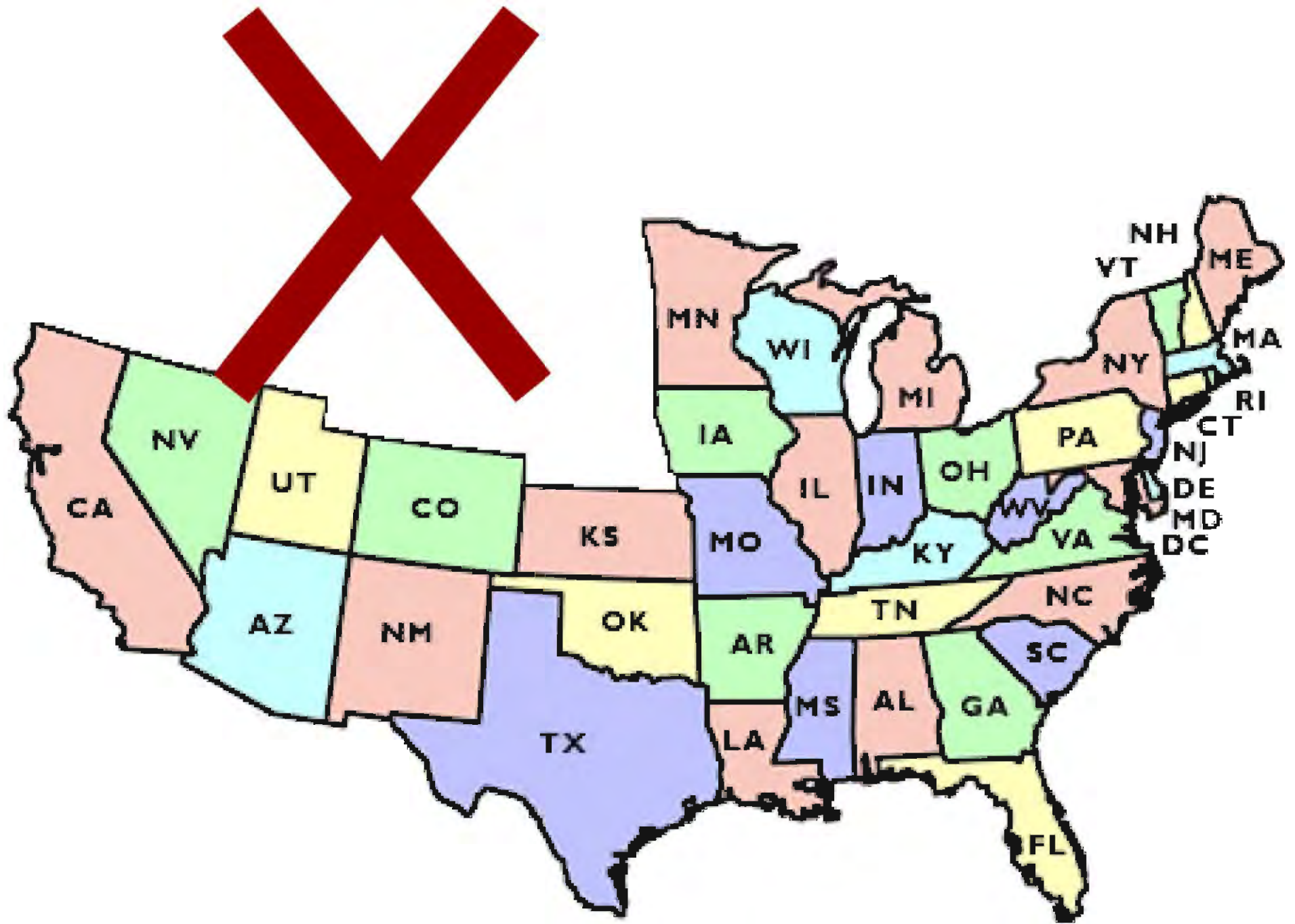
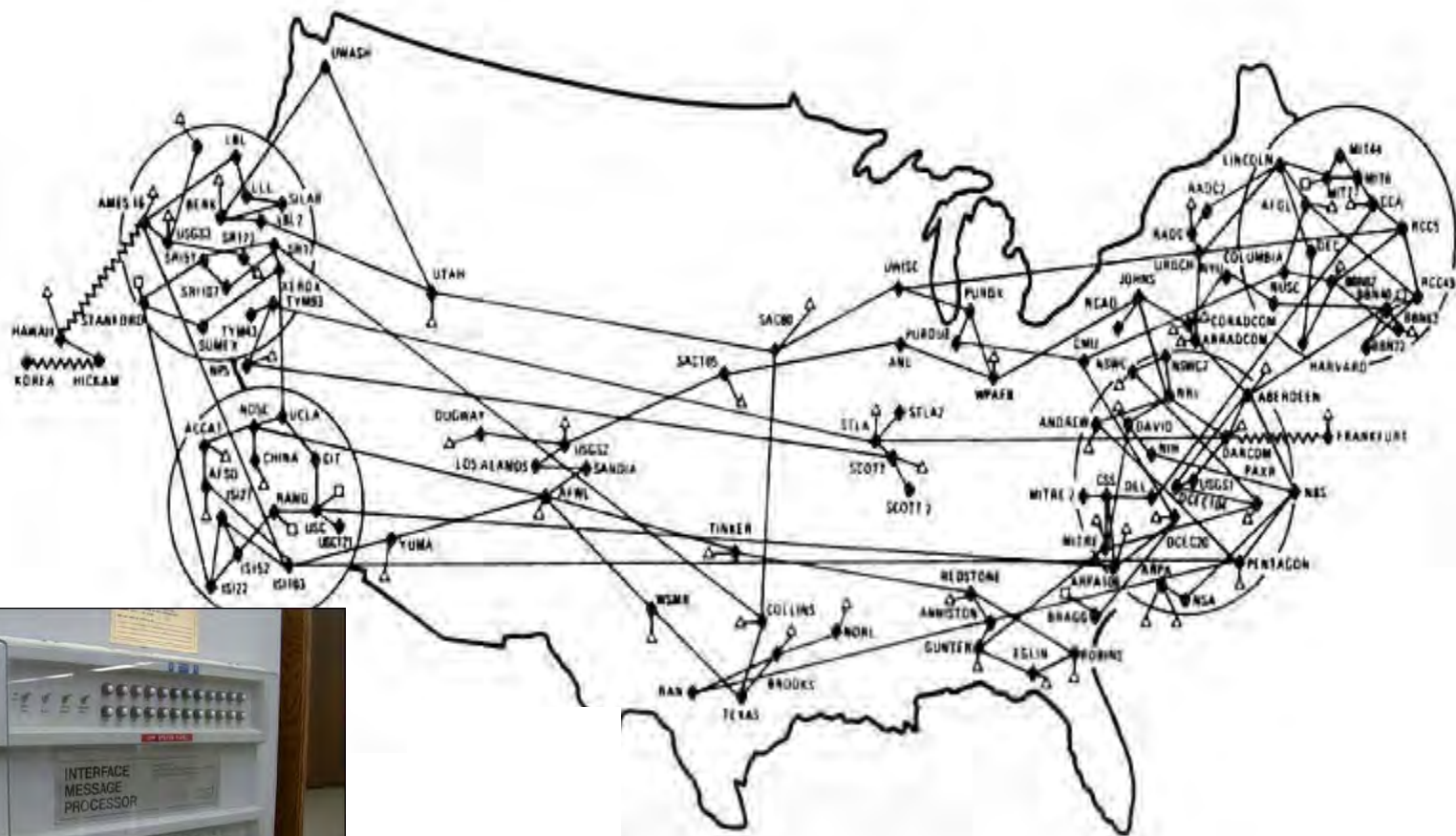


