Making Sense of Information Through Planetary Scale Computing

Invited Presentation to the
Diamond Exchange—Brave New World
Monterey, CA
March 1, 2009

Dr. Larry Smarr
Director, California Institute for Telecommunications and Information Technology
Harry E. Gruber Professor,
Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD

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Data Mining a Decade Ago - NCSA Industrial Partner Projects

- **Caterpillar**
  - Effluent Quality Control
  - Smart Selling
  - Warranty Claims Analysis
  - Customer Value Analysis
- **Ford**
  - Product Compatibility
  - Harshness, Noise, Vibration
  - Marketing
- **Sears**
  - Transaction Management
- **Boeing**
  - Post-Flight Diagnostics
- **Allstate**
  - Medical Claims

- Financial Impact May Be Greater Than $30 Million

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Slide from NCSA 1998

it2

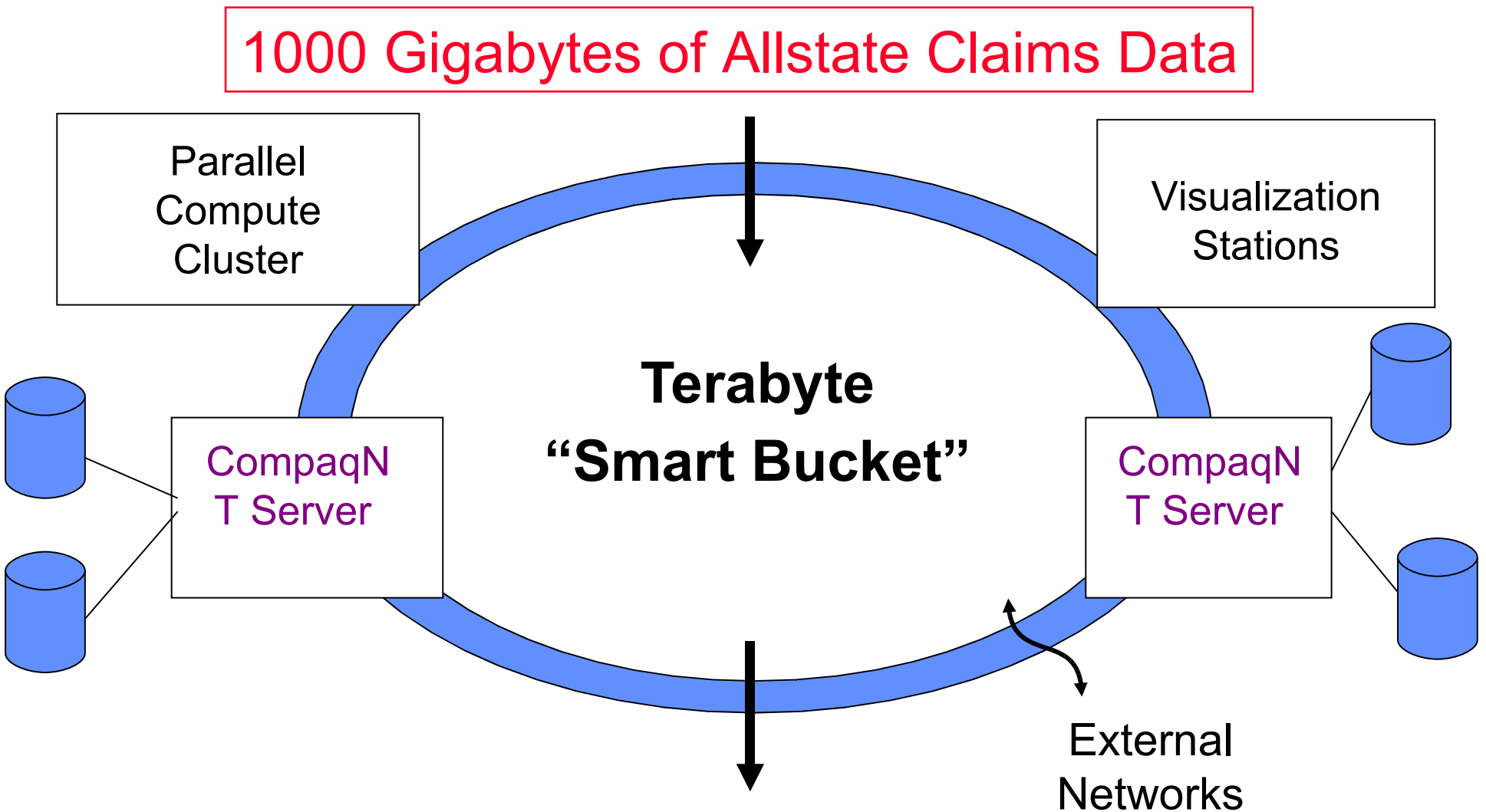
JP Morgan Hero Risk Management Calculation Using NCSA Supercomputer

- **Extended JPM's Risk Management Capabilities After Southeast Asia Meltdown**
  - **Two Week Period in January 1998**
  - **NCSA and SGI Doubled Memory in a Week**
  - **Hundreds of Market Scenarios Simulated**
- **HPC Strategic Business Analysis**
  - **Calculations Used 128-Processor SGI Origin**
- **NCSA, Strategic Vendor (SGI), Industrial Partner (JPM)**
  - **Existing Relationships Facilitated Quick Startup**
  - **Win-Win-Win Result**

Slide from NCSA 1998

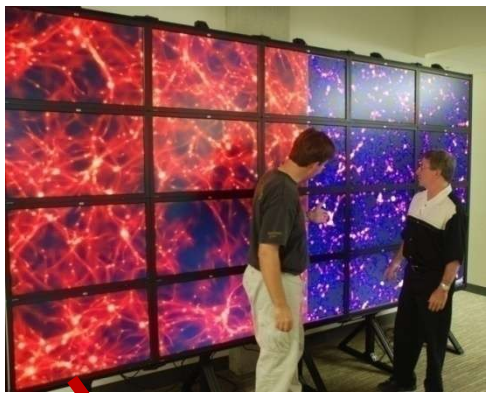
NCSA / Allstate NT Cluster Data Refinery

NCSA 1998



Source: Allstate & Tilt Thompkins, NCSA

Academic Research "OptIPlatform" Cyberinfrastructure: A 10,000 Mbps (10Gbps) Lightpath Cloud



End User OptIPortal



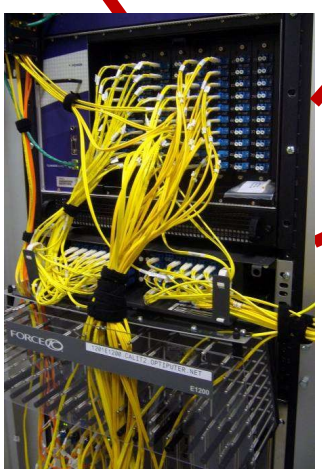
Instruments



HD/4k Telepresence

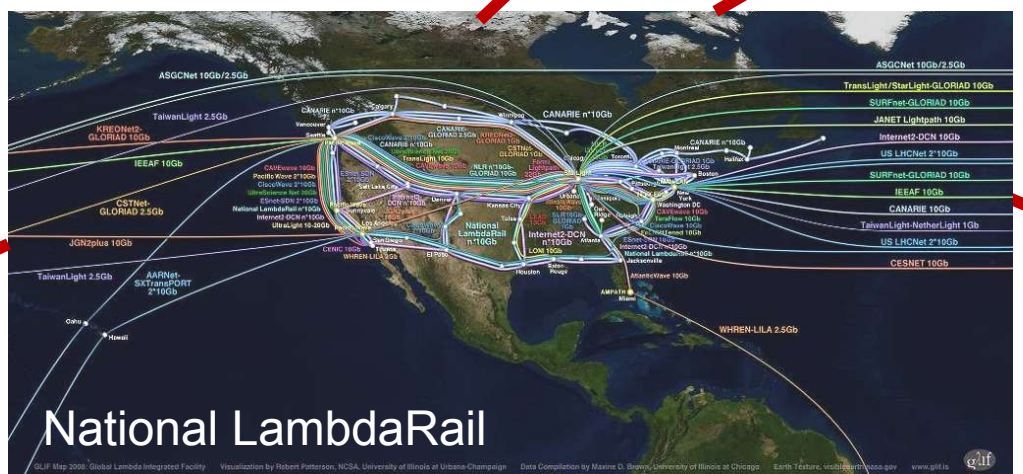


HD/4k Video Cams



Campus Optical Switch

10G Lightpath



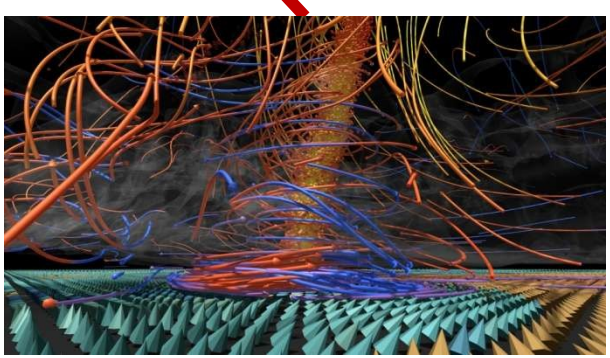
National LambdaRail

HPC

TeraGrid™



Data Repositories & Clusters

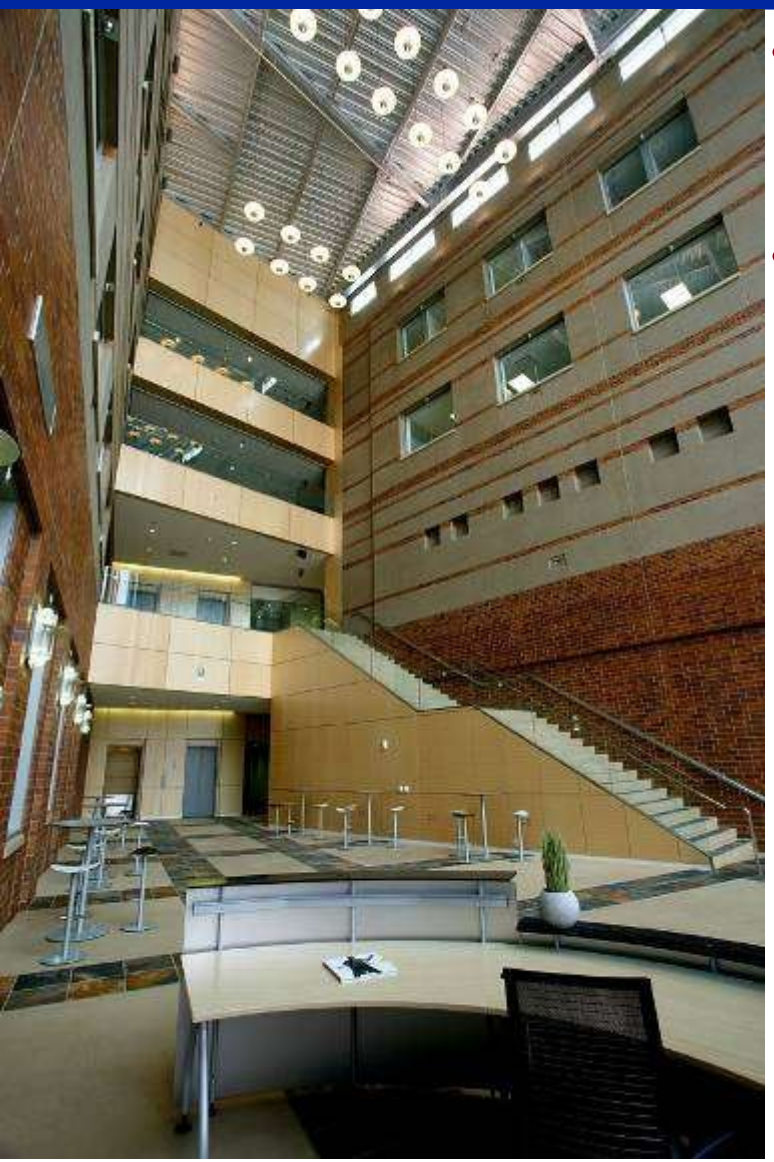


HD/4k Video Images

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Two New Calit2 Buildings Provide Laboratories for "Living in the Future"



- "Convergence" Laboratory Facilities
  - Nanotech, BioMEMS, Chips, Radio, Photonics
  - Virtual Reality, Digital Cinema, HDTV, Gaming
- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks



www.calit2.net

OptIPuter

Over 400 Federal Grants, 200 Companies

it²

The Calit2 OptIPortals at UCSD and UCI Are Now a 2 Gbit/s HD Collaboratory



UCSD cluster: 15 x Quad core Dell XPS with Dual nVIDIA 5600s
UCI cluster: 25 x Dual Core Apple G5

Data Transmission:
From Shared Internet to Dedicated Lightpaths

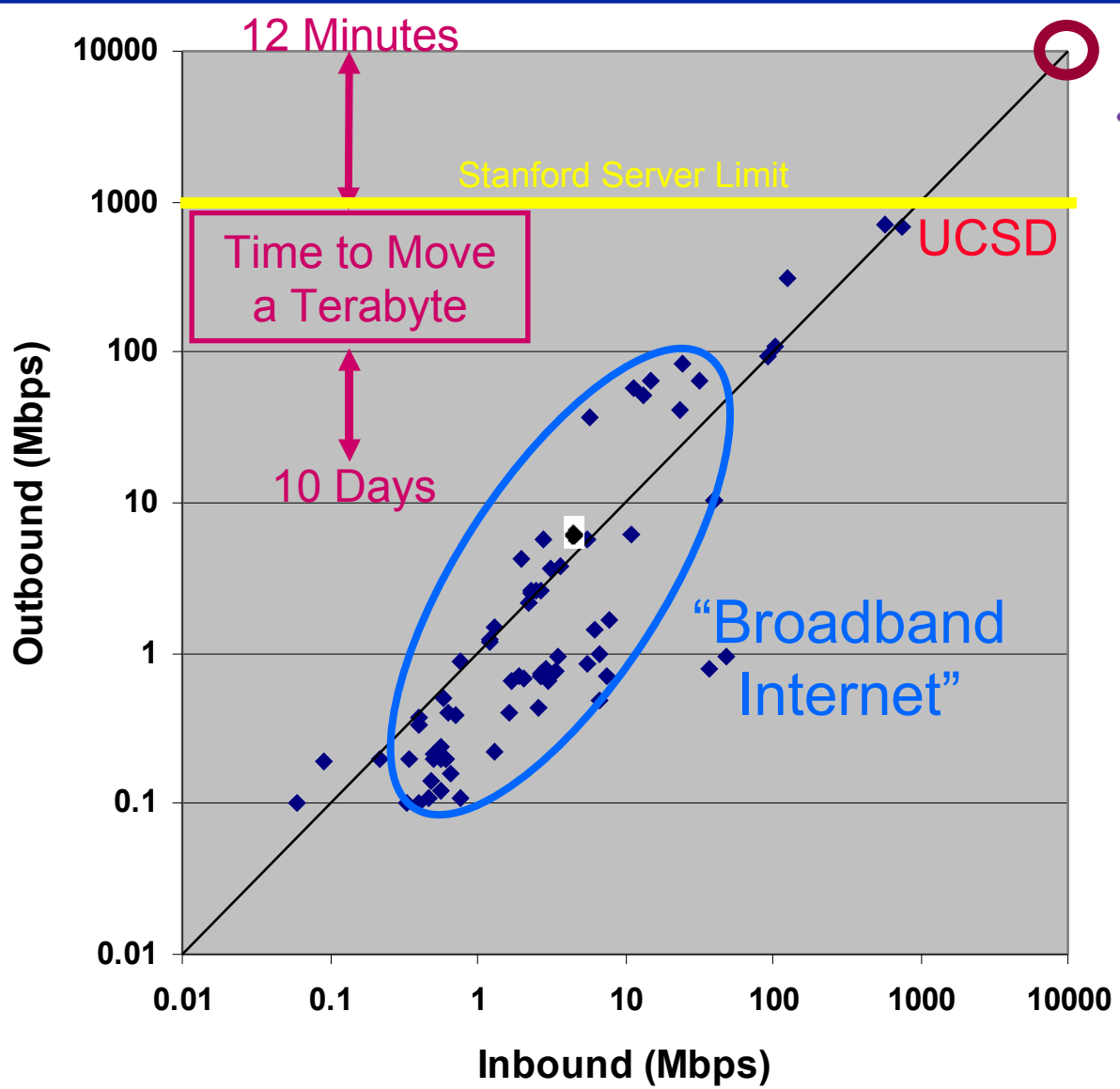
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The Shared Internet is Fine for Email and Web - But It is Not Adequate for Data-Intensive Research

Computers In:

Australia
Canada
Czech Rep.
India
Japan
Korea
Mexico
Moorea
Netherlands
Poland
Taiwan
United States



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100-1000x Normal Internet!

