Sustainability Requires Green Cyberinfrastructure

Invited Talk

UCSD Jacobs School of Engineering

Council of Advisors

May 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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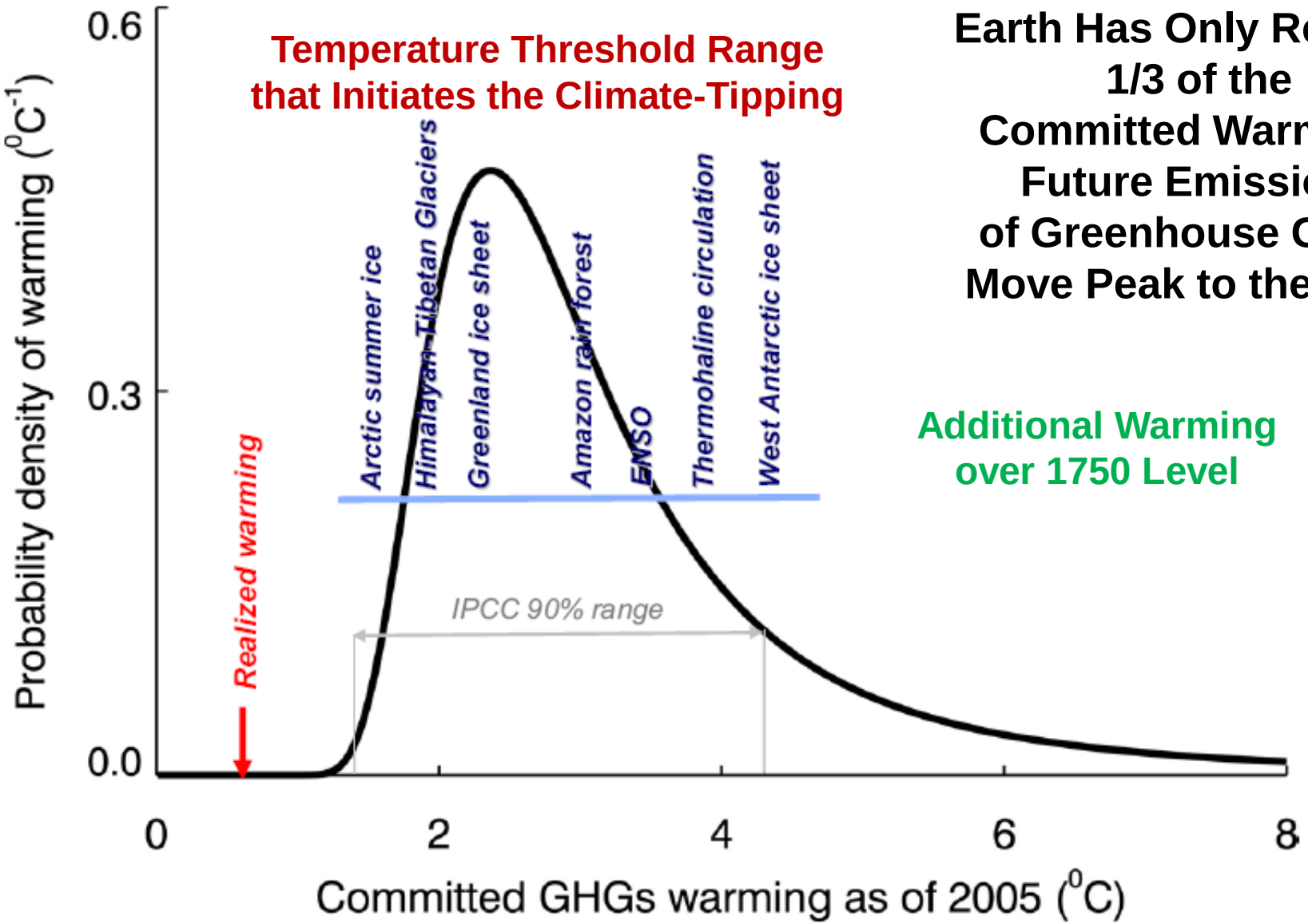
Calit2 Continues to Pursue Its Initial Mission:

Envisioning How the Extension of Innovative Telecommunications and Information Technologies Throughout the Physical World will Transform Critical Applications Important to the California Economy and its Citizens' Quality Of Life.