Table	
Ascend GRF 400	--- DS-3
Cisco 7507	— OC-3C
FORE ASX-1000	— OC-12C
Network Access Point	

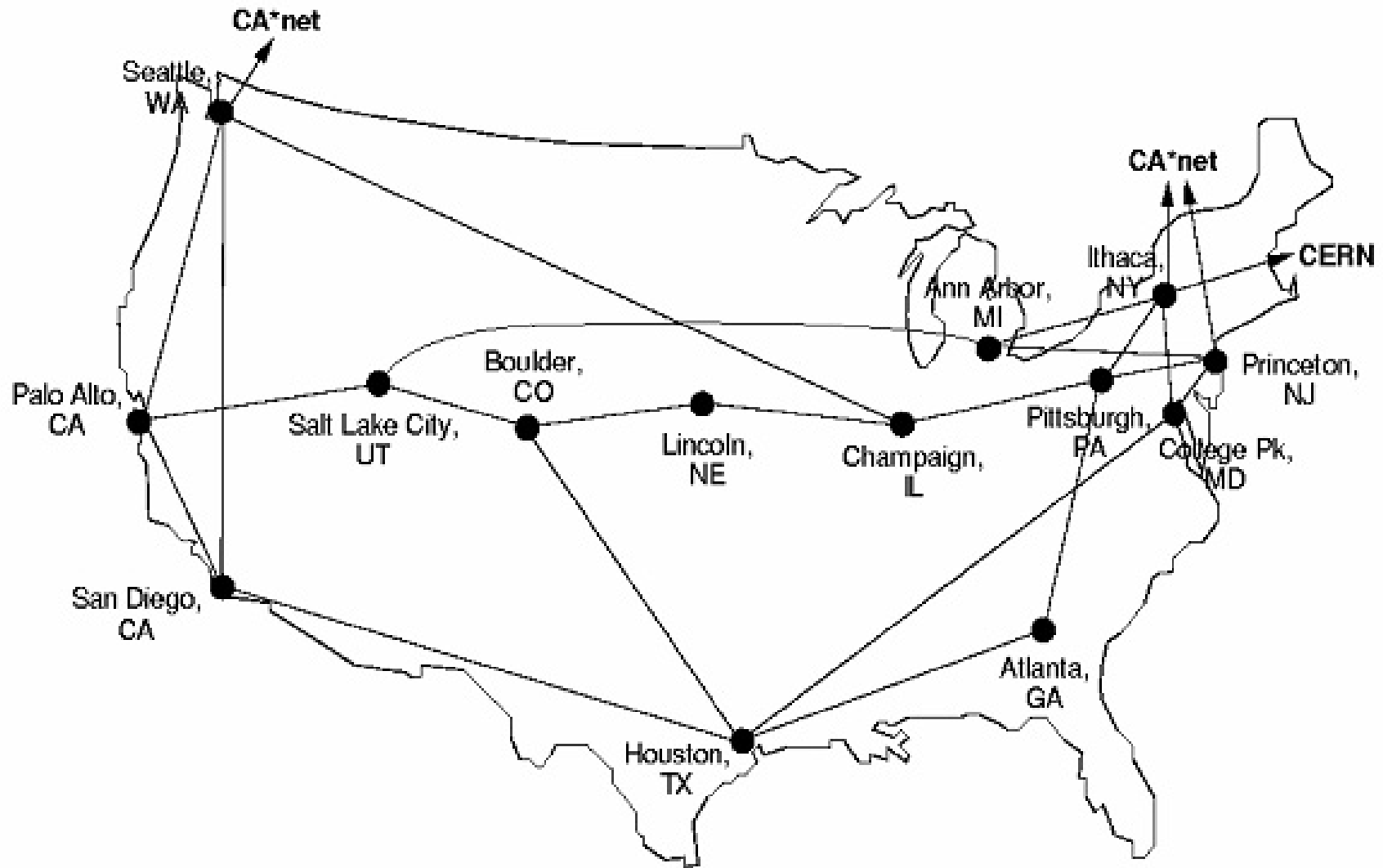
NSF vBNS, 1997





ARPANET, 1983

NSFNET T1 Network 1991

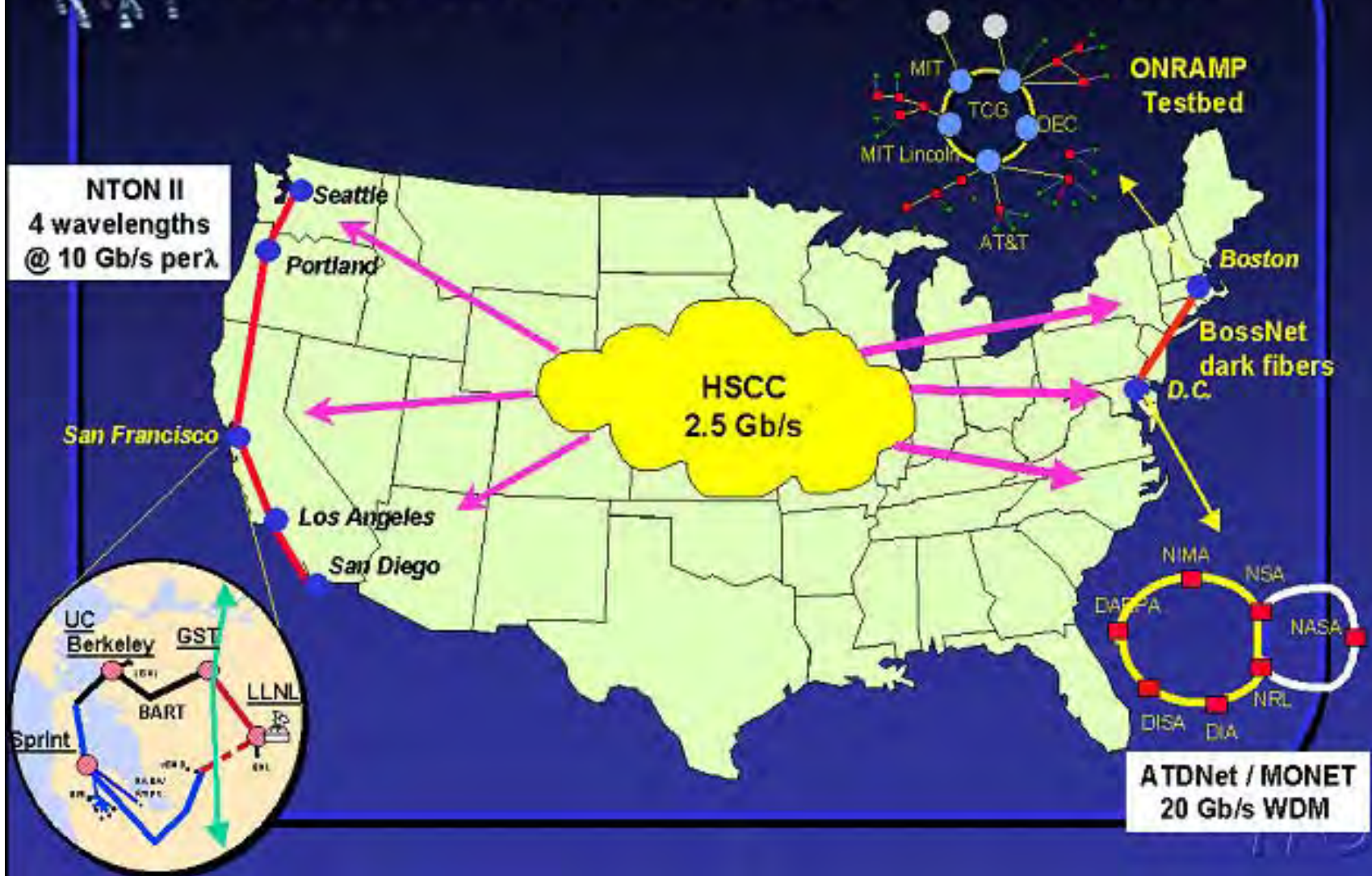


© Merit Network, Inc.