Data Intensive Sciences Require Fast Predictable Bandwidth

Source: Larry Smarr and Friends

Measured Bandwidth from User Computer to Stanford Gigabit Server in Megabits/sec
http://netspeed.stanford.edu/

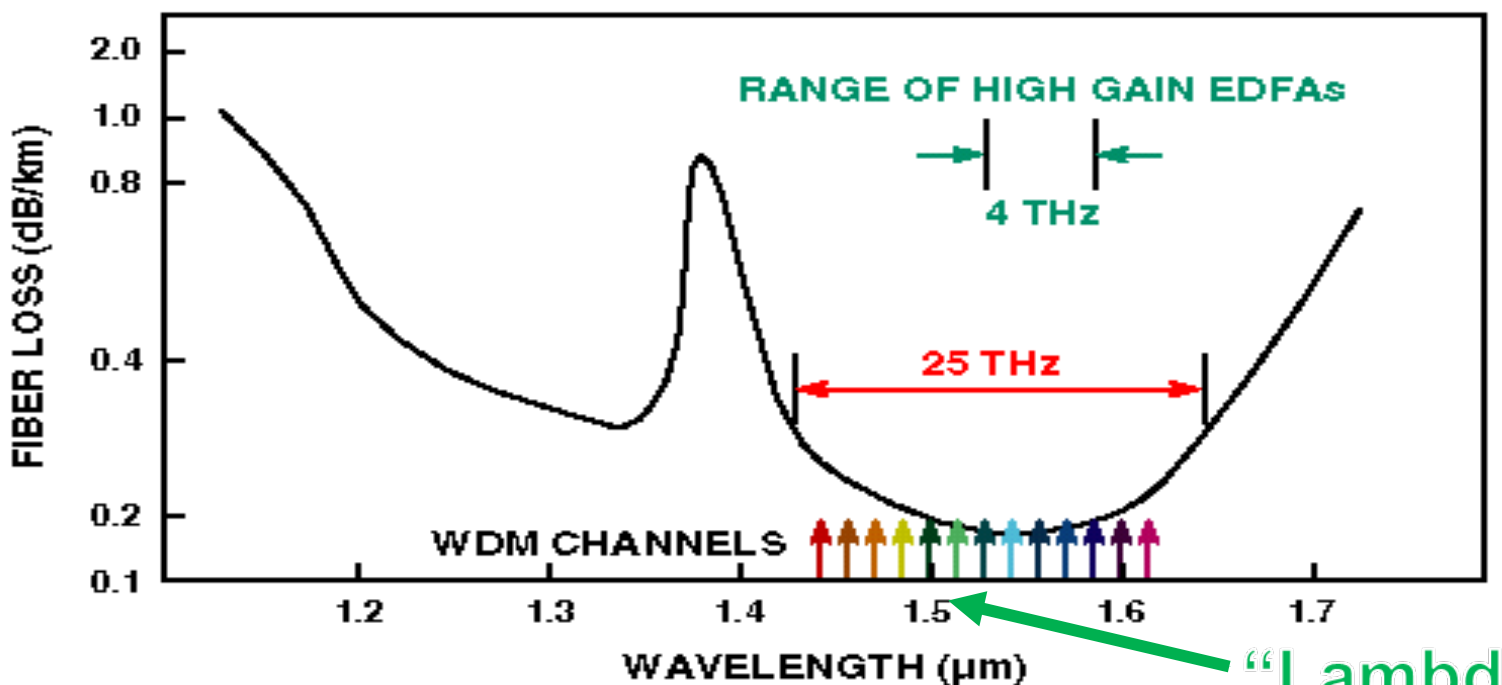
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Dedicated Optical Fiber Channels Makes High Performance Cyberinfrastructure Possible

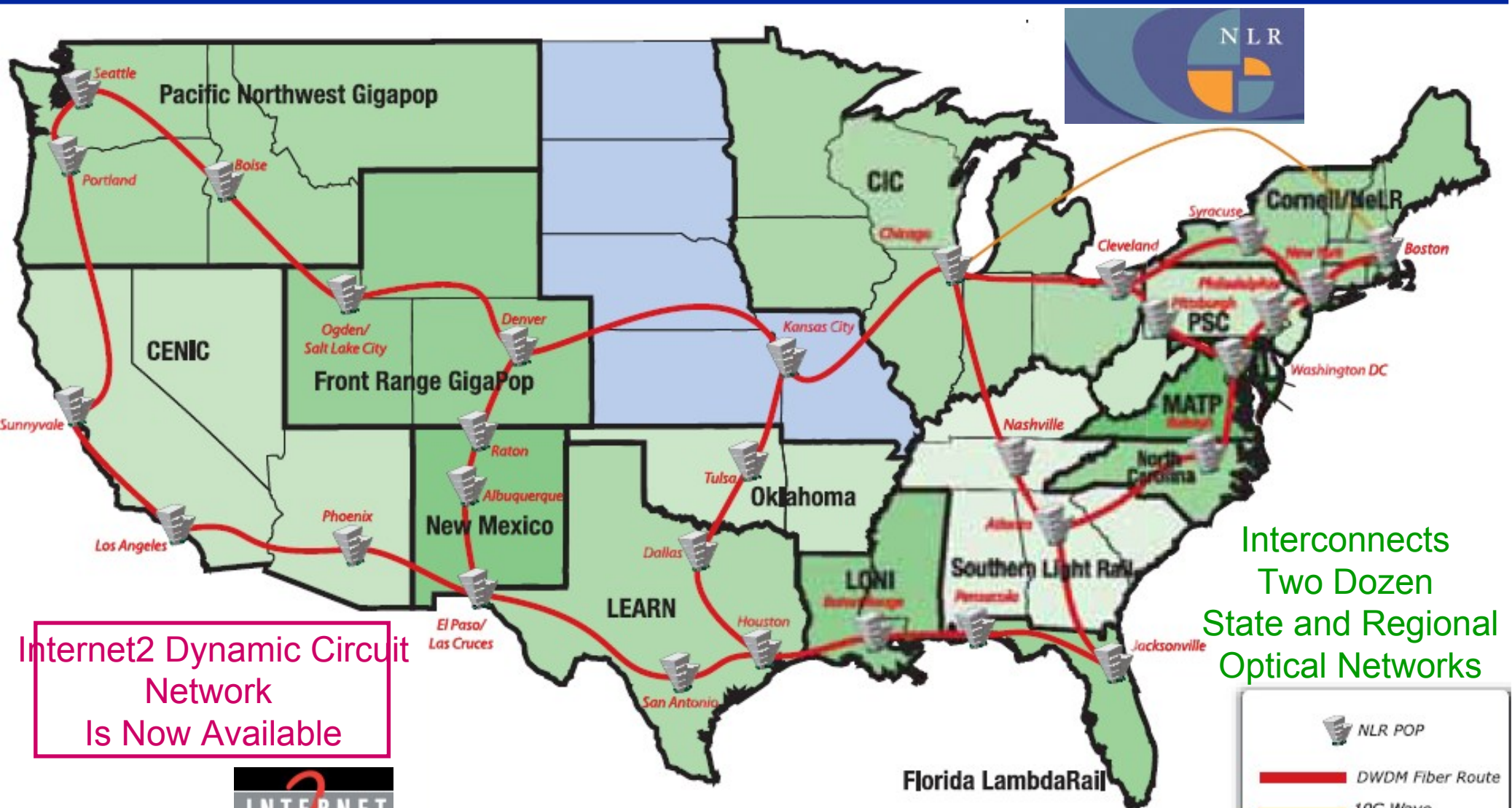
WAVELENGTH DIVISION MULTIPLEXING (WDM)

- EXPLOITS
  - ENORMOUS BANDWIDTH OF SILICA FIBER
  - HIGH-GAIN WIDEBAND OPTICAL AMPLIFIERS



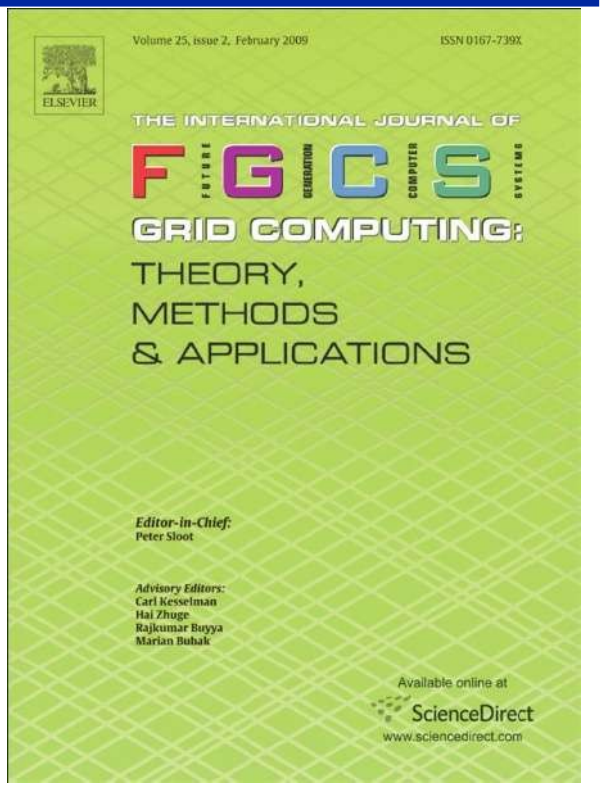
WDM Enables 10Gbps Shared Internet on One Lambda and a Personal 10Gbps Lambda on the Same Fiber!

Dedicated 10Gbps Lightpaths Tie Together State and Regional Fiber Infrastructure



The OptIPuter Creates an OptIPlanet Collaboratory: Enabling Data-Intensive e-Research





"OptIPlanet: The OptIPuter Global Collaboratory" – Special Section of Future Generations Computer Systems, Volume 25, Issue 2, February 2009

evl electronic visualization laboratory

NSF

ROCKS www.rocksclusters.org

SAGE

OptIPuter

Calit2 (UCSD, UCI), SDSC, and UIC Leads—Larry Smarr PI
Univ. Partners: NCSA, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST
Industry: IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent

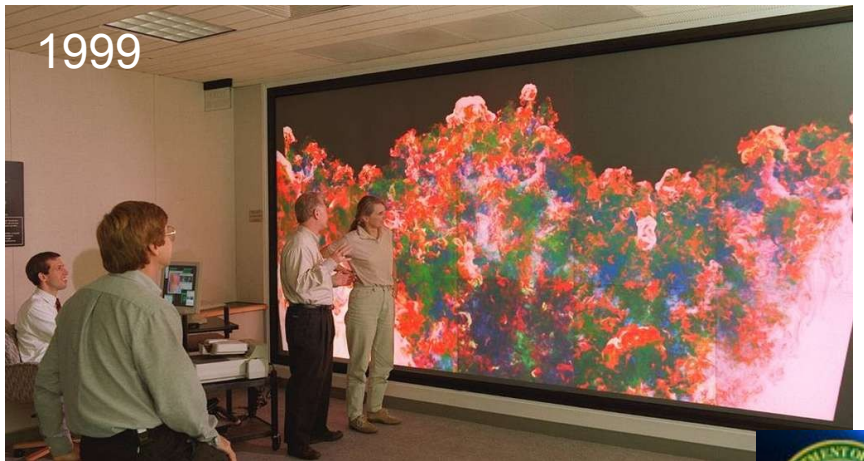
it²

Data Portals:
From User Analysis on PCs to OptIPortals

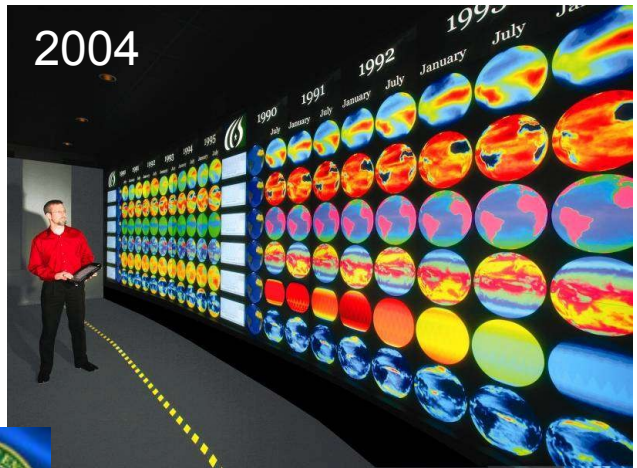
The Rapid Growth in Scalable Visualization



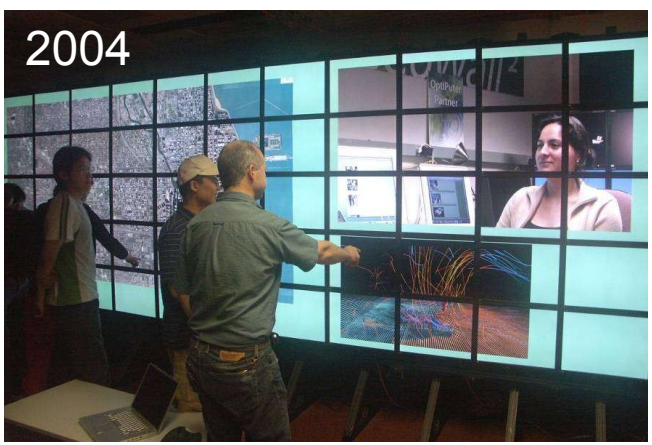
NCSA 4 MPixel
NSF Alliance PowerWall



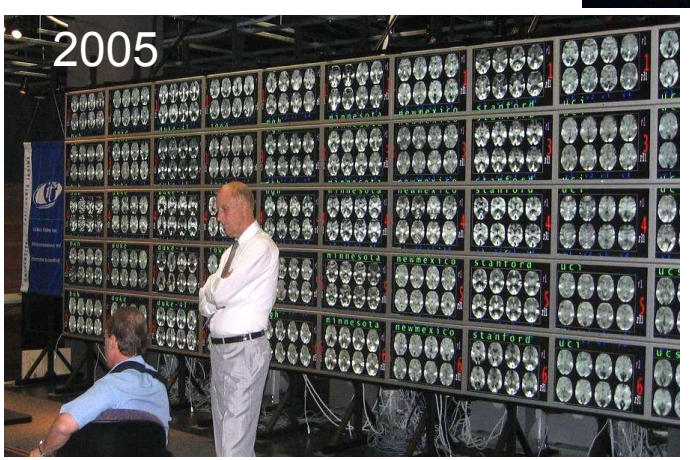
LLNL 20 Mpixel Wall



ORNL 35Mpixel EVEREST



EVL 100 Mpixel LambdaVision
NSF MRI



Calit2@UCI 200 Mpixel HiPerWall
NSF MRI



TACC 307 Mpixel Stallion
NSF TeraGrid

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A Decade of NSF Investment
Two Orders of Magnitude Growth!