In the Coming Decade, We Believe that Sustainability and Climate Disruption Will Dominate California's Future

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The Planet is Already Committed to a Dangerous Level of Warming



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

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The Hindu Kush/Himalayan Plateau Has the Most Snow and Ice Outside of the Polar Regions

Gordon and Betty MOORE FOUNDATION

UNIVERSITY OF CAMBRIDGE

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"Water Towers of Asia"
Impact
40% of the
World's Population

UCSD-Cambridge Workshop
May 4 – May 6, 2009
University of California San Diego
La Jolla, CA

Ice, Snow, and Water

Impacts of Climate Change on California and Himalayan Asia

"California Faces Water Rationing, Governor Proclaims Drought Emergency"
--February 27, 2009



HKH Map with major river basins

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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 Only to 1990 Levels**
    - **10% Reduction from 2008 Levels; 30% from BAU 2020 Levels**
    - **4 Tons of CO_2-equiv. Reduction 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 Obama Has Endorsed the AB32 2020 Goal**

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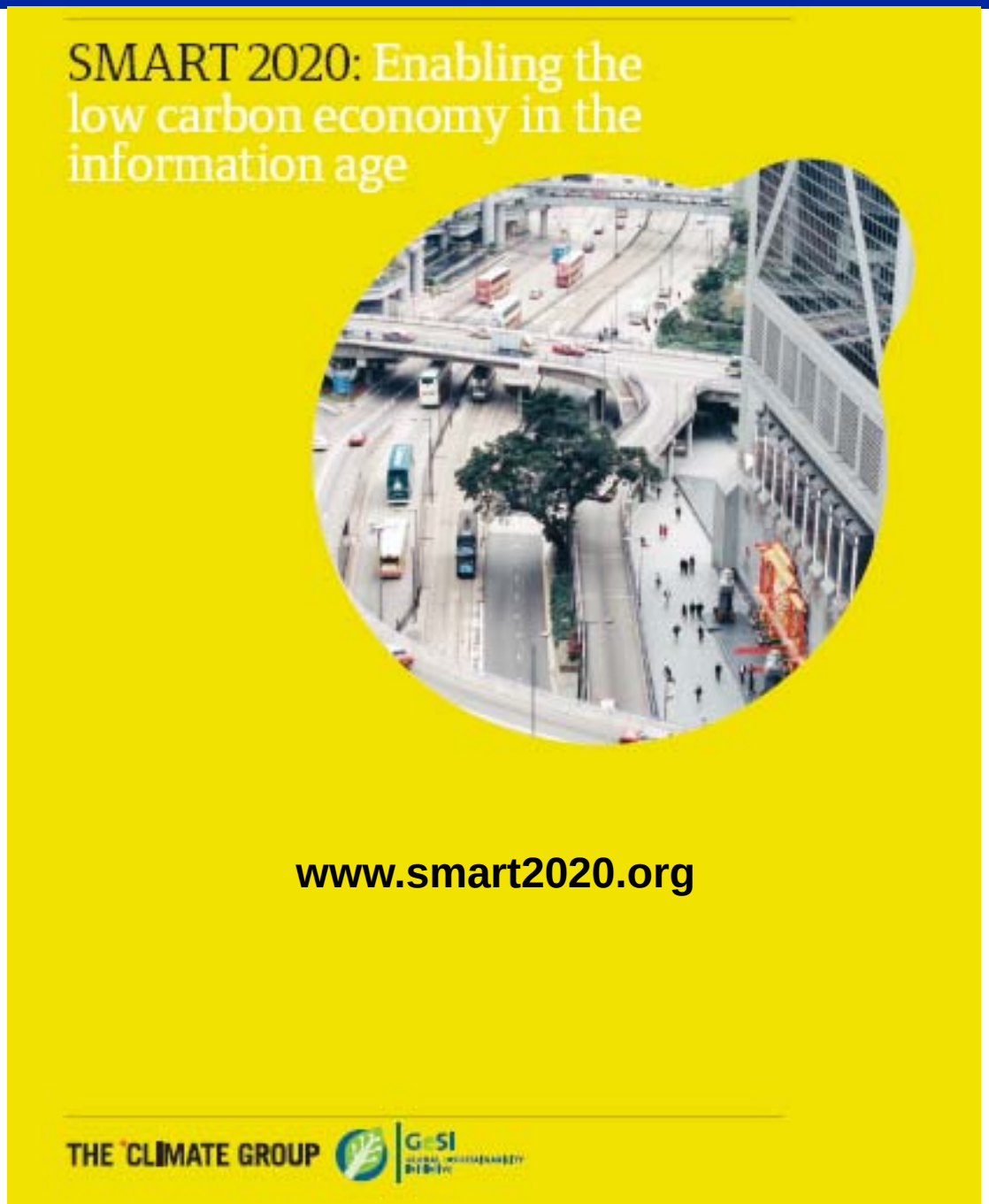
ICT is a Critical Element in Achieving Countries Greenhouse Gas Emission Reduction Targets