NSFNET, 1991

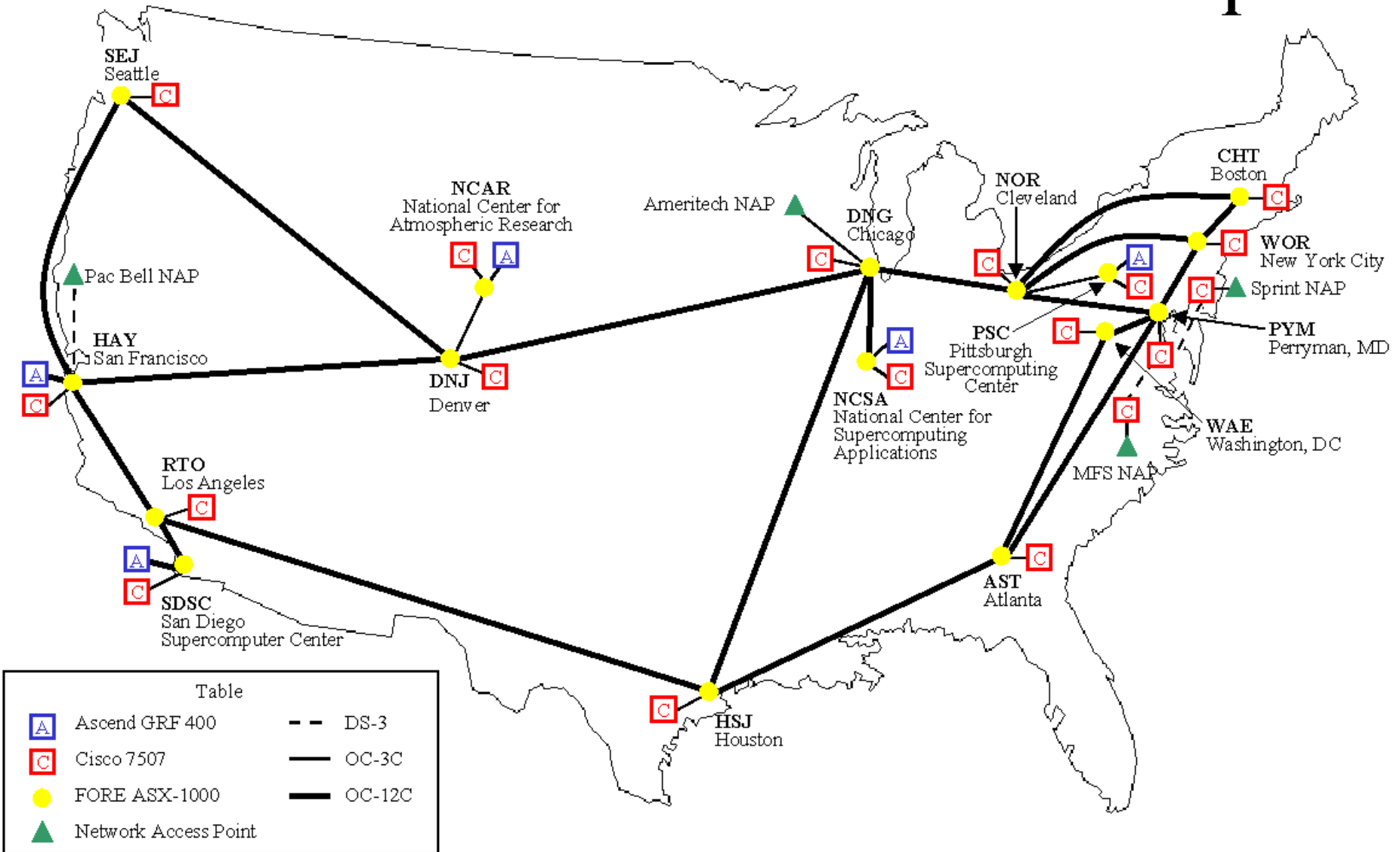


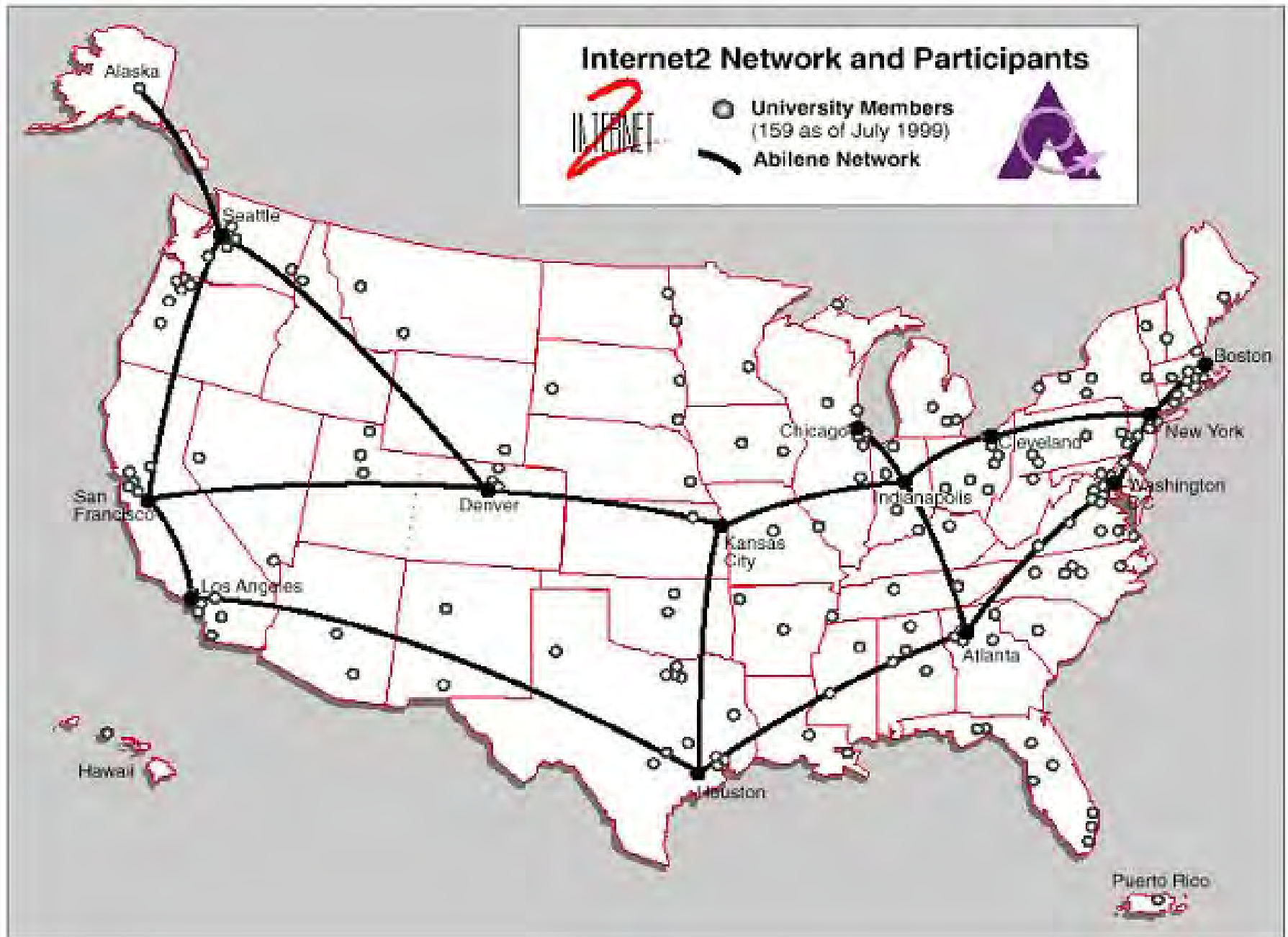
DARPA / NGI Testbed



DARPA / NGI Testbed, late 1990's

vBNS Backbone Network Map





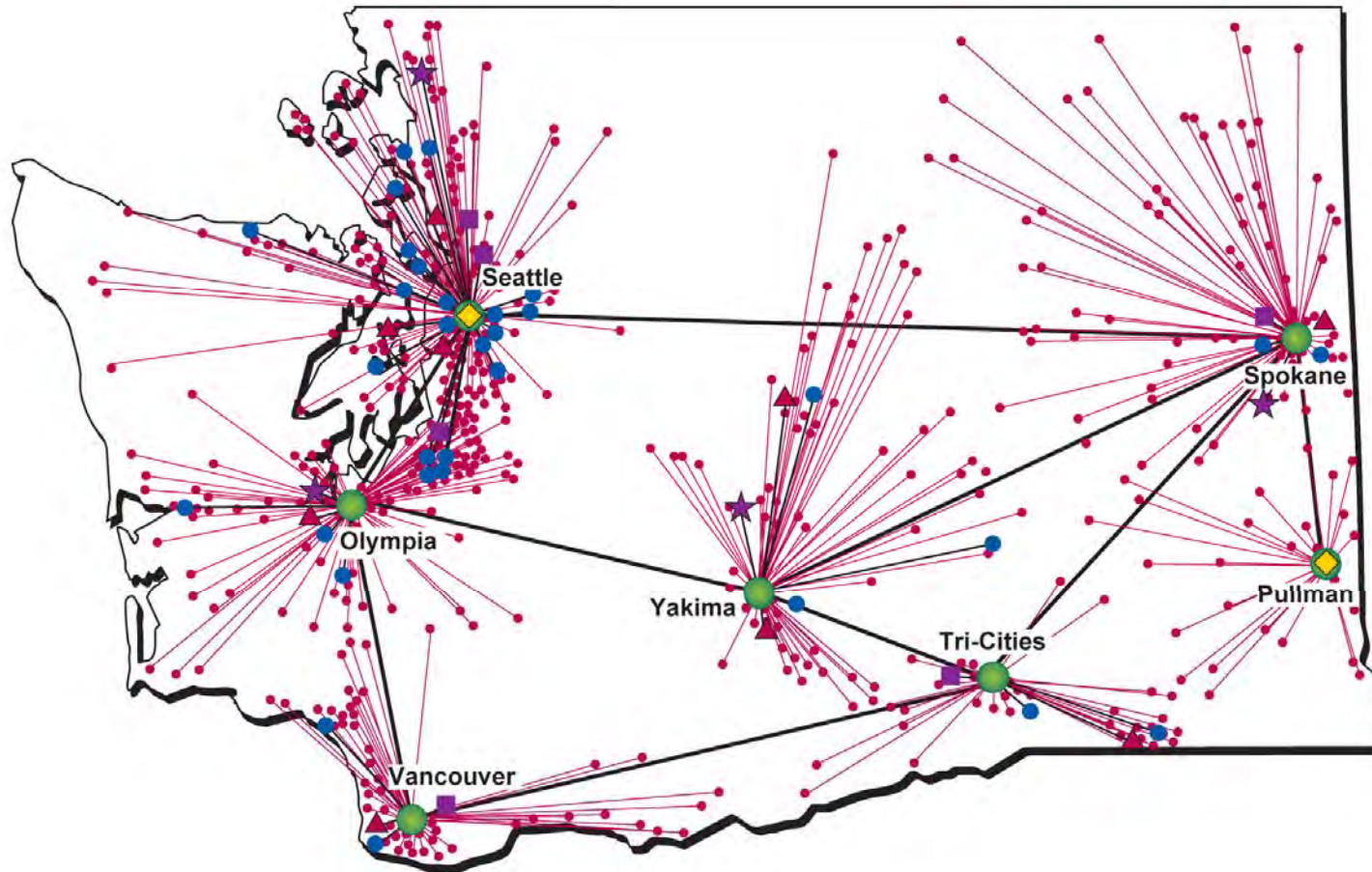
Internet2, 1999

NLR – Optical Infrastructure - Phase 1



National LambdaRail, 2004

Who reaches K-12 institutions, CC's, tribal colleges, libraries, telemedicine sites?



Educational Telecommunications Network

CaIREN-XD

Experimental/Developmental Network

Bleeding-edge Services for Network Researchers

Tier 1

CaIREN-HPR

High-Performance Research Network

Leading-edge Services for Large Application Users

Tier 2

CaIREN-DC

Digital California Network

All K-20 California Research and Education Users

Tier 3




The Corporation for Education Network Initiatives in California • 16700 Valley View Ave. Ste 400 • La Mirada, CA 90638

Who reaches unserved and underserved regions?



The broadband stimulus

<p>National Tele</p> <p>FED</p> <p>In the matter of</p> <p>American Recovery and Reinvestm Act of 2009 Broadband Initiatives</p> <p>The Commission's Consultative Ro Broadband Provisions of the Recov</p> <hr/> <p>CONSOLIDATED</p>	<p style="text-align: center;">Unleashing Waves of Innovation Transformative Broadband for America's Future</p> <p style="text-align: center;">Version 18: April 18, 2009¹</p> <p><u>Executive Summary</u></p> <p>A forward-thinking National Broadband Strategy should focus on the transformative power of advanced networks to unleash new waves of innovation, jobs, economic growth, and national competitiveness. Such a strategy should create new tools to deliver health care, education, and a low carbon economy. The American Recovery and Reinvestment Act broadband decisions should target high-impact investments with these criteria in mind. They should seek to rebuild U.S. global leadership in networking and in the economic innovations that networking can create. Broadband investments should “pull from the future.”</p> <p style="text-align: center;">. . .</p> <div style="display: flex; justify-content: space-around; align-items: center;"><div style="text-align: center;">  </div><div style="text-align: center;"> </div><div style="text-align: center;">   </div></div>