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My OptIPortal™ – Affordable Termination Device for the OptIPuter Global Backplane

- 20 Dual CPU Nodes, 20 24” Monitors, ~$50,000
- 1/4 Teraflop, 5 Terabyte Storage, 45 Mega Pixels--Nice PC!
- Scalable Adaptive Graphics Environment (SAGE) Jason Leigh, EVL-UIC

evl electronic visualization laboratory





NSF

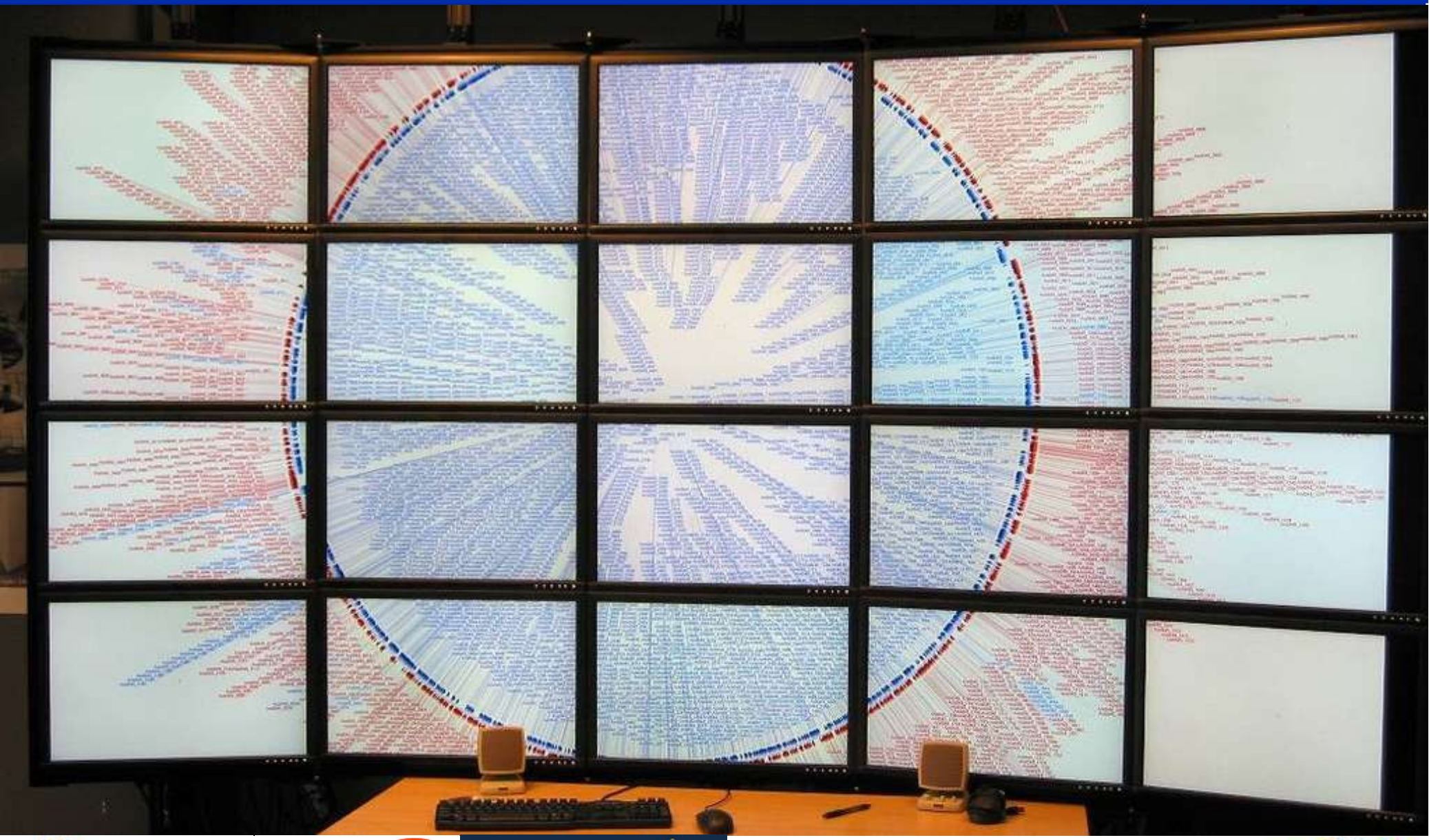
OptIPuter

Powered by Rocks ROCKS

Source: Phil Papadopoulos SDSC, Calit2

it2

Visual Analytics--Use of Tiled Display Wall OptIPortal to Interactively View Microbial Genome (5 Million Bases)



camera Marine Microbial Ecology

OptIPuter

Powered by Rocks ROCKS

Acidobacteria bacterium Ellin345 Soil Bacterium 5.6 Mb; ~5000 Genes

Source: Raj Singh, UCSD

it²

Use of Tiled Display Wall OptIPortal to Interactively View Microbial Genome



camera Marine Microbial Ecology

OptIPuter

Powered by Rocks ROCKS

Source: Raj Singh, UCSD

it²

Use of Tiled Display Wall OptIPortal to Interactively View Microbial Genome



camera Marine Microbial Ecology

OptIPuter

Powered by Rocks ROCKS

Source: Raj Singh, UCSD

it²

OptIPortals Scale to 1/3 Billion Pixels Enabling Viewing of Very Large Images or Many Simultaneous Images



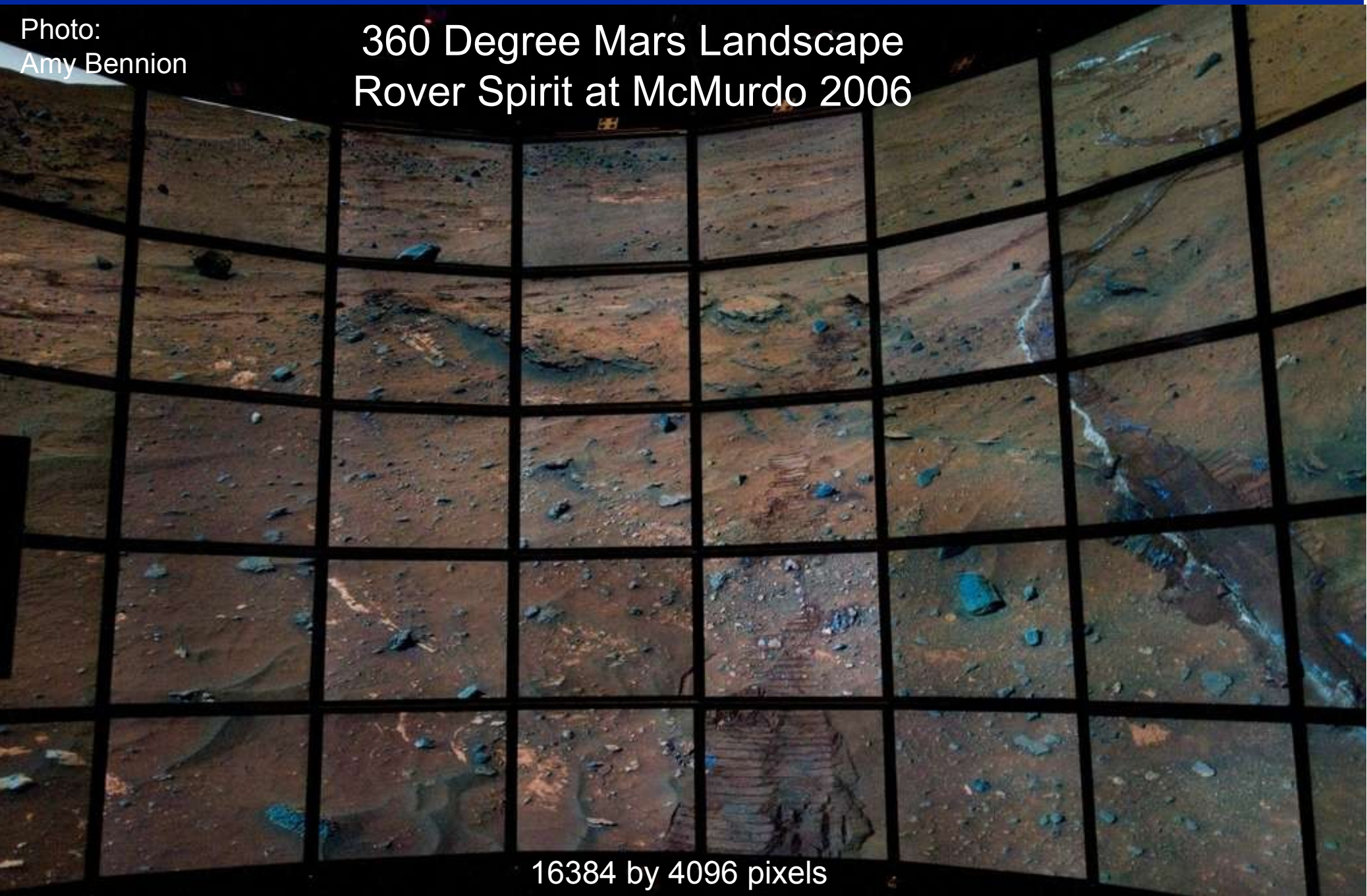
Spitzer Space Telescope (Infrared)



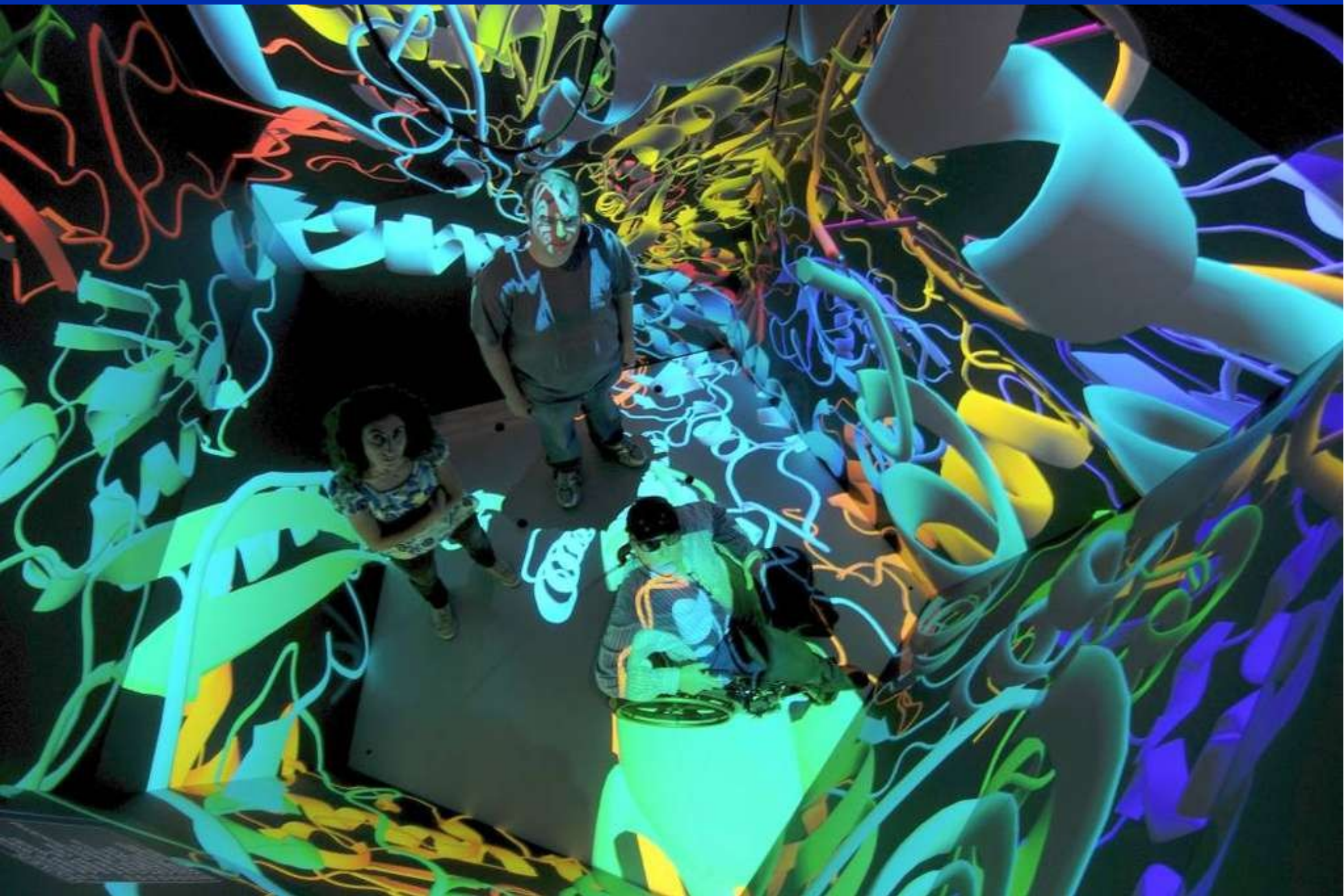
NASA Earth Satellite Images Bushfires October 2007 San Diego

Source: Falko Kuester, Calit2@UCSD

Calit2/EVL Varrier -- 60 Screen Panorama OptIPortal



Calit2 3D Immersive StarCAVE OptIPortal: Enables Exploration of High Resolution Simulations



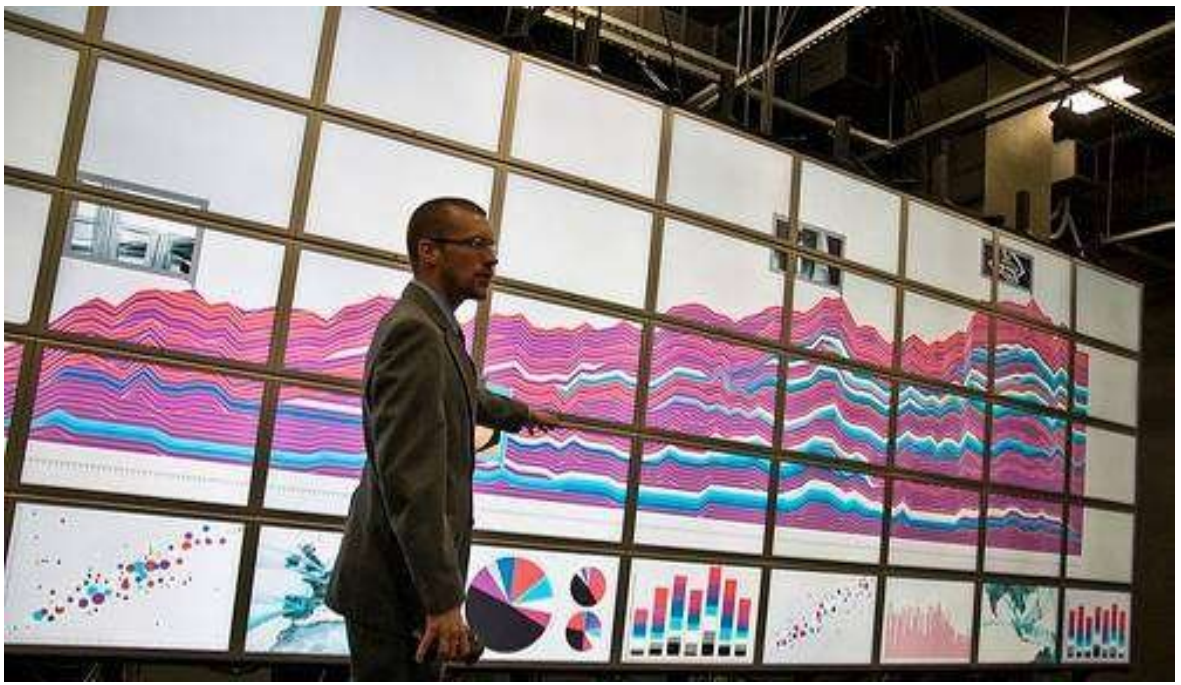
Calit2 VirtuLab-
Our Visual Skunkworks



Source: Tom DeFanti, Calit2

Analyzing Very Large Data Sets Remotely

Pattern Recognition Out of Massive Amounts of Cultural Data



Calit2@UCI
200 Mpixel
HIPerWall



Software Studies Initiative, Calti2@UCSD

Interface Designs for Cultural Analytics Research Environment

Jeremy Douglass (top) & Lev Manovich (bottom)

Second Annual Meeting of the Humanities, Arts, Science, and Technology Advanced Collaboratory (HASTAC II)
UC Irvine May 23, 2008