GeSI member companies:

- **Bell Canada,**
- **British Telecomm.,**
- **Plc,**
- **Cisco Systems,**
- **Deutsche Telekom AG,**
- **Ericsson,**
- **France Telecom,**
- **Hewlett-Packard,**
- **Intel,**
- **Microsoft,**
- **Nokia,**
- **Nokia Siemens Networks,**
- **Sun Microsystems,**
- **T-Mobile,**
- **Telefónica S.A.,**
- **Telenor,**
- **Verizon,**
- **Vodafone Plc.**

Additional support:

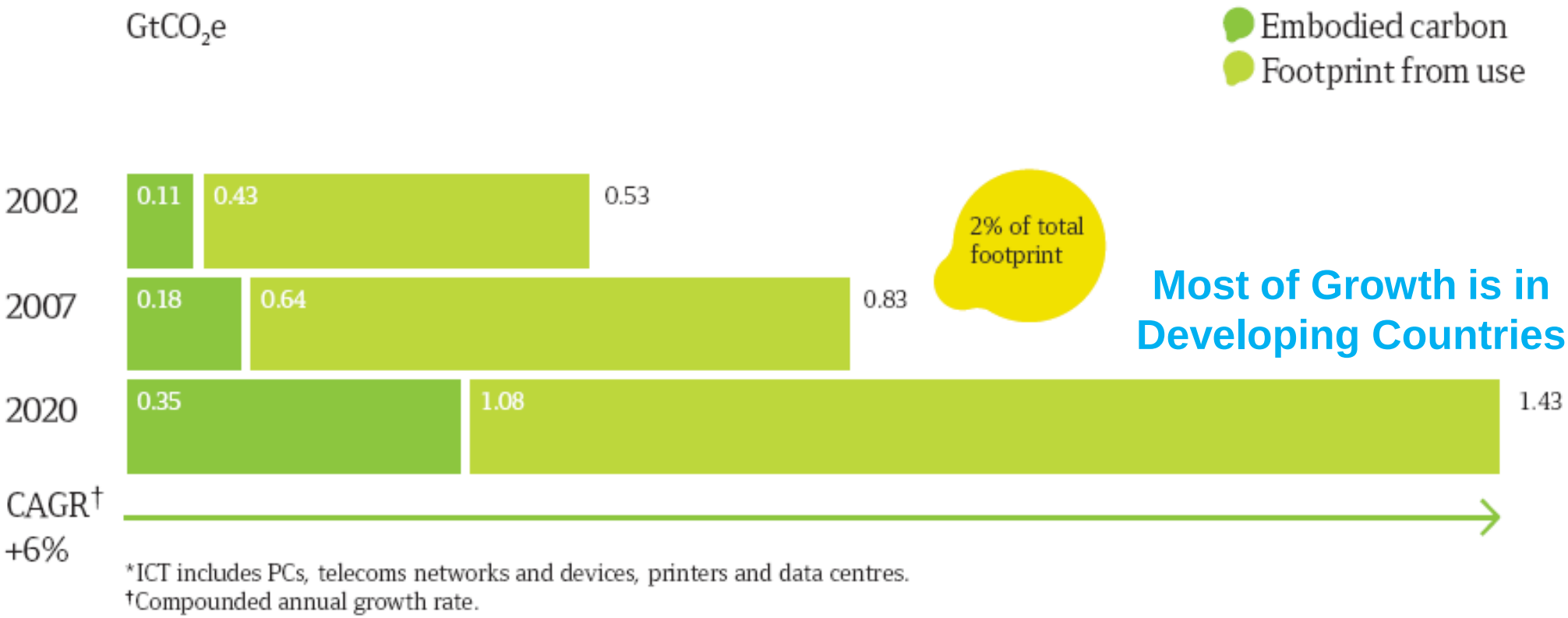
- **Dell, LG.**