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In its recent NOI seeking input on a National Broadband Plan, the FCC acknowledges that there is not enough money in the 2009 Recovery Act to underwrite the deployment of broadband to all Americans. Microsoft agrees. Given that reality, the Administration and the FCC now face the challenge of how to derive the most social benefit from the approximately \$7 billion that has been allocated for broadband. As we have stated elsewhere, we believe the highest and best use of these limited funds is, at a minimum, to ensure all the nation's schools, public libraries and hospitals have robust, affordable connections to the Internet. With such connections, all Americans will have available to them the distance learning and telemedicine capabilities that 21st century learning and healthcare require. In this regard, by focusing broadband deployment funds on these anchor institutions, the federal government also will be supporting the Administration's broader goals of modernizing our educational and healthcare systems.

By "robust" connections, we mean at least 100 Mbps, symmetrical, capacity. Only this level of capacity is capable of supporting the video and multimedia-rich scenarios that are part and parcel of e-learning and e-medical care. By "schools," we mean K-12 institutions, community colleges and at least those universities that engage in basic research and, often at the same time, serve as hubs for creating connections to other schools and colleges. By "hospitals," we mean traditional hospitals, as well as the approximately 3,500 stand-alone ambulatory care facilities that often serve as stand-ins for hospitals in rural and inner city areas. By connecting these anchor institutions to fulsome capacity, the US government can assure that every community in the nation has multiple, credible on-ramps to a new Internet "highway" system. No community will be left off the network.