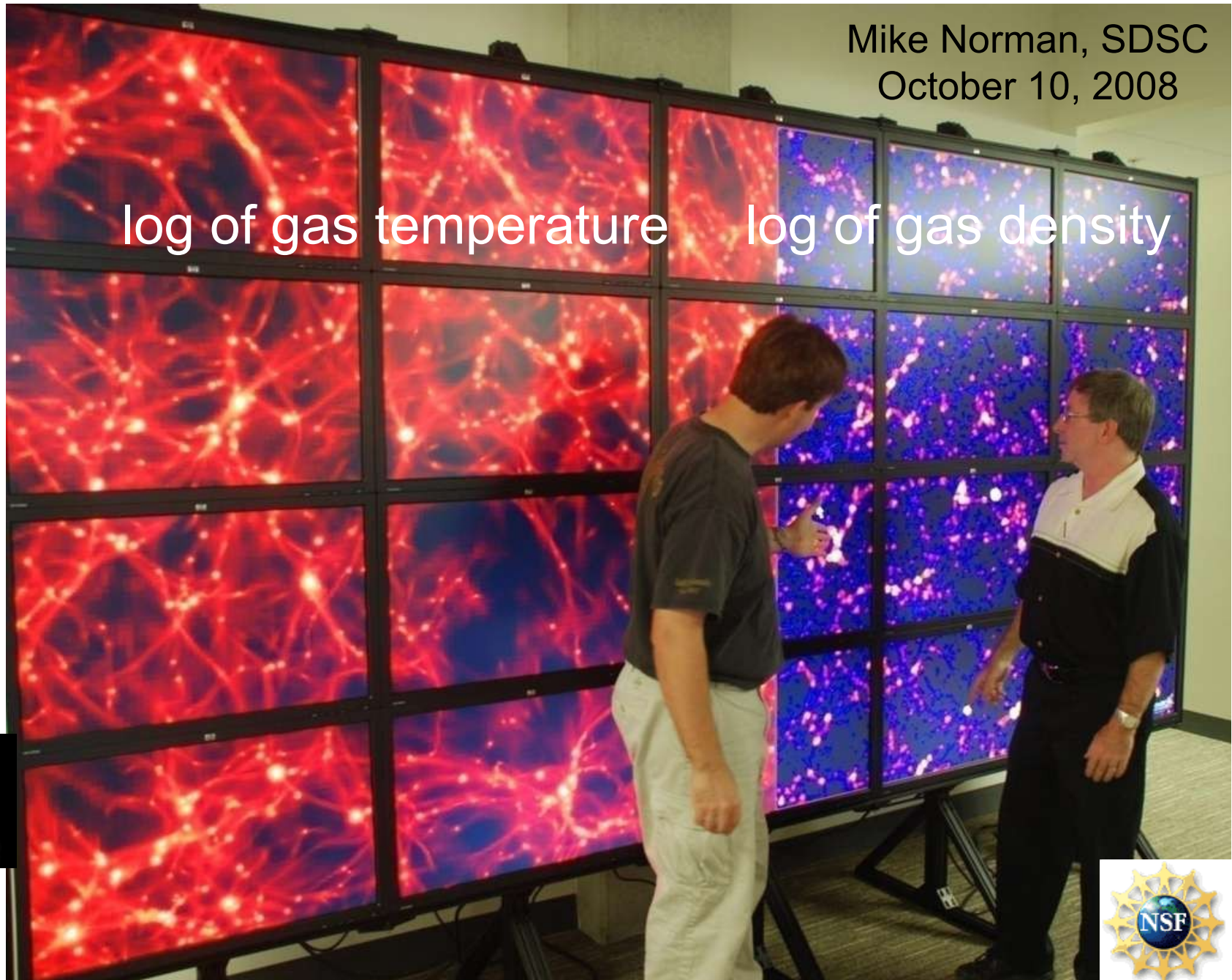
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Interactive Analysis of Time Evolving Cubes of Data: Cosmological Supercomputer Simulations

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

Two 64K Images From a Cosmological Simulation of Galaxy Cluster Formation



ROCKS
www.rocksclusters.org

CGLX

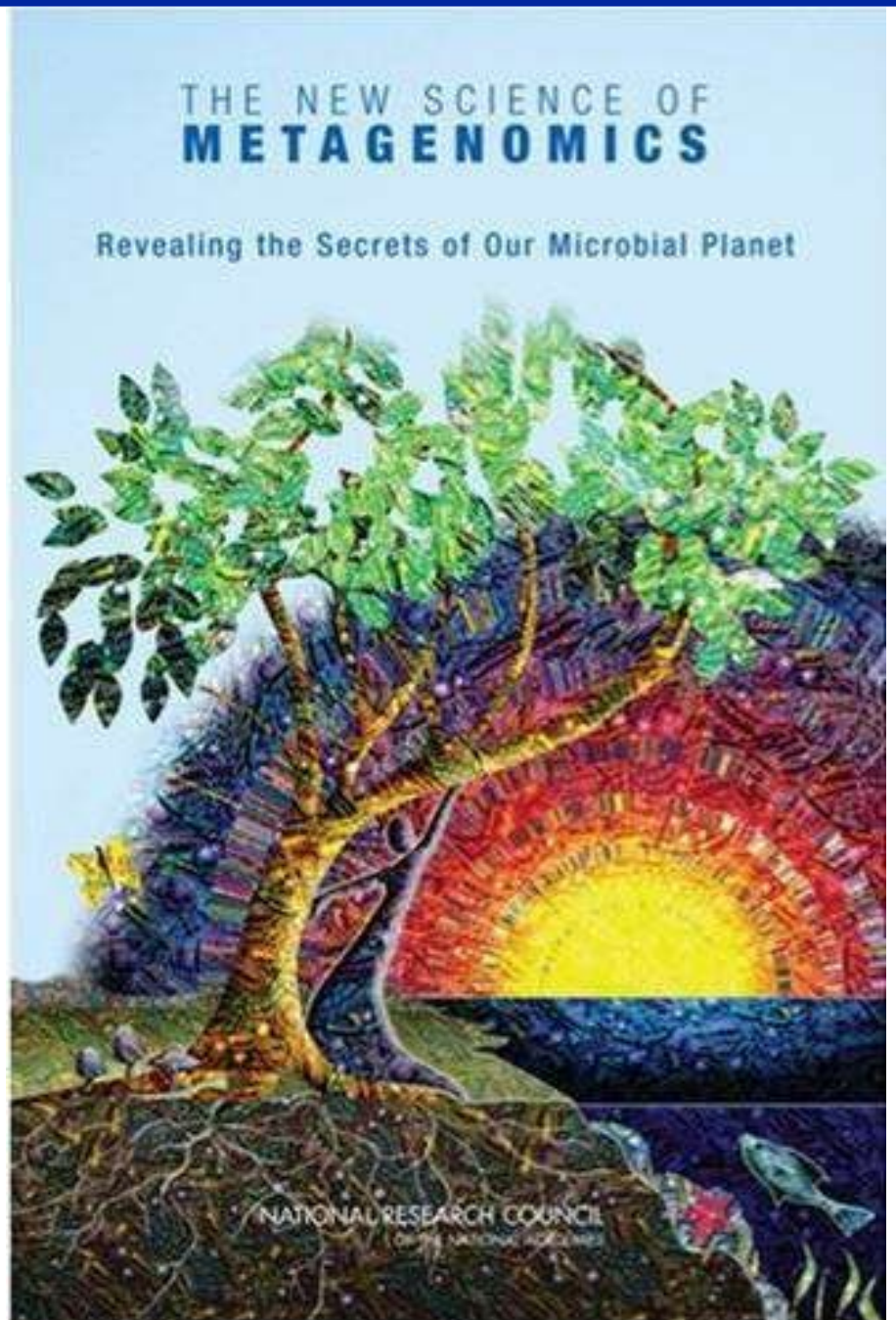
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NSF

The New Science of Metagenomics

NRC Report:

Metagenomic data should be made publicly available in international archives as rapidly as possible.



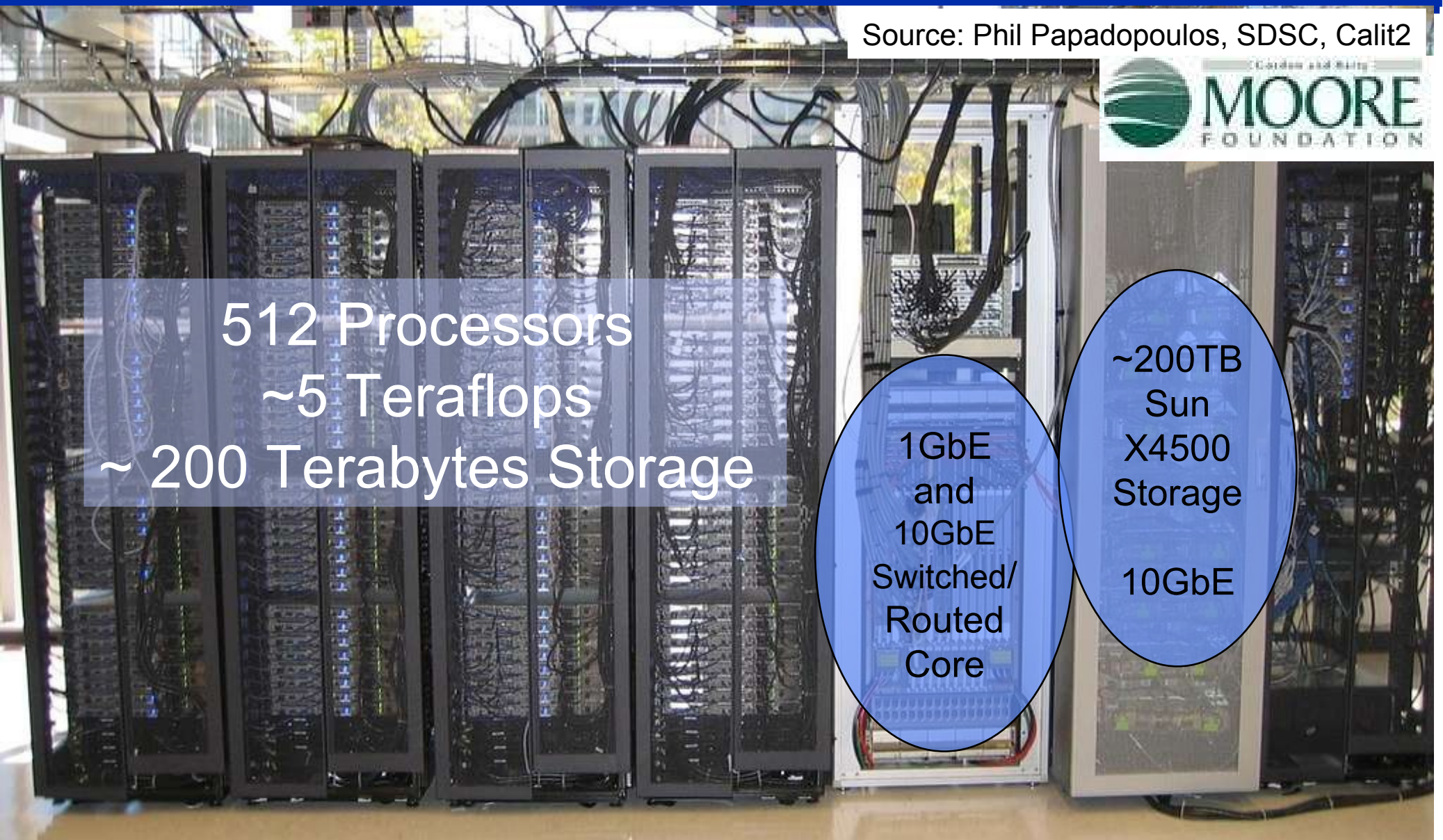
"The emerging field of metagenomics, where the DNA of entire communities of microbes is studied simultaneously, presents the greatest opportunity -- perhaps since the invention of the microscope – to revolutionize understanding of the microbial world." –

National Research Council
March 27, 2007

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Calit2 Microbial Metagenomics Cluster- Next Generation Optically Linked Science Data Server



OptIPuter SDSC ROCKS camera Marine Microbial Ecology J. Craig Venter INSTITUTE it²

CAMERA's
Global Microbial Metagenomics CyberCommunity



Nearly 2500 Registered Users
From 55 Countries

OptIPuter Persistent Infrastructure Enables Calit2 and U Washington CAMERA Collaboratory



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Ginger Armbrust's Diatoms: Micrographs, Chromosomes, Genetic Assembly

ROCKS



MOORE FOUNDATION



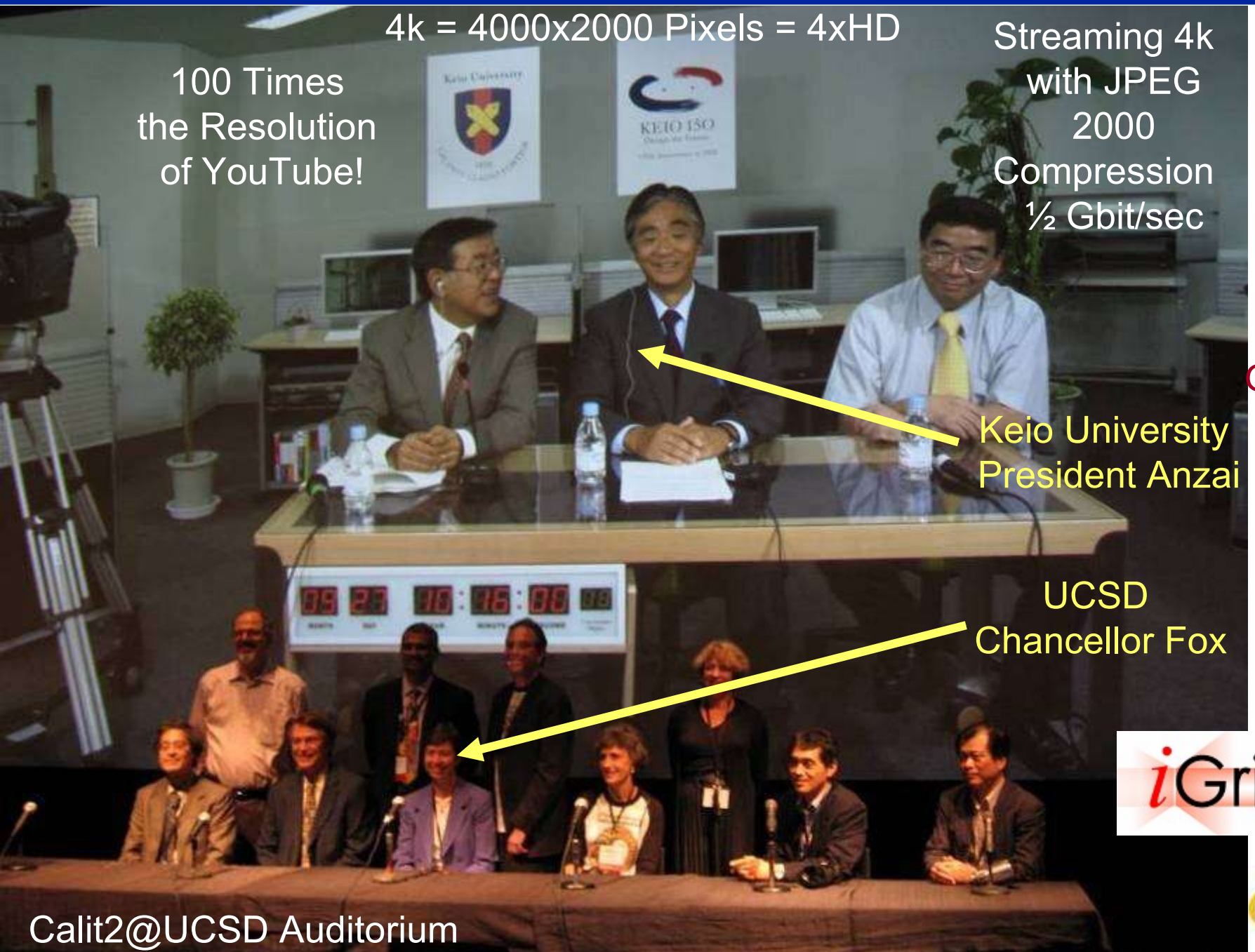
camera
Marine Microbial Ecology

NSF

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Telepresence Meeting
Using Digital Cinema 4k Streams