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

But ICT Emissions are Growing at 6% Annually!



Most of Growth is in Developing Countries

the assumptions behind the growth in emissions expected in 2020:

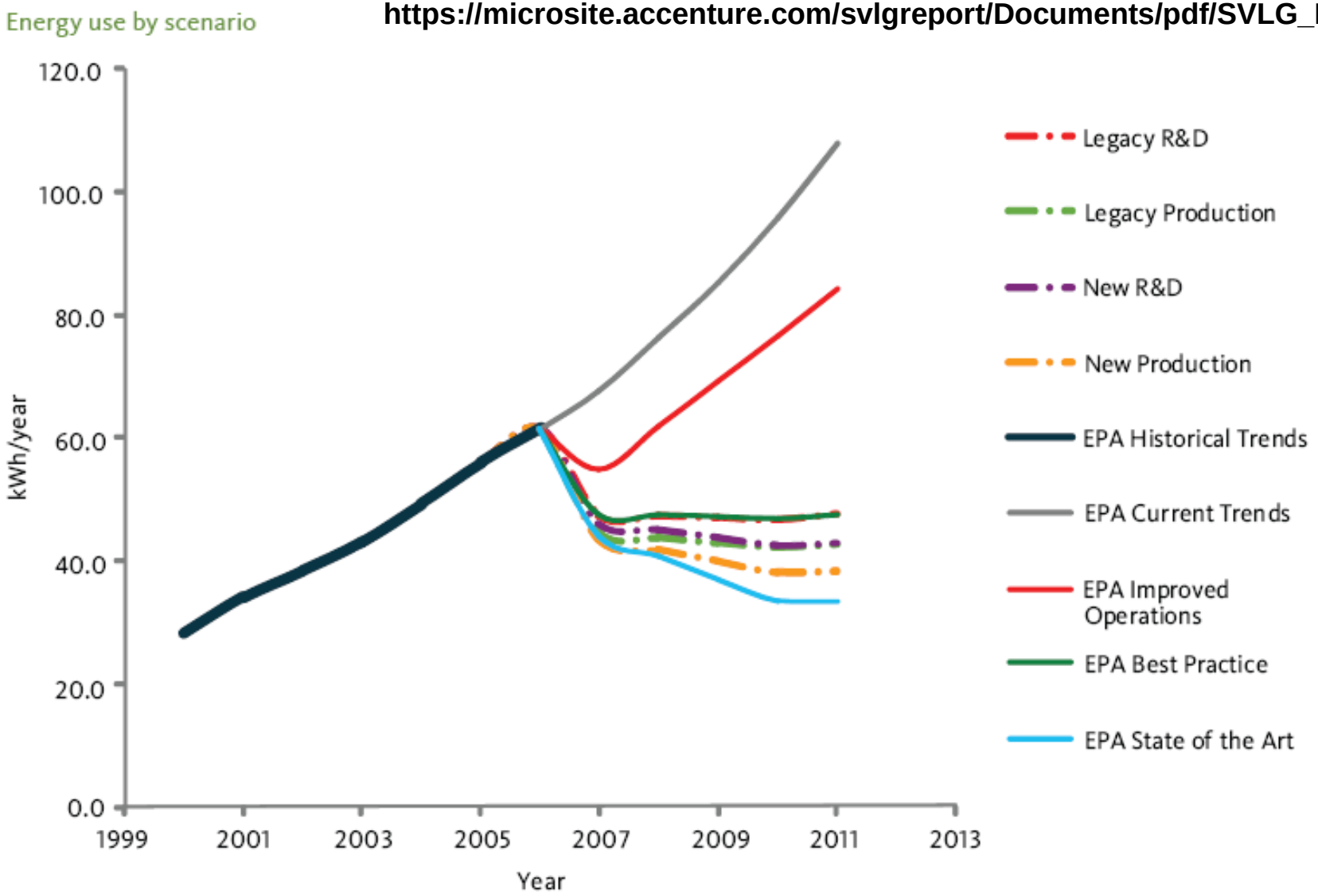
- **takes into account likely efficient technology developments that affect the power consumption of products and services**
- **and their expected penetration in the market in 2020**