In its recent NOI seeking input on a National Broadband Plan, the FCC acknowledges that there

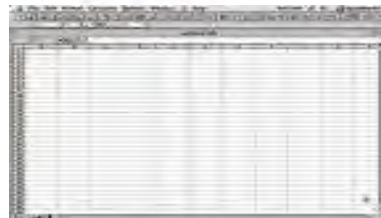
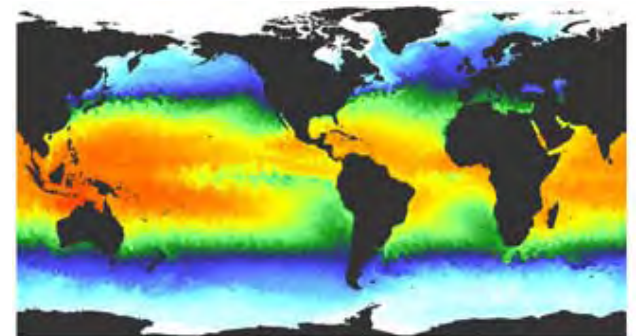
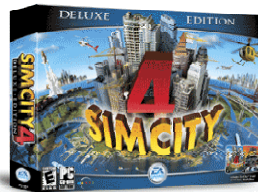
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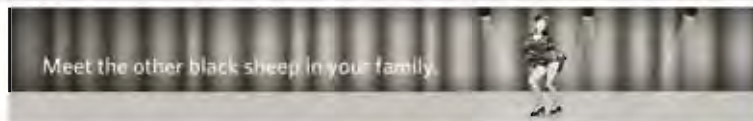
A National Broadband Strategy should begin with America's colleges and universities, community colleges, K-12 schools, public libraries, hospitals, clinics, and the state, regional and national research and education networks that connect them and extend to reach government agencies, agricultural extension sites, and community centers across the nation. A proven track record of innovating in networking and its applications, of deploying and continually upgrading advanced networks, and of extending those networks to the unserved and underserved across our nation, lies not with telephone or cable companies, nor with most state governments, but with our nation's colleges and universities and the state, regional and national research and education networks that this community has built, in many instances forged through partnerships with telecommunications providers and state agencies to achieve these goals.

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- 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





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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?," nearby office workers in a recent informal survey gave the following answers: the wheel, the engine, the ballpoint pen, diapers and the cheese Danish.

Life Changers

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

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

THE NEW YORK TIMES

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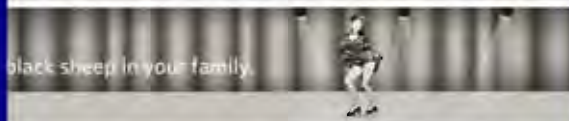
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Named Most Important Inventions

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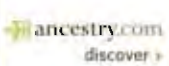
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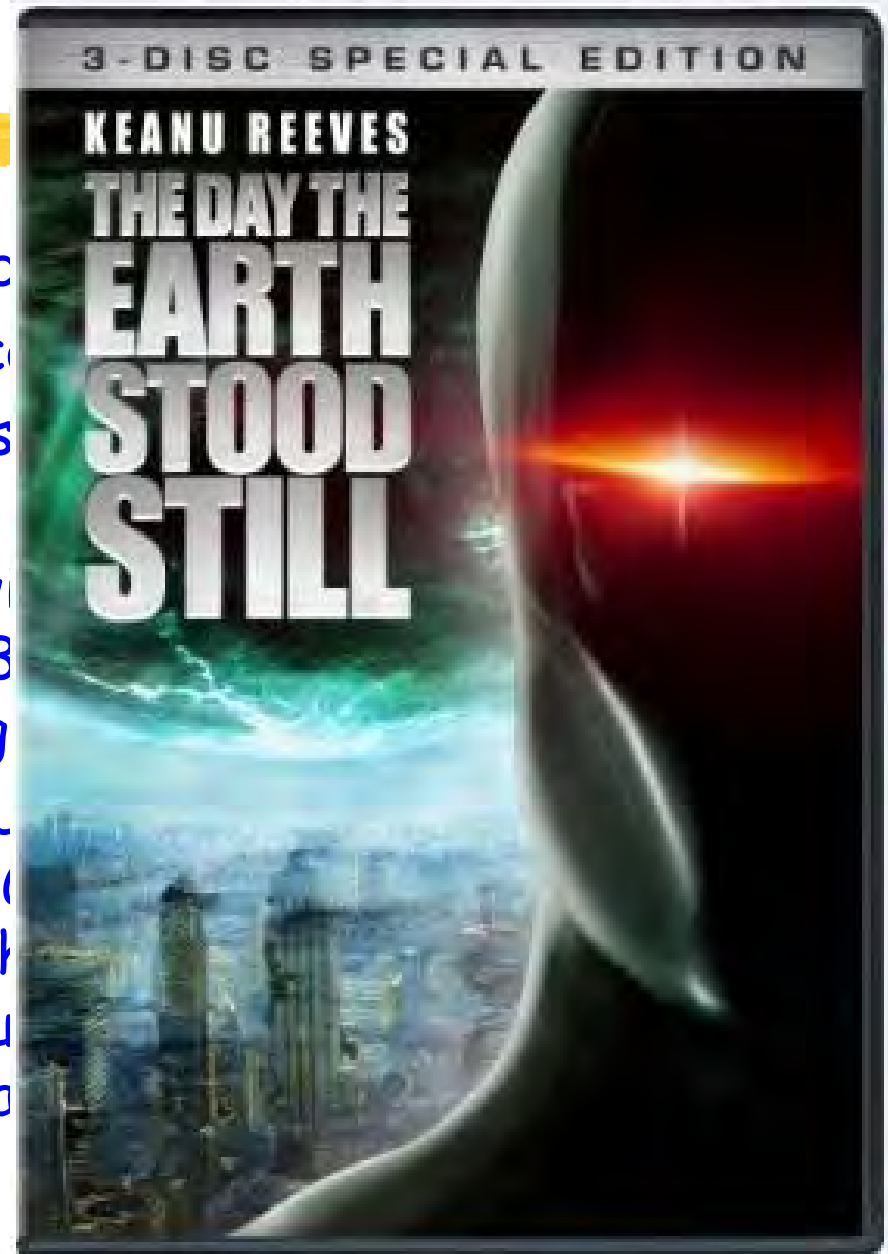
Imagine spending a day without information technology