CineGrid

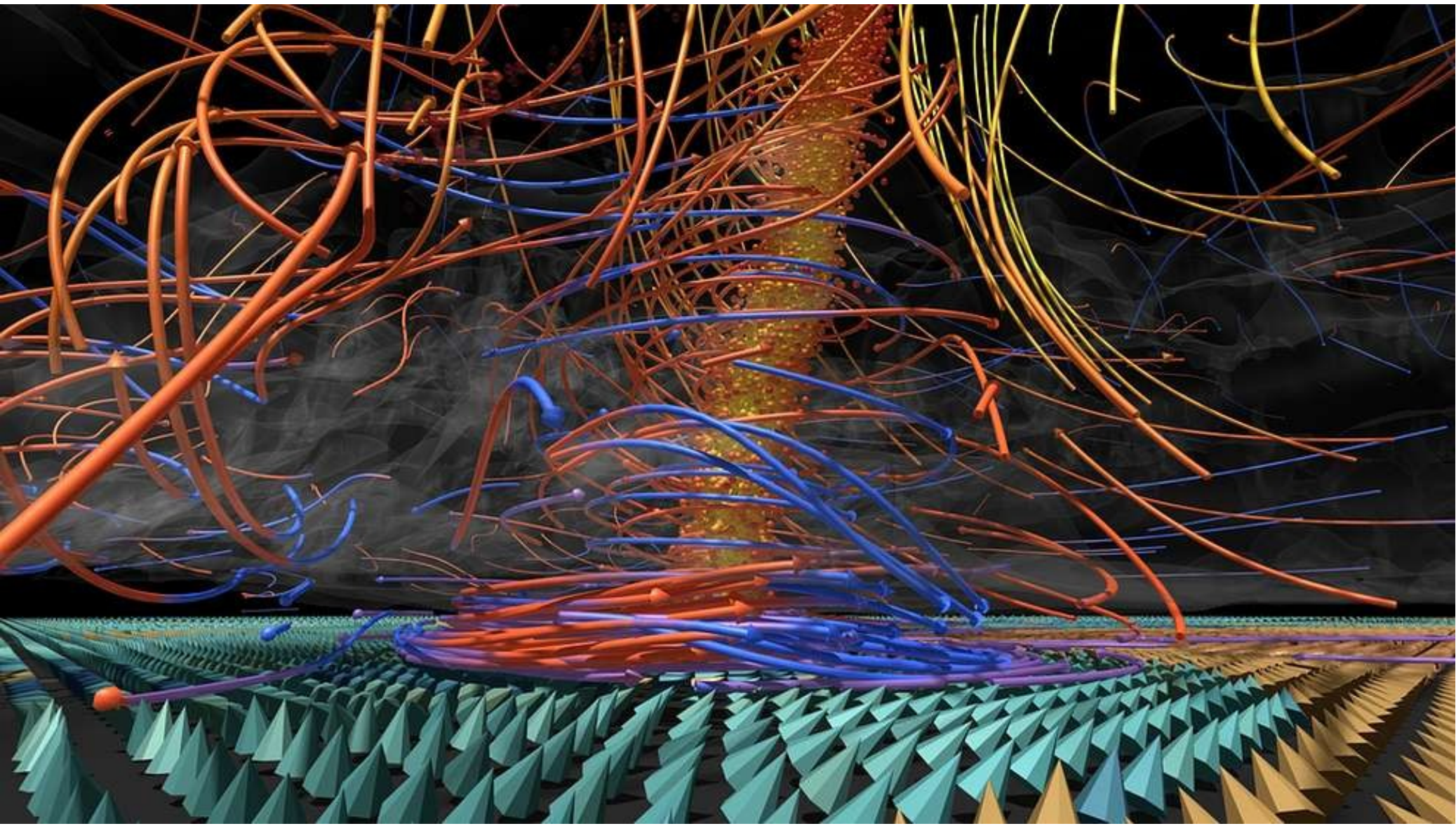
Lays
Technical
Basis for
Global Digita
Cinema

Sony
NTT
SGI

iGrid 2005

it²

Rendering Supercomputer Data at Digital Cinema Resolution



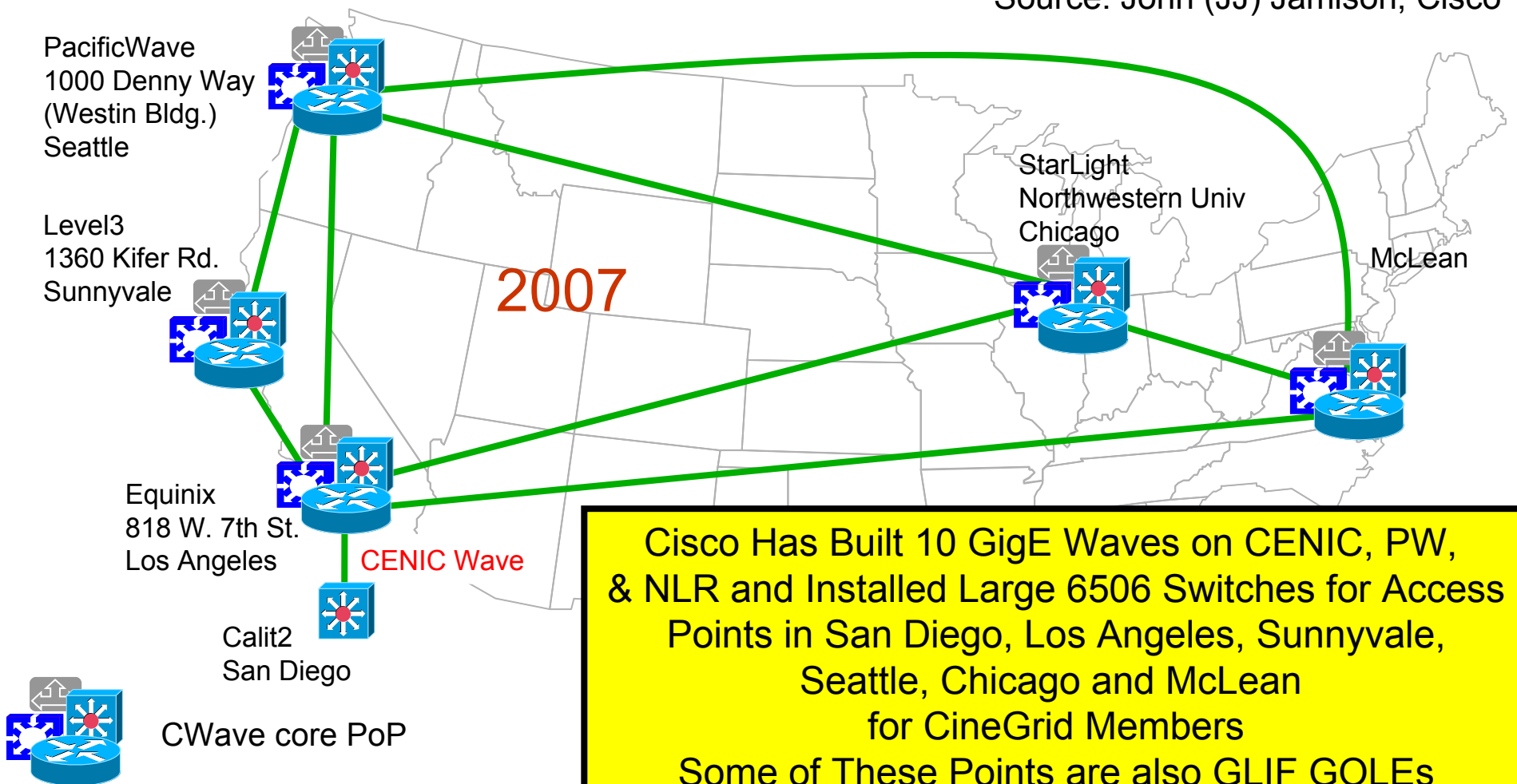
OptIPuter

Source: Donna Cox, Robert Patterson, Bob Wilhelmson, NCSA

it2

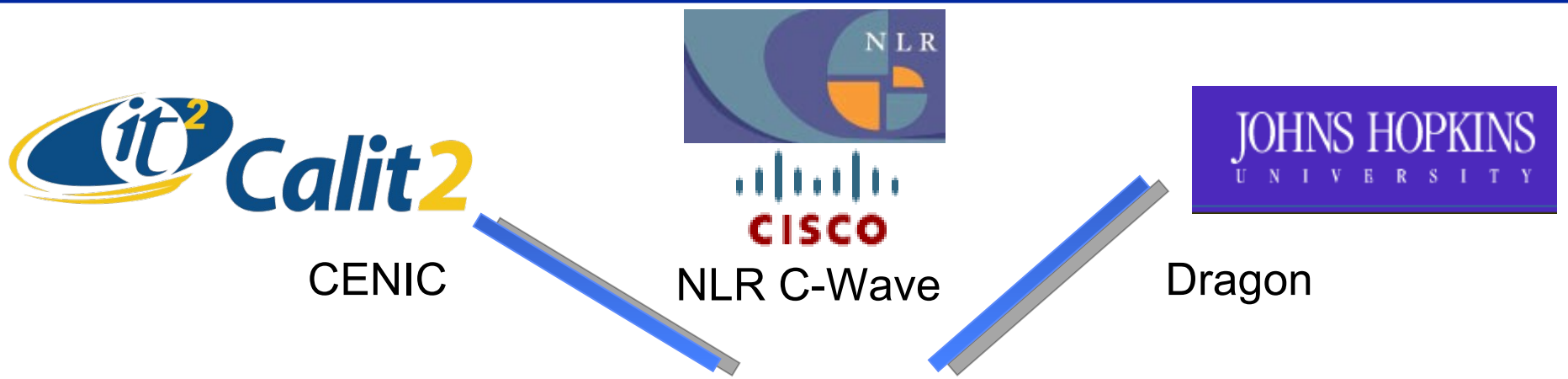
Cisco CWave for CineGrid: A New Cyberinfrastructure for High Resolution Media Streaming*

Source: John (JJ) Jamison, Cisco



Cisco Has Built 10 GigE Waves on CENIC, PW, & NLR and Installed Large 6506 Switches for Access Points in San Diego, Los Angeles, Sunnyvale, Seattle, Chicago and McLean for CineGrid Members
Some of These Points are also GLIF GOLEs

Open Cloud OptIPuter Testbed--Manage and Compute Large Datasets Over 10Gbps Lambdas



HW Phase 1 (2008)

- **4 racks**
  - **120 Nodes**
  - **480 Cores**
- **10+ Gb/s WAN**

STARLIGHT℠
The Optical STAR TAP™

MREN

UIC

Open Source SW

- Hadoop
- Sector/Sphere
- Thrift, GPB
- Eucalyptus
- Benchmarks

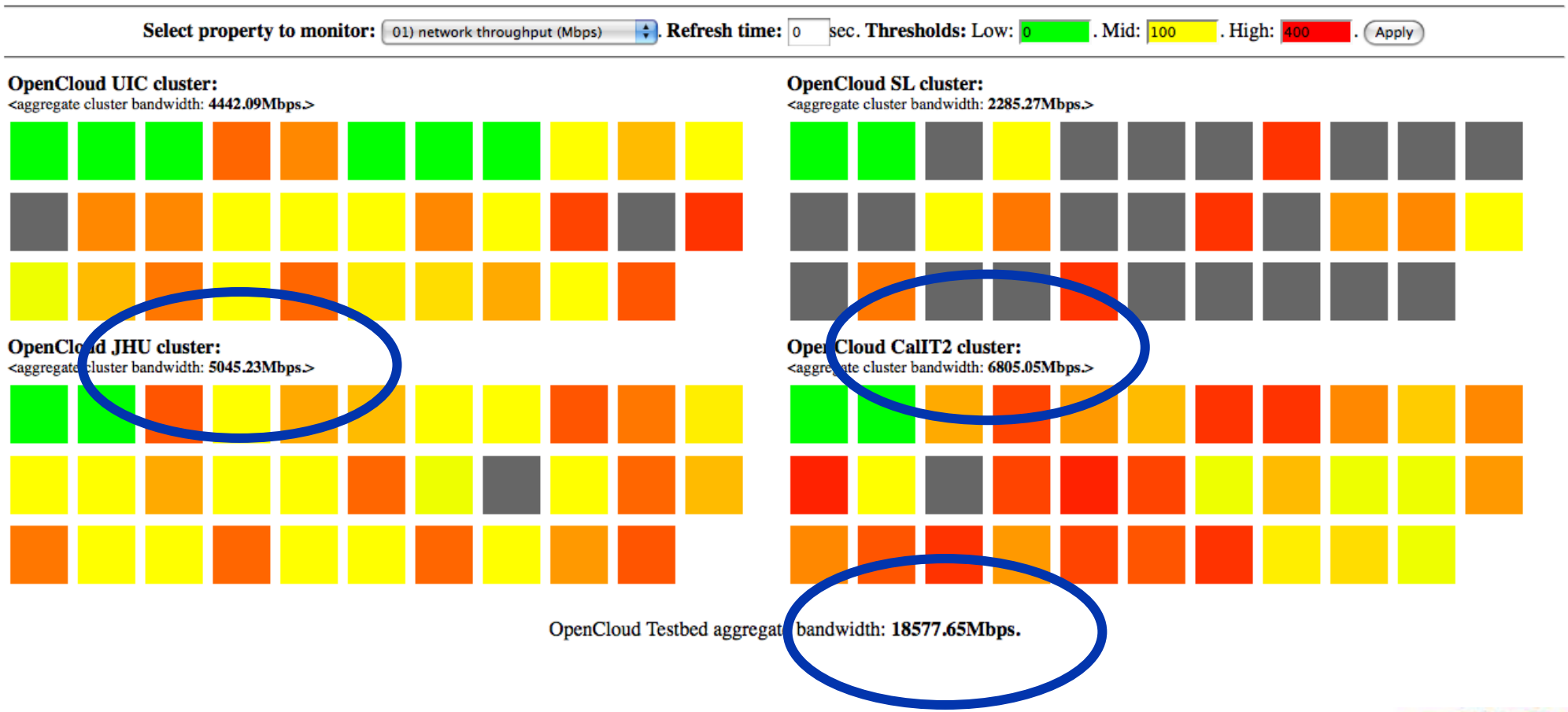
Phase 2 (2009) will add additional racks to current sites and increase number of sites

OptIPuter

Source: Robert Grossman, UIC

Terasort on Open Cloud Testbed

Sorting 10 Billion Records (1.2 TB) at 4 Sites (120 Nodes) Sustaining >5 Gbps--Only 5% Distance Penalty

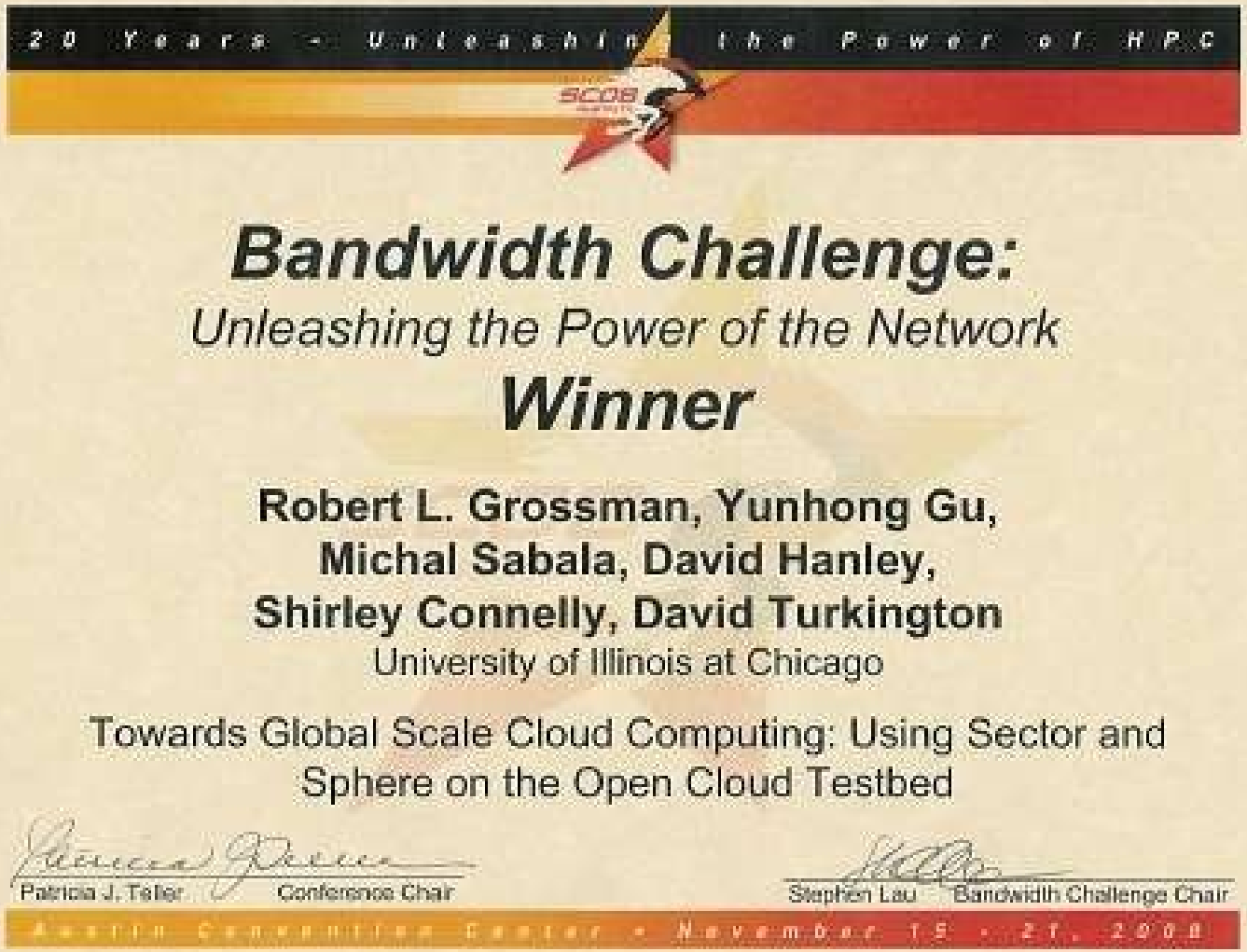


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OpenCloud Testbed Wins Against All Comers!