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www.smart2020.org

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



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The NSF-Funded GreenLight Project
Giving Users Greener Compute and Storage Options

UCSD Structural Engineering Dept. Conducted Sun MD Tests May 2007



7 Racks plus Network



Takes up 2 Parking Spaces



Data Power Cooling

- **Measure, Publish, and Control Energy Usage:**
  - **Sun Has Shown up to 40% Reduction in Energy**
  - **Active Management of Disks, CPUs, etc.**
  - **Measures Temperature at 5 Levels in 8 Racks**
  - **Power Utilization in Each of the 8 Racks**
  - **Chilled Water Cooling Systems**



Source: Tom DeFanti, Calit2; GreenLight PI

UCSD (Calit2 & SOM) Bought Two Sun MDs May 2008

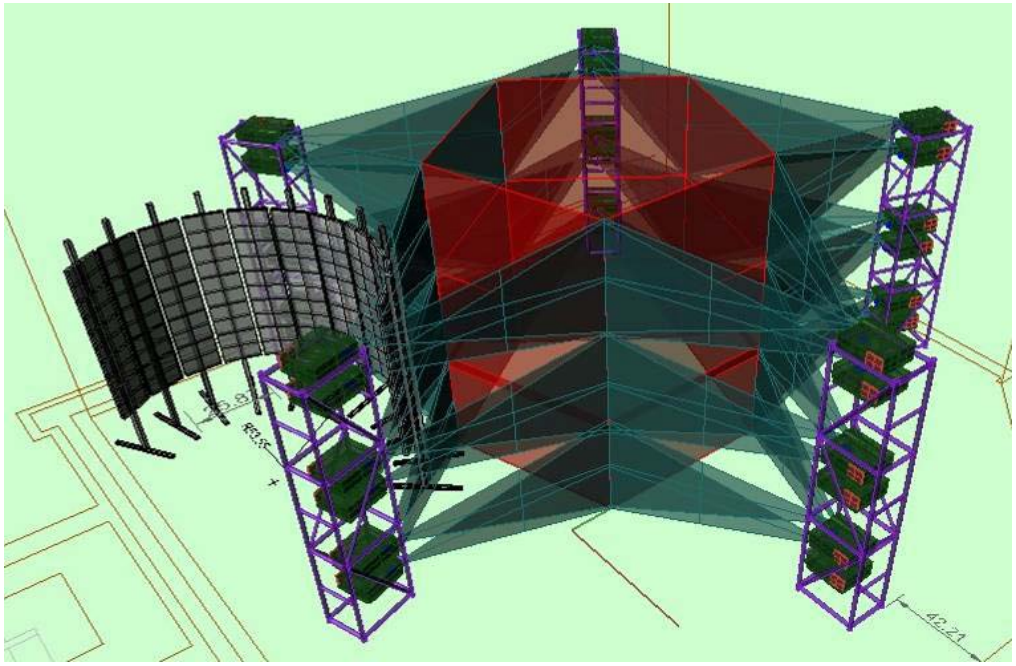
GreenLight's Data is Available Remotely: Virtual Version in Calit2 StarCAVE