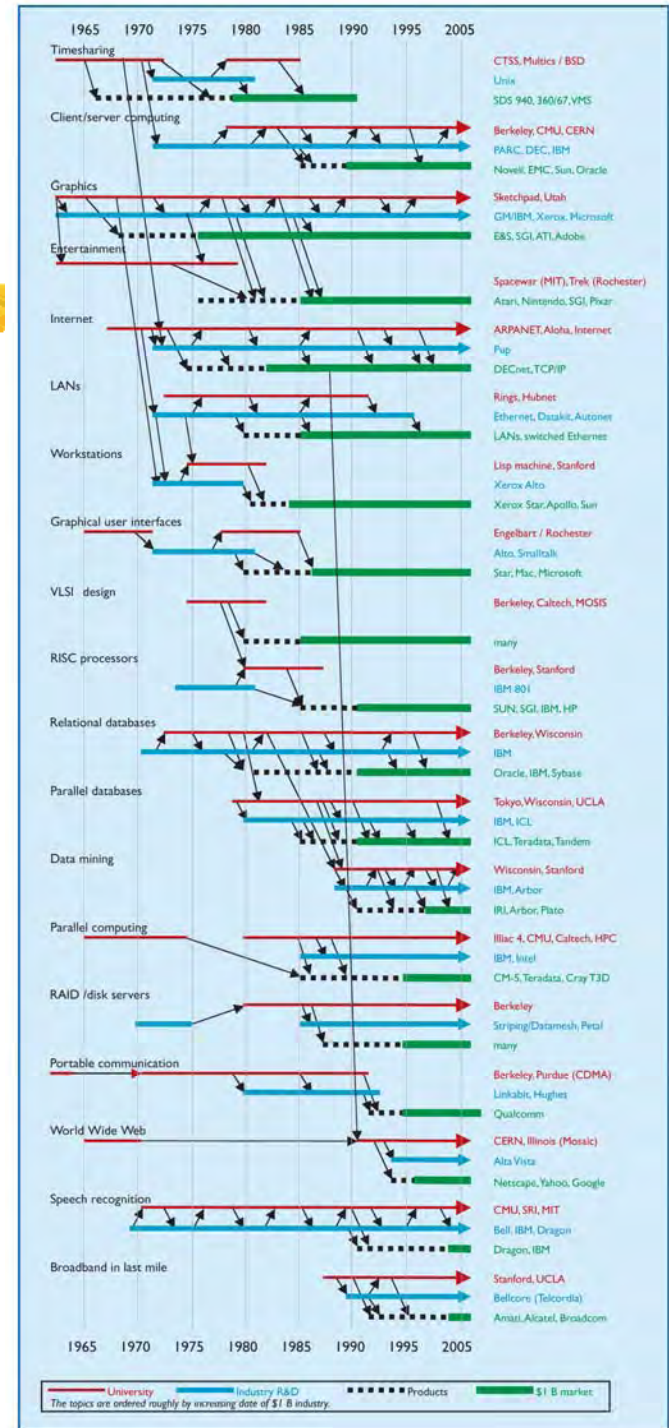
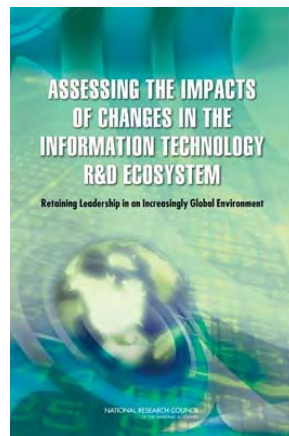
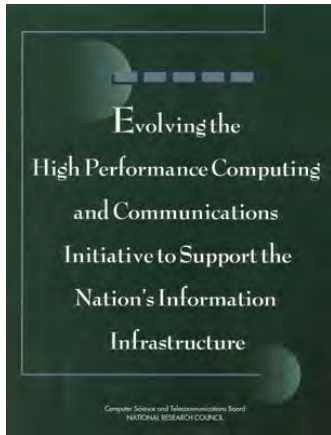
- A day without the Internet and all that it enables
- A day without diagnostic medical imaging
- A day during which automobiles lacked electronic ignition, antilock brakes, and electronic stability control
- A day without digital media - without wireless telephones, high-definition televisions, MP3 audio, DVD video, computer animation, and videogames
- A day during which aircraft could not fly, travelers had to navigate without benefit of GPS, weather forecasters had no models, banks and merchants could not 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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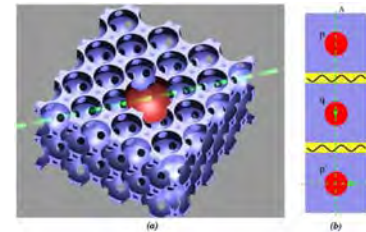
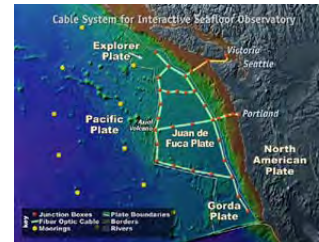
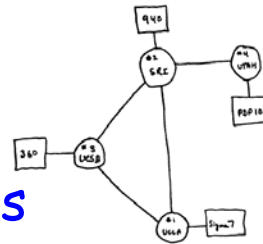


Research has built the foundation



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 of the developing world
- Personalized health monitoring => quality of life
- Neurobotics
- Synthetic biology



Why do students choose the field?

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Software Jobs Go Begging, Threatening Technology Boom

By AMY HARMON

Published: Tuesday, January 13, 1998

"The pitch I make to high school kids is: 'Where's the intellectual excitement? Why would you choose civil engineering or mechanical engineering? There's only so much you can do with asphalt.'"

Power to change the world



- People enter the field for a wide variety of aspirational reasons
- <http://www.cs.washington.edu/WhyCSE/>

Pathways in computer science



- People pursue diverse careers following their education in computer science
- <http://www.cs.washington.edu/WhyCSE/>