Supercomputing 2008



Cyberinfrastructure Integration: Integration of Data Generators, Transmission, and Portals

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Just in Time OptIPlanet Collaboratory: Live Session with NASA Ames from Calit2



From Start to This Image in Less Than 2 Weeks!

View from NASA Ames Lunar Science Institute Mountain View, CA

Virtual Handshake

HD compressed 6:1

Visit Yesterday by JPL's Firouz Naderi

OptIPuter

CGLX

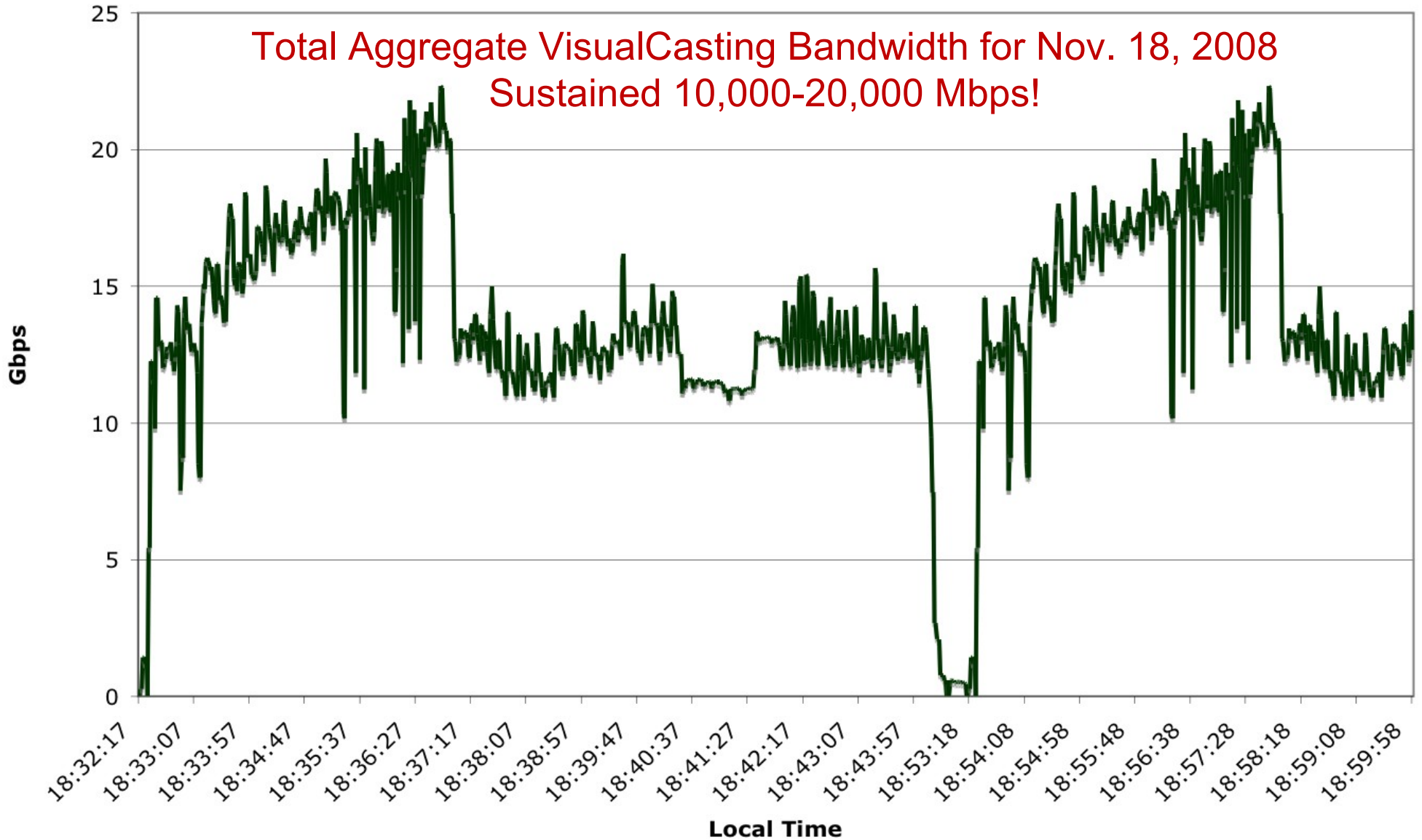
Source: Falko Kuester, Calit2; Michael Sims, NASA

Remote Control of Scientific Instruments: Live Session with JPL and Mars Rover from Calit2



Source: Falko Kuester, Calit2; Michael Sims, NASA

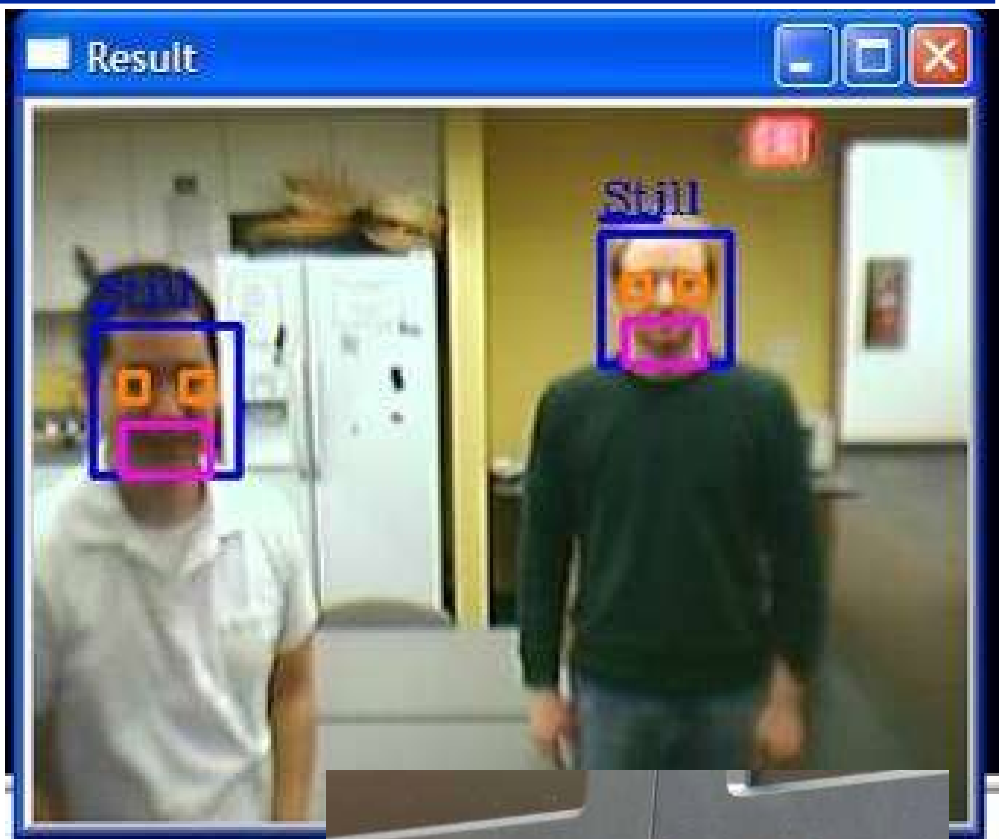
EVL's SAGE OptIPortal VisualCasting Multi-Site OptIPuter Collaboratory



Source: Jason Leigh, Luc Renambot, EVL, UI Chicago

U Michigan Virtual Space Interaction Testbed (VISIT) Instrumenting OptIPortals for Social Science Research

- **Using Cameras Embedded in the Seams of Tiled Displays and Computer Vision Techniques, we can Understand how People Interact with OptIPortals**
  - **Classify Attention, Expression, Gaze**
  - **Initial Implementation Based on Attention Interaction Design Toolkit (J. Lee, MIT)**
- **Close to Producing Usable Eye/Nose Tracking Data using OpenCV**





Leading U.S. Researchers on the Social Aspects of Collaboration

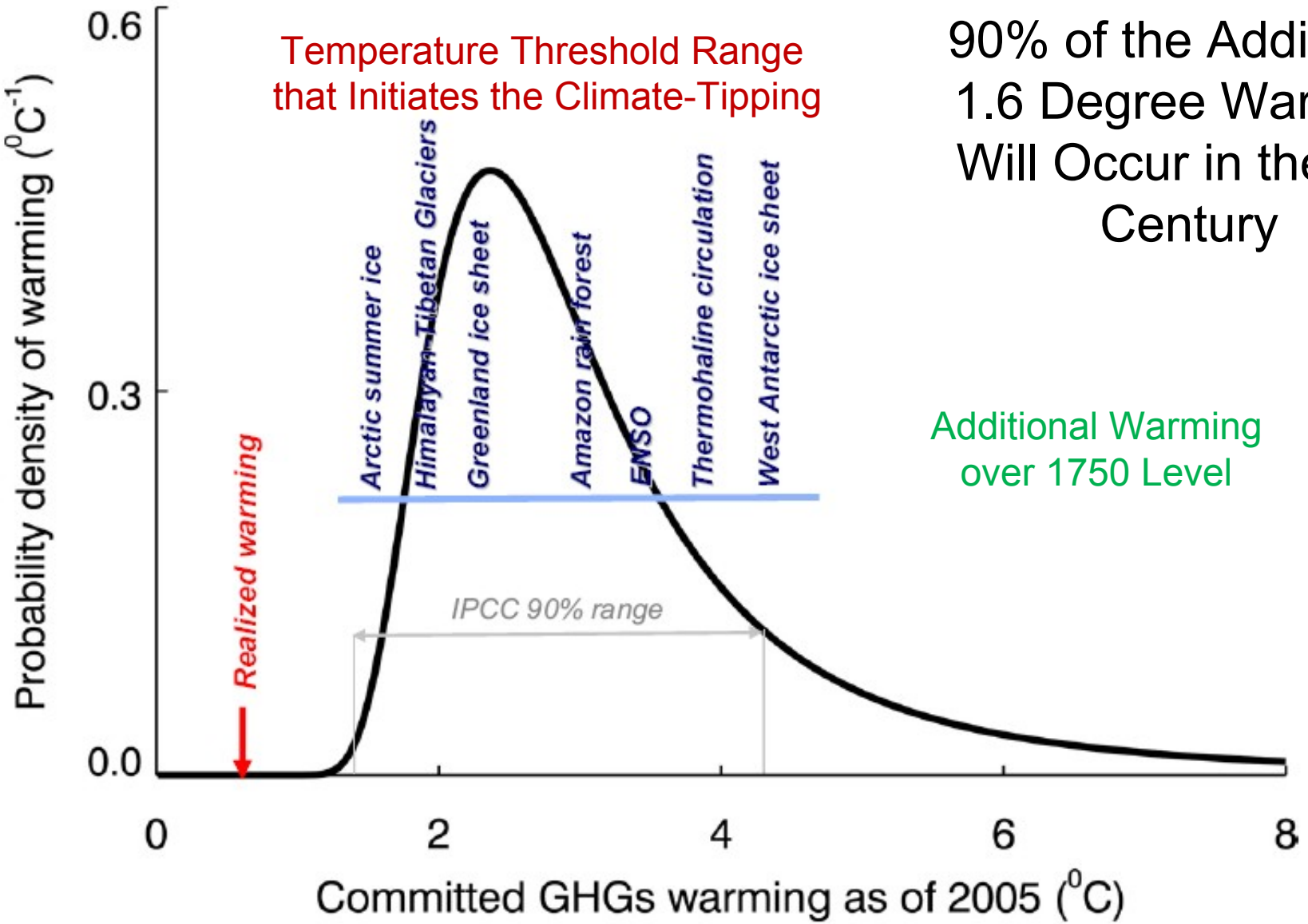
Source: Erik Hofer, UMich, School of Information

The Green IT Challenge

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The Planet is Already Committed to a Dangerous Level of Warming



90% of the Additional 1.6 Degree Warming Will Occur in the 21st Century

Additional Warming over 1750 Level

V. Ramanathan and Y. Feng, Scripps Institution of Oceanography, UCSD
September 23, 2008
www.pnas.orgcgidoi10.1073pnas.0803838105

The IPCC Recommends a 25-40% Reduction Below 1990 Levels by 2020

- On September 27, 2006, Governor Schwarzenegger signed California the Global Warming Solutions Act of 2006
  - Assembly Bill 32 (AB32)
  - Requires Reduction of GHG by 2020 to 1990 Levels
    - 15% Reduction from 2008 Levels
    - 4 Tons of CO_2-equiv. for Every Person in California
- The European Union Requires Reduction of GHG by 2020 to 20% Below 1990 Levels (12/12/2008)
- Australia has Pledged to Cut by 2020 its GHG Emissions 5% from 2000 Levels via the World's Broadest Cap &Trade Scheme (12/15/08) [~5% Below 1990 Levels]
- Neither the U.S. or Canada has an Official Target Yet
  - President Elect Obama Has Endorsed the AB32 2020 Goal

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ICT is a Critical Element in Achieving Countries Greenhouse Gas Emission Reduction Targets

Applications of ICT
could enable emissions reductions
of 7.8 Gt CO_2e in 2020,
or 15% of business as usual emissions.
But it must keep its own growing footprint in check
and overcome a number of hurdles
if it expects to deliver on this potential.



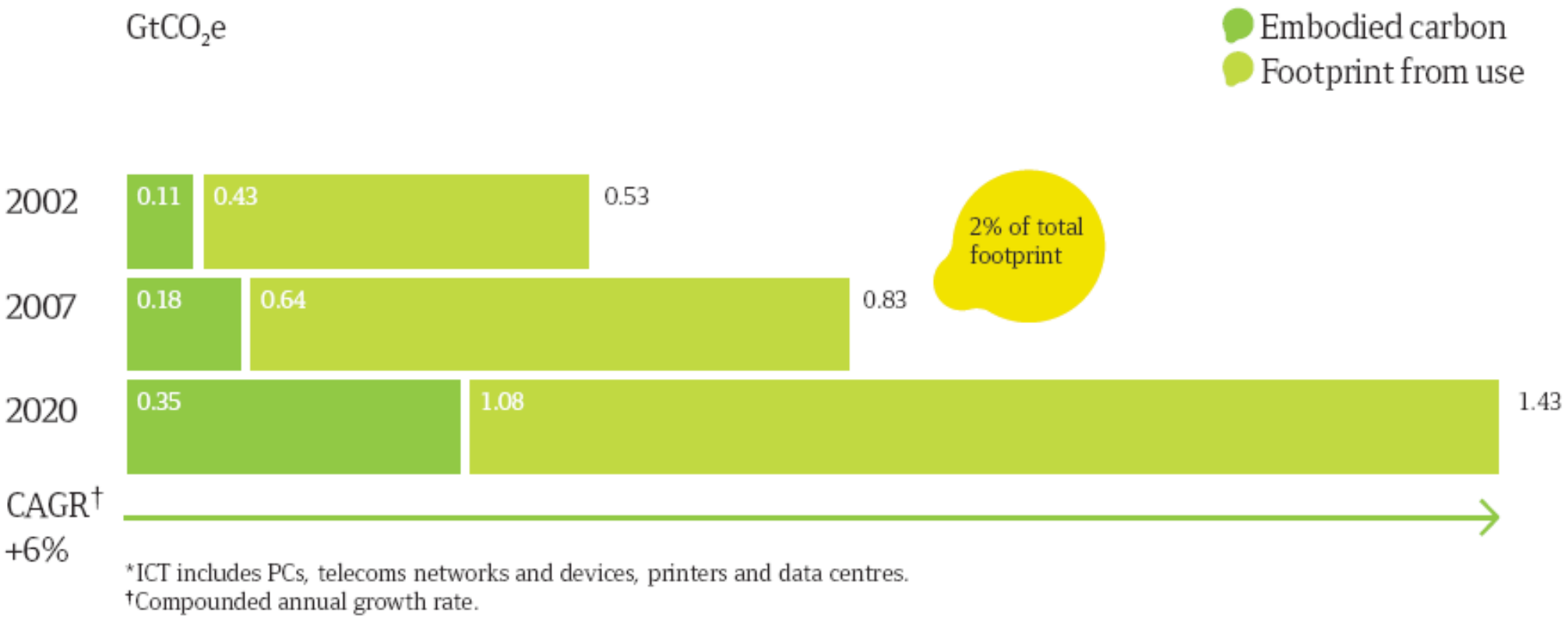


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www.smart2020.org

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The Global ICT Carbon Footprint
Roughly the Same as the Aviation Industry Today



ICT Industry is Already Acting to Reduce Carbon Footprint

Sun's 'portable' Blackbox data center

Company unveils new one-box data center

Sun Microsystems' CEO Jonathan Schwartz showed off the company's new "Project Blackbox" in a Menlo Park, Calif., parking lot Tuesday. Sun says the gear is not only preassembled, but it's tough and arrives ready to run.