30 HD Projectors!



Connected at 50 Gb/s to Quartzite

Source: Tom DeFanti, Greg Dawe, Jurgen Schulze, Calit2

Research Needed on How to Deploy a Green CI



- **Computer Architecture**
  - Rajesh Gupta/CSE
- **Software Architecture**
  - Amin Vahdat, Ingolf Kruger/CSE
- **CineGrid Exchange**
  - Tom DeFanti/Calit2
- **Visualization**
  - Falko Kuster/Structural Engineering
- **Power and Thermal Management**
  - Tajana Rosing/CSE
- **Analyzing Power Consumption Data**
  - Jim Hollan/Cog Sci
- **Direct DC Datacenters**
  - Tom Defanti, Greg Hidley

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http://greenlight.calit2.net

it²

New Techniques for Dynamic Power and Thermal Management to Reduce Energy Requirements



NSF Project Greenlight

- Green Cyberinfrastructure in Energy-Efficient Modular Facilities
- Closed-Loop Power &Thermal Management

Dynamic Power Management (DPM)

- Optimal DPM for a Class of Workloads
- Machine Learning to Adapt
  - Select Among Specialized Policies
  - Use Sensors and Performance Counters to Monitor
  - Multitasking/Within Task Adaptation of Voltage and Frequency
  - Measured Energy Savings of Up to 70% per Device

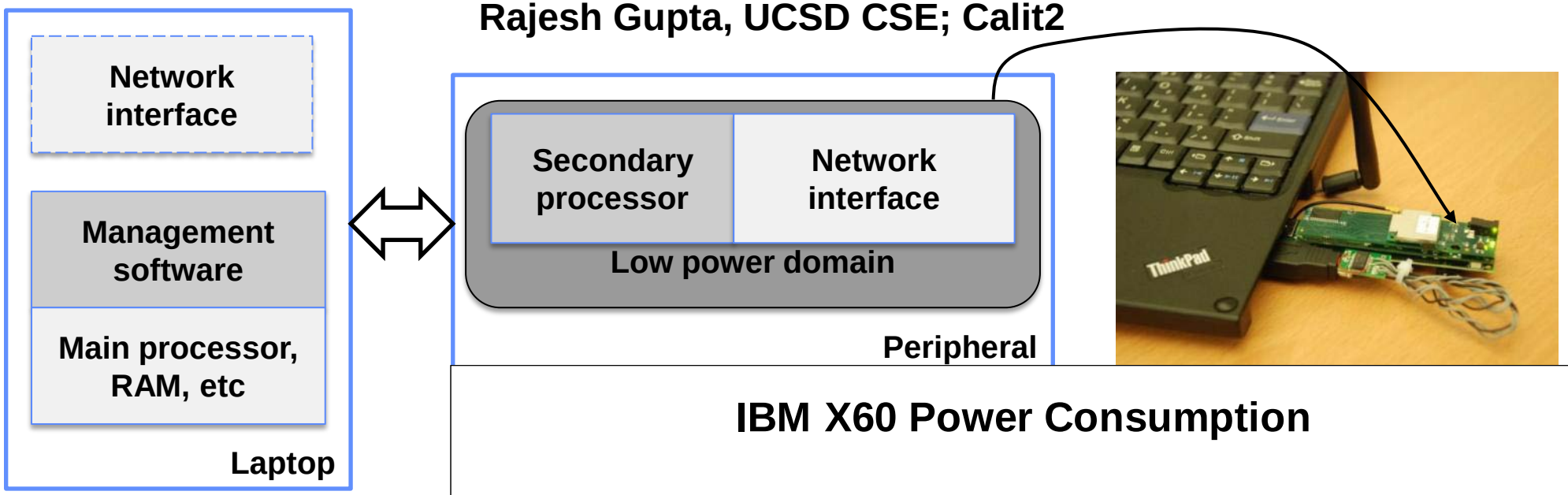
Dynamic Thermal Management (DTM)

- Workload Scheduling:
  - Machine learning for Dynamic Adaptation to get Best Temporal and Spatial Profiles with Closed-Loop Sensing
  - Proactive Thermal Management
  - Reduces Thermal Hot Spots by Average 60% with No Performance Overhead