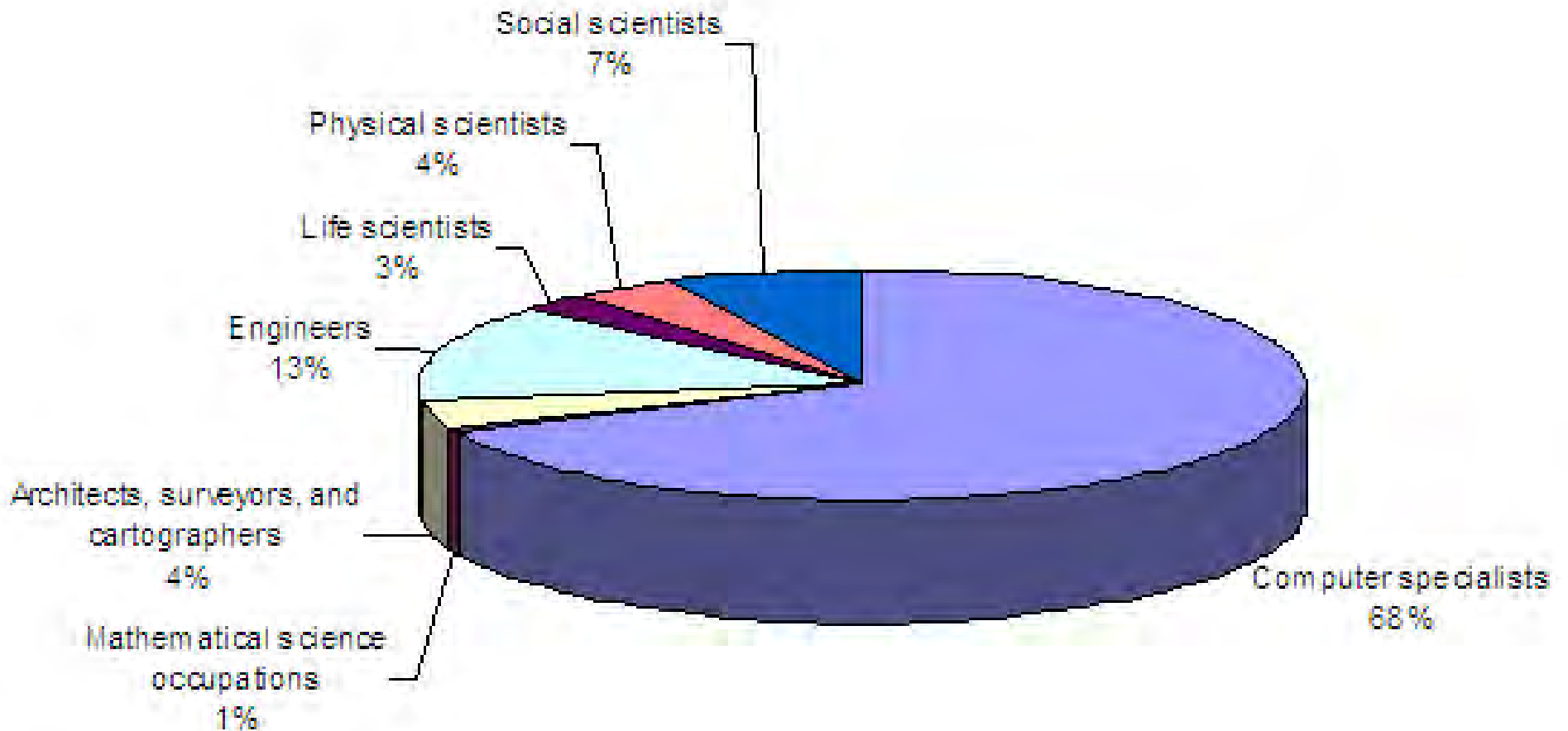
A day in the life



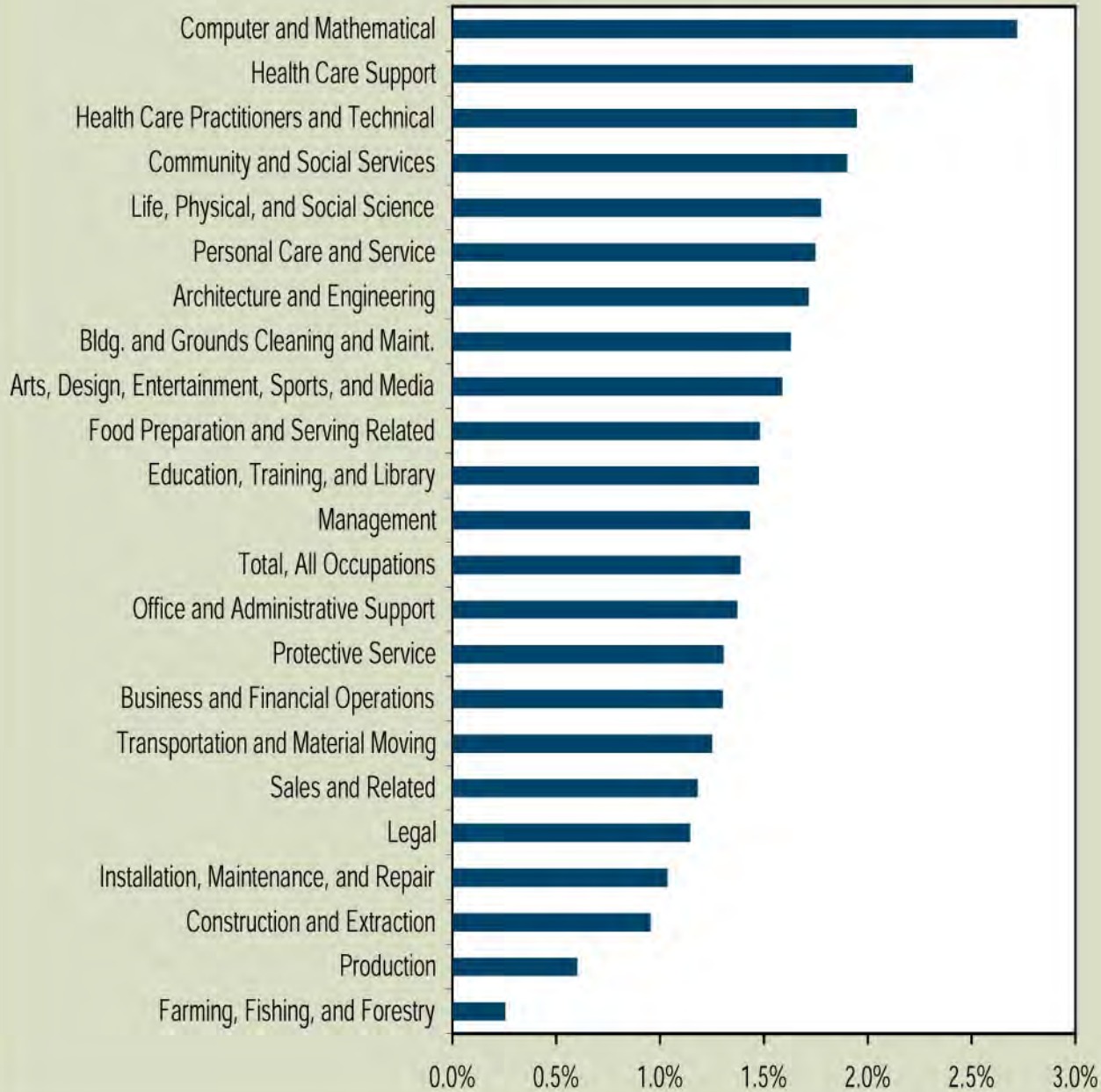
- Working in the software industry is creative, interactive, empowering
- <http://www.cs.washington.edu/WhyCSE/>

Science & Engineering Job Growth, 2006-16

(BLS Occupational Employment Projections)



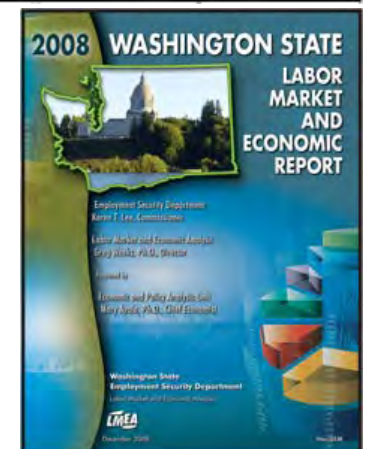
Washington State Major Occupational Groups



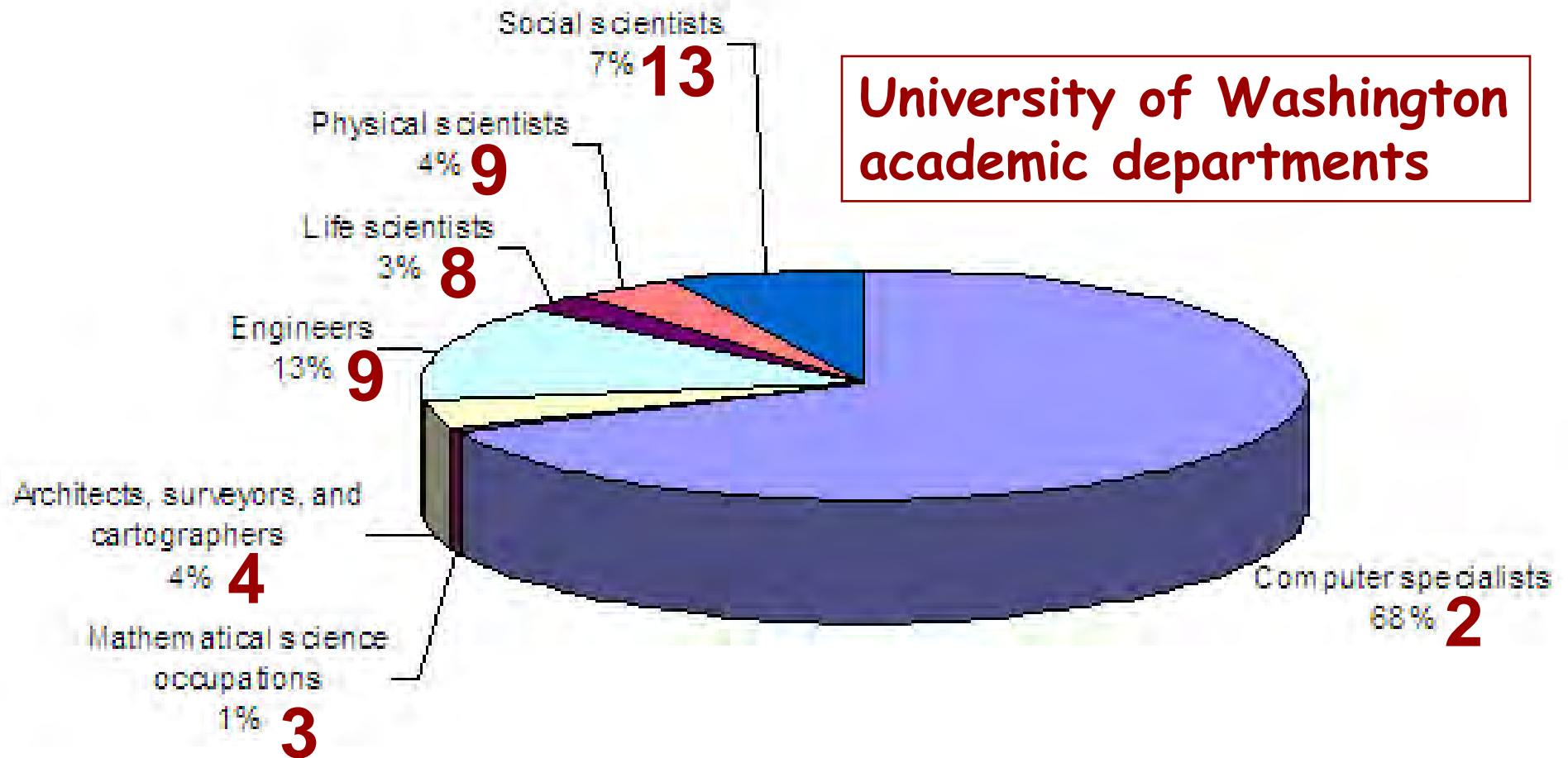
Average annual projected growth rates for all 22 major occupational groups in Washington State, 2006 to 2016