HP's Green Business Technology Initiative



Innovative Dynamic Smart Cooling

Cut cooling costs in the data center as much as 40%.

» Learn more

Buying Green

updated 10:47 a.m. EST, Wed November 28, 2007

Google pushes 'green' power initiative

Intel Becomes Largest Purchaser of Green Power in the U.S.

Company Tops EPA Green Power Partner List, Vows to Drive for Greater Efficiency While Spurring Growth in Renewable Market

How Microsoft is going green

Biodiesel trucks, solar-powered data centers are just a couple environmentally friendly track

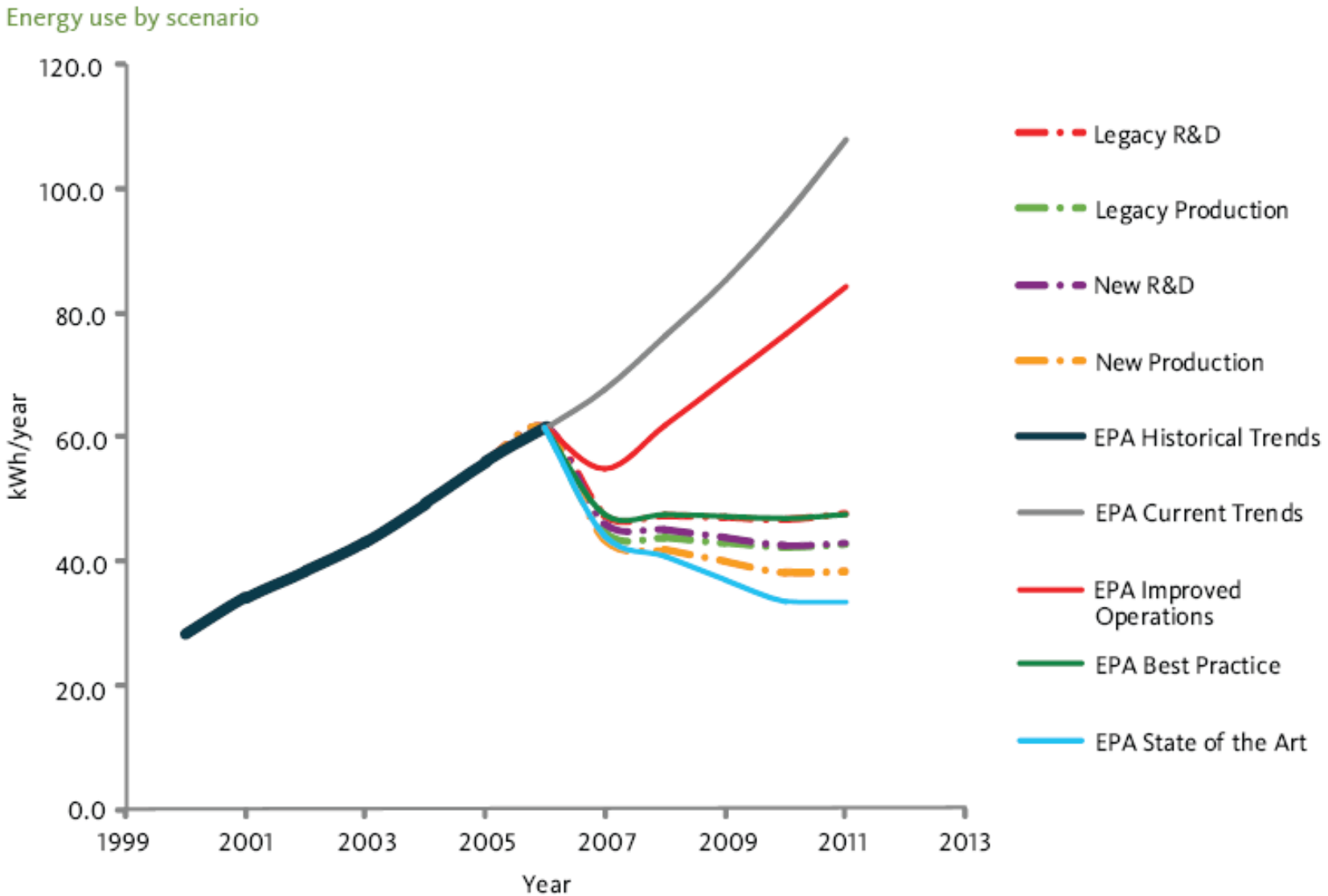
By John Fontana , Network World , 01/09/2008

IBM Project Big Green

Big Green Banner

Project Big Green is a $1 billion investment to dramatically increase the efficiency of IBM products. New IBM products and services,

Electricity Usage by U.S. Data Centers: Emission Reductions are Underway



Source: Silicon Valley Leadership Group Report July 29, 2008
https://microsite.accenture.com/svlgreport/Documents/pdf/SVLG_Report.pdf

The UCSD GreenLight Project: Instrumenting the Energy Cost of Computational Science

- **Focus on 5 Communities with At-Scale Computing Needs:**
  - Metagenomics
  - Ocean Observing
  - Microscopy
  - Bioinformatics
  - Digital Media





- **Measure, Monitor, & Web Publish Real-Time Sensor Outputs**
  - Instrument Eight Racks of Compute, Storage, Routers
  - Outputs Available Via Service-oriented Architectures
  - Allow Researchers Anywhere To Study Computing Energy Cost
- **Develop Middleware that Automates Optimal Choice of Compute/RAM Power Strategies for Desired Greenness**
- **Partnering With Minority-Serving Institutions Cyberinfrastructure Empowerment Coalition**

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Source: Tom DeFanti, Calit2; GreenLight PI

Application of ICT Can Lead to a 5-Fold Greater Decrease in GHGs Than its Own Carbon Footprint

While the sector plans to significantly step up the energy efficiency of its products and services, ICT's largest influence will be by enabling energy efficiencies in other sectors, an opportunity that could deliver carbon savings five times larger than the total emissions from the entire ICT sector in 2020.

--Smart 2020 Report

Major Opportunities for the United States*

- **Smart Electrical Grids**
- **Smart Transportation Systems**
- **Smart Buildings**
- **Virtual Meetings**

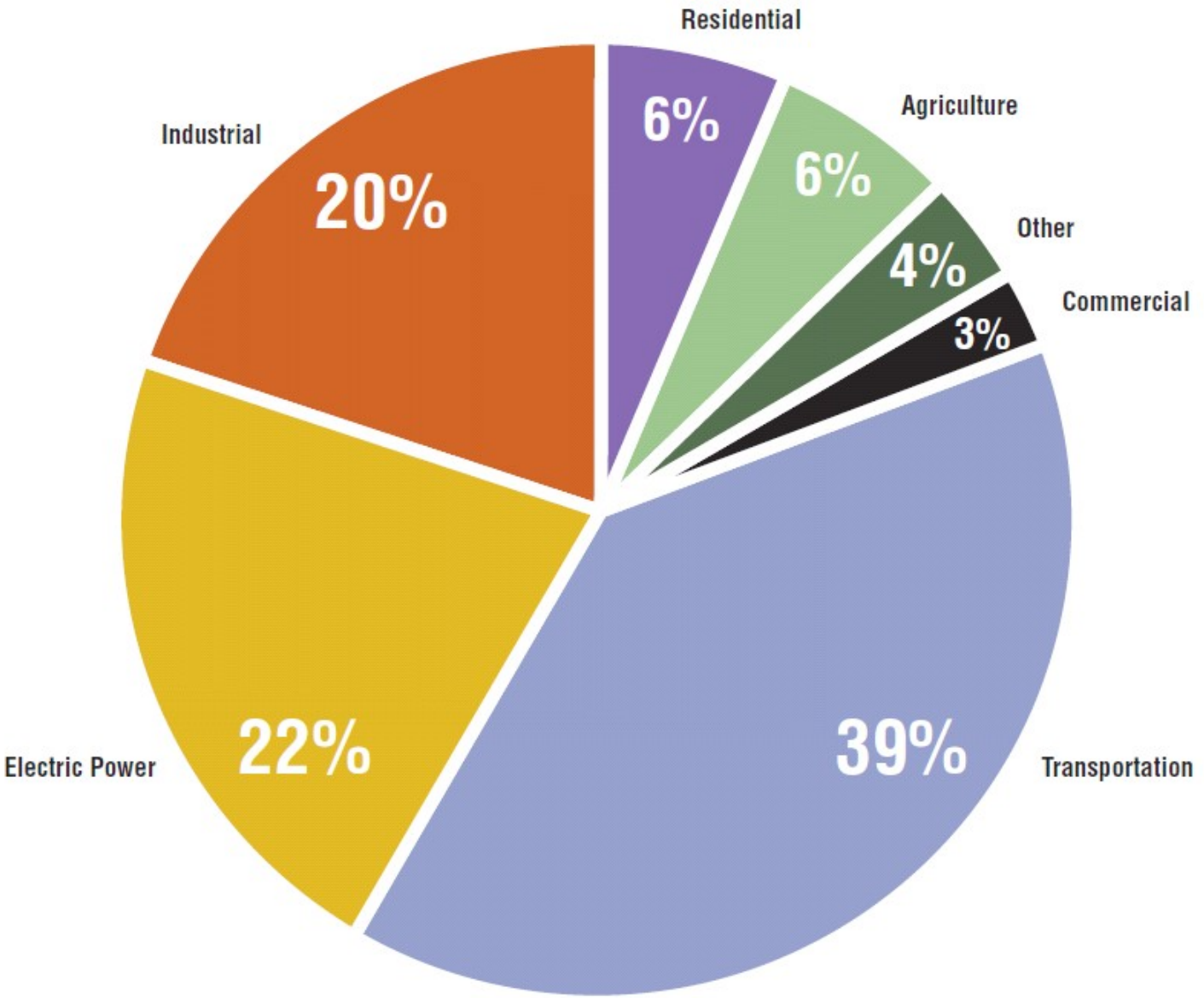
*** Smart 2020 United States Report Addendum**

www.smart2020.org

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Greenhouse Gas Emissions in California by Source 2006



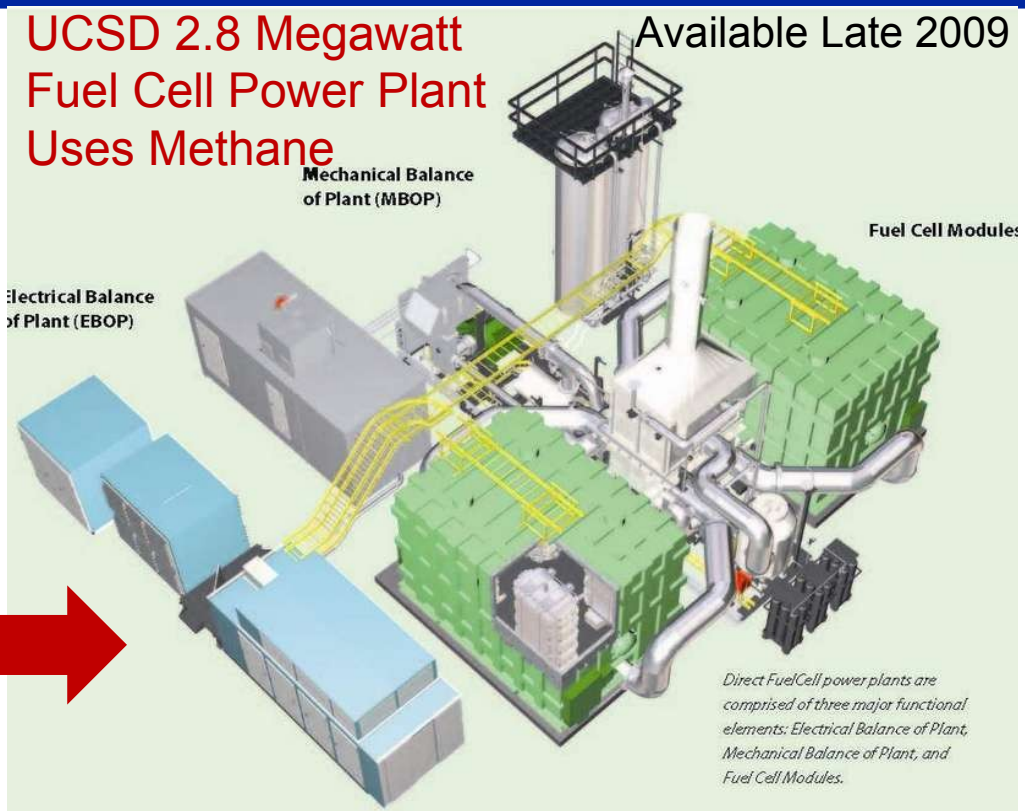
UCSD is Installing Zero Carbon Emission Solar and Fuel Cell DC Electricity Generators

San Diego's Point Loma Wastewater Treatment Plant Produces Waste Methane



UCSD 2.8 Megawatt Fuel Cell Power Plant Uses Methane

Available Late 2009





2 Megawatts of Solar Power Cells Being Installed

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Launch of ZEVnet Fleet of Wireless Cars-- First Calit2 Testbed for Intelligent Transportation

TOYO



April 18,
Irvine,
www.zevr

Toyota Delivers Plug-in Prius to UC Irvine and UC Berkeley as Part of Clean Mobility Partnership









TORRANCE, Calif., Nov. 9, 2007 -- Toyota Motor Sales, U.S.A.,

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STUDIES

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Reducing Traffic Congestion: Calit2 California Peer-to -Peer Wireless Traffic Report

- **Citizen to Citizen Accident Reports**
- **Real-Time Freeway Speeds**
- **"Leave Now" Paging Services**

20,000+ Users
> 1000 Calls Per Day

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http://traffic.calit2.net

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Source: Ganz Chockalingam, Calit2

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Using High Definition to Link the Calit2 Buildings: Living Greener



une 2, 2008

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UCSD is Becoming a "Living Laboratory of the Green Future



www.gogreentube.com/watch.php?v=NDc4OTQ1

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International Symposia on Green ICT

CUBIN

Symposium on Sustainability of the Internet and ICT

THE UNIVERSITY OF MELBOURNE

November 25 & 26, 2008, The University of Melbourne

January 22-23, 2009

Greening the Internet Economy

ICT & GLOBAL CHANGE



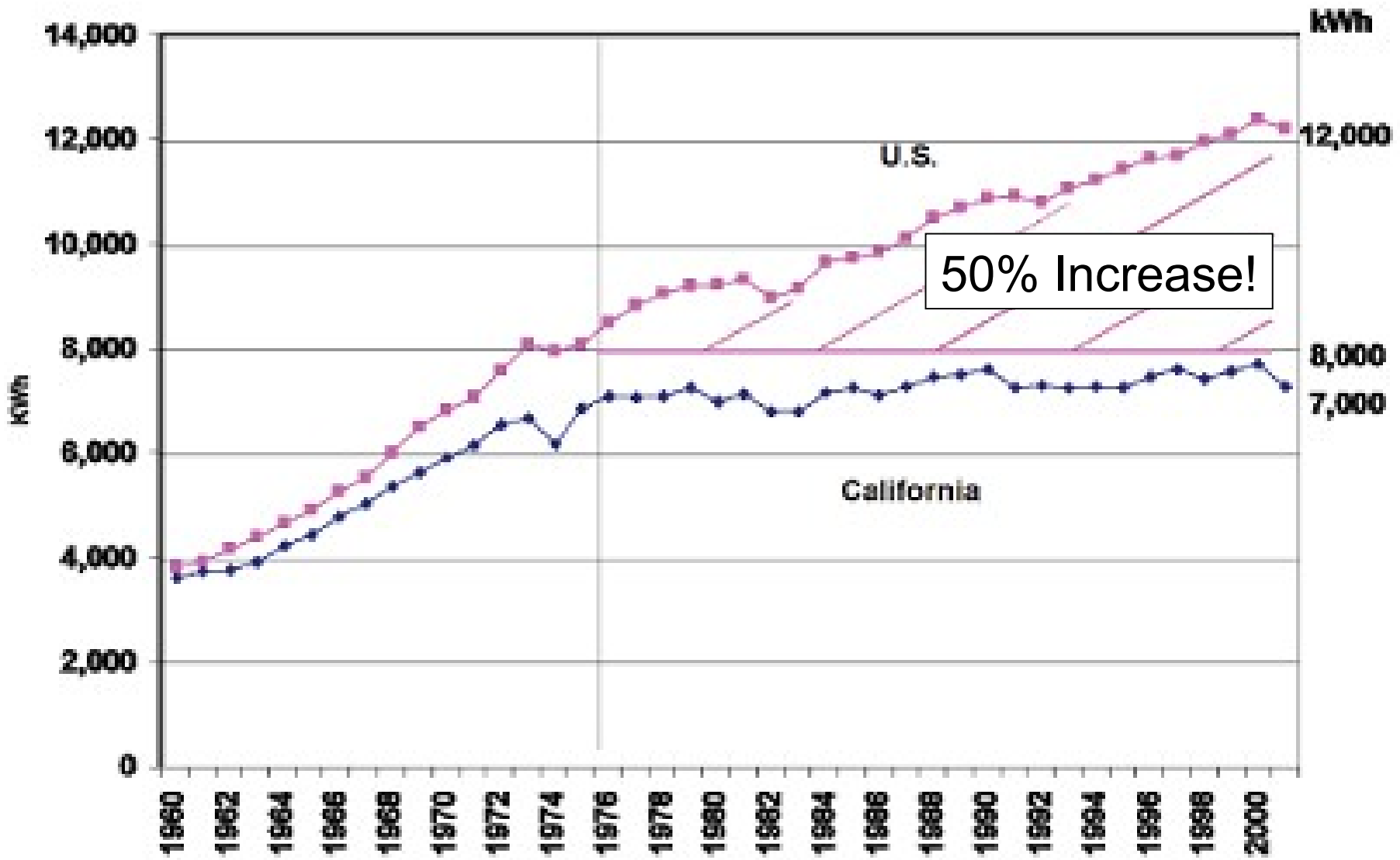
California Public Utilities Commission

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Co-Hosted By Calit2 & CPUC

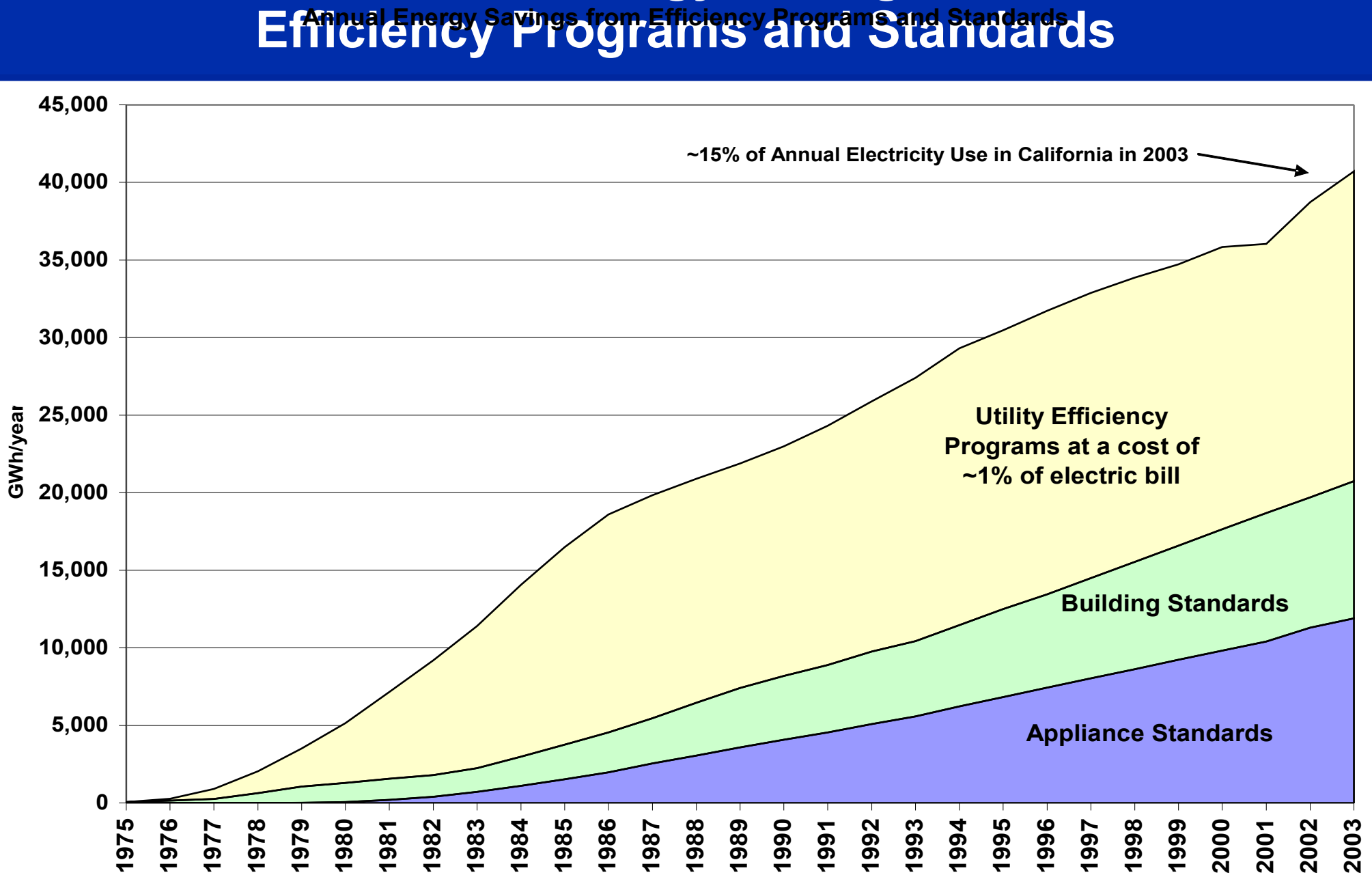
Electricity Usage Per Capita
California vs. U.S.



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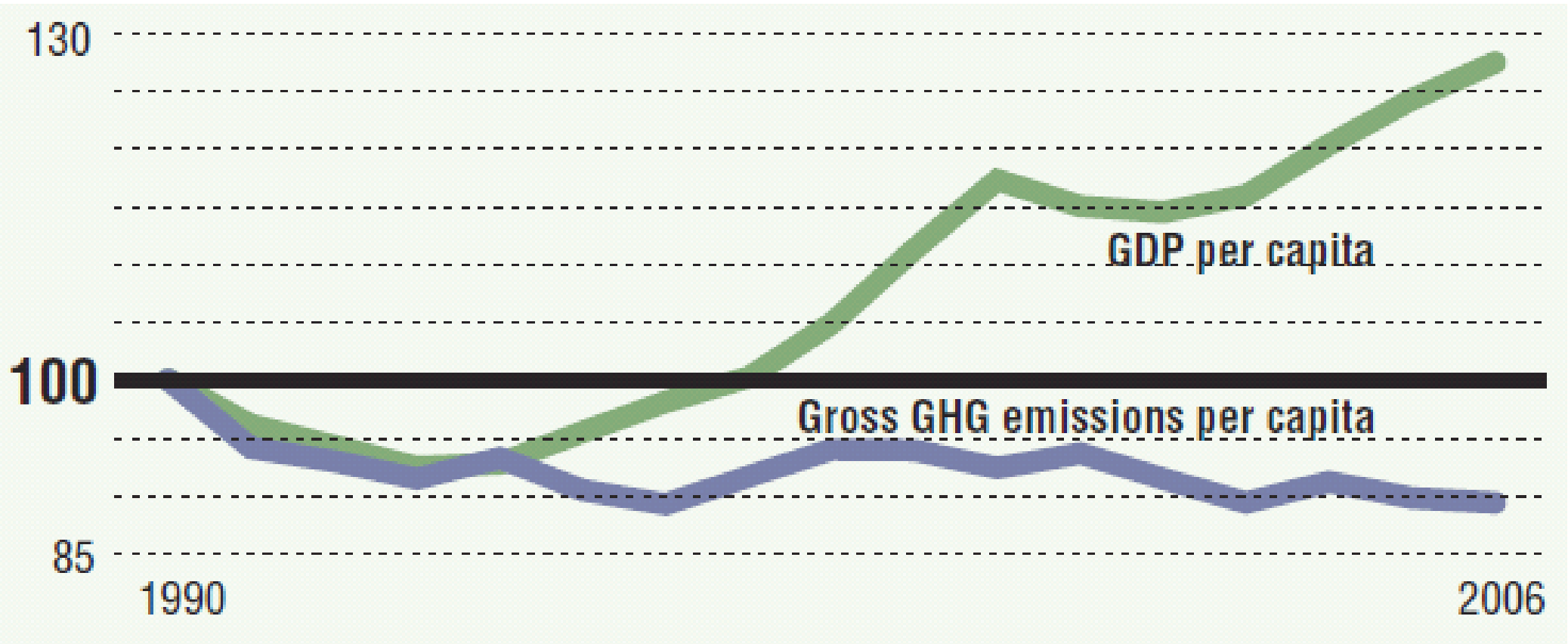
California Energy Savings from Efficiency Programs and Standards



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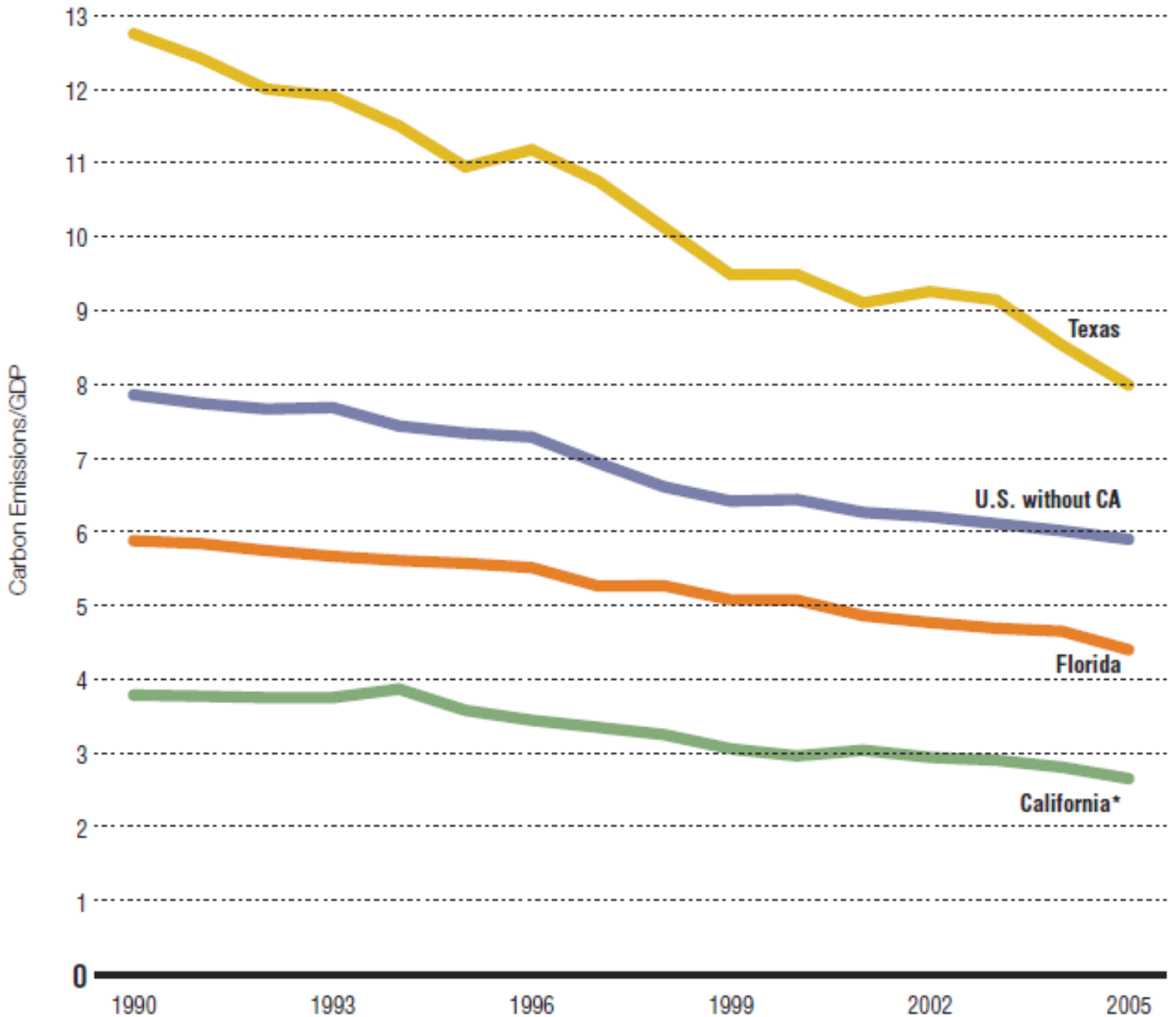
Decoupling Economic Growth From Greenhouse Gas Emissions—the California Story



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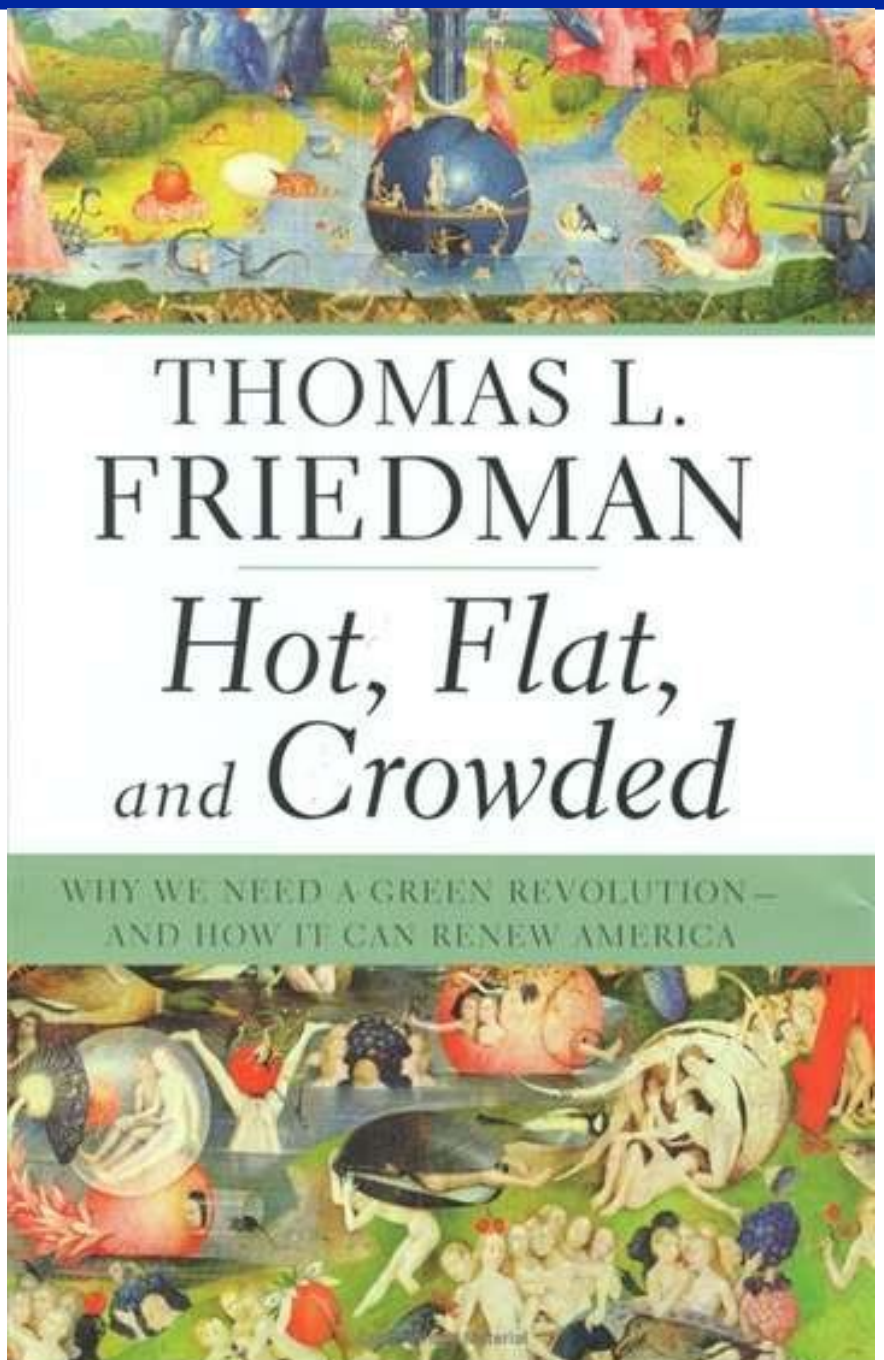
Toward a Zero Carbon Economy
Carbon Emissions/$GDP



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“It Will Be the Biggest Single Peacetime Project Humankind Will Have Ever Undertaken”



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