Top Ten Occupations for Washington State					
Occupational Titles	Preparation Level	Estimated Employment 2006	Average Annual Growth Rate	Average Annual Total Openings	Average Wage March 2008
Computer Software Engineers, Applications	Bachelor's degree or higher ✓	24,922	2.90%	1,246	\$86,829
Personal and Home Care Aides	Short-term on-the-job training (short demonstration up to one month)	22,909	2.90%	1,199	\$22,169
Computer Software Engineers, Systems Software	Bachelor's degree or higher ✓	13,760	3.40%	779	\$92,622
Computer Programmers	Bachelor's degree or higher ✓	11,134	3.30%	710	\$82,798
Computer Systems Analysts	Bachelor's degree or higher ✓	12,574	2.60%	761	\$78,478
Landscaping and Groundskeeping Workers	Short-term on-the-job training (short demonstration up to one month)	25,577	2.20%	1,000	\$27,934
Multi-Media Artists and Animators	Bachelor's degree or higher ✓	4,608	3.40%	314	\$57,515
Home Health Aides	Short-term on-the-job training (short demonstration up to one month)	10,071	2.70%	418	\$21,815
Medical Secretaries	Moderate on-the-job training (1-12 months)	17,909	2.20%	757	\$35,006
Hairdressers, Hairstylists, and Cosmetologists	AA degree, post-secondary training, or Long-term on the job training	17,658	2.20%	670	\$29,753

Occupations are ranked based on the average of two criteria: average annual growth rate for 2006 to 2016 and total number of job openings due to growth and replacement



Science & Engineering Job Growth, 2006-16 (BLS Occupational Employment Projections)



The transformation of our economy, and of educational requirements

- Once upon a time, the “content” of the goods we produced was largely physical



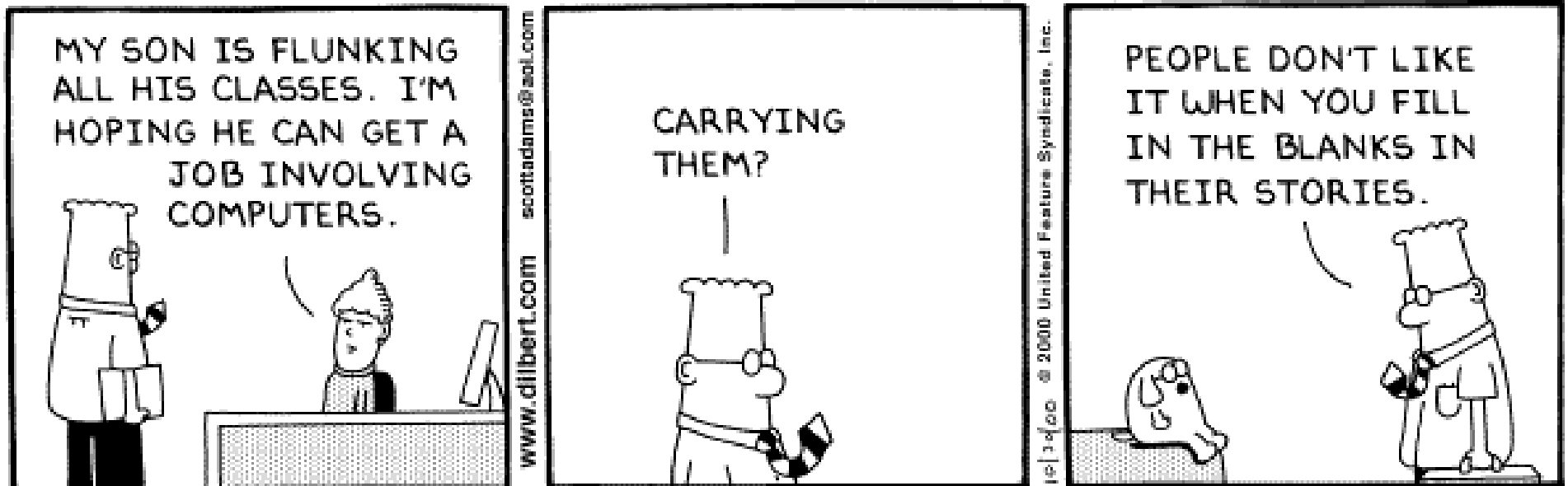
- Then we transitioned to goods whose “content” was a balance of physical and intellectual



-
- In today's knowledge-based economy, the "content" of goods is almost entirely intellectual rather than physical



- What kind of education is required to produce a good whose content is almost entirely intellectual?



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Education in Washington: Where do we stand among the states?

The Nation's S&E Top 5

(Workforce intensity, all S&E occupations, 2006)

1. Virginia
2. Massachusetts
3. Maryland
- 4. Washington**
5. Colorado

ENGINEERS

PEERS: 2
NATION: 3

LIFE/PHYS. SCIENTISTS

PEERS: 3
NATION: 7

COMPUTER SPECIALISTS

PEERS: 6
NATION: 8

HIGHER EDUCATION:

(BACHELOR'S PRODUCTION, S&E GRADUATE PARTICIPATION, S&E PhD PRODUCTION)

BACHELOR'S PRODUCTION

PEERS: 8
NATION: 36

S&E DEGREE PRODUCTION

PEERS: 7
NATION: 31

S&E GRADUATE PARTICIPATION

PEERS: 10
NATION: 46

S&E PhDs AWARDED

PEERS: 10
NATION: 27

K-12 ACHIEVEMENT:

(2007 8TH GRADE NAEP & GRADUATION RATE FROM POSTSECONDARY.ORG)

HIGH SCHOOL GRADUATION

PEERS: 7
NATION: 32



Washington State is gambling with its future!



How about you?

This morning



- The nature of eScience
- The advances that enable it
- Scalable computing for everyone
- Networking in the West
- "There's only so much you can do with asphalt"
- "What happens in Vegas, stays in Vegas" - don't gamble with the future of your region and of the kids who grow up there

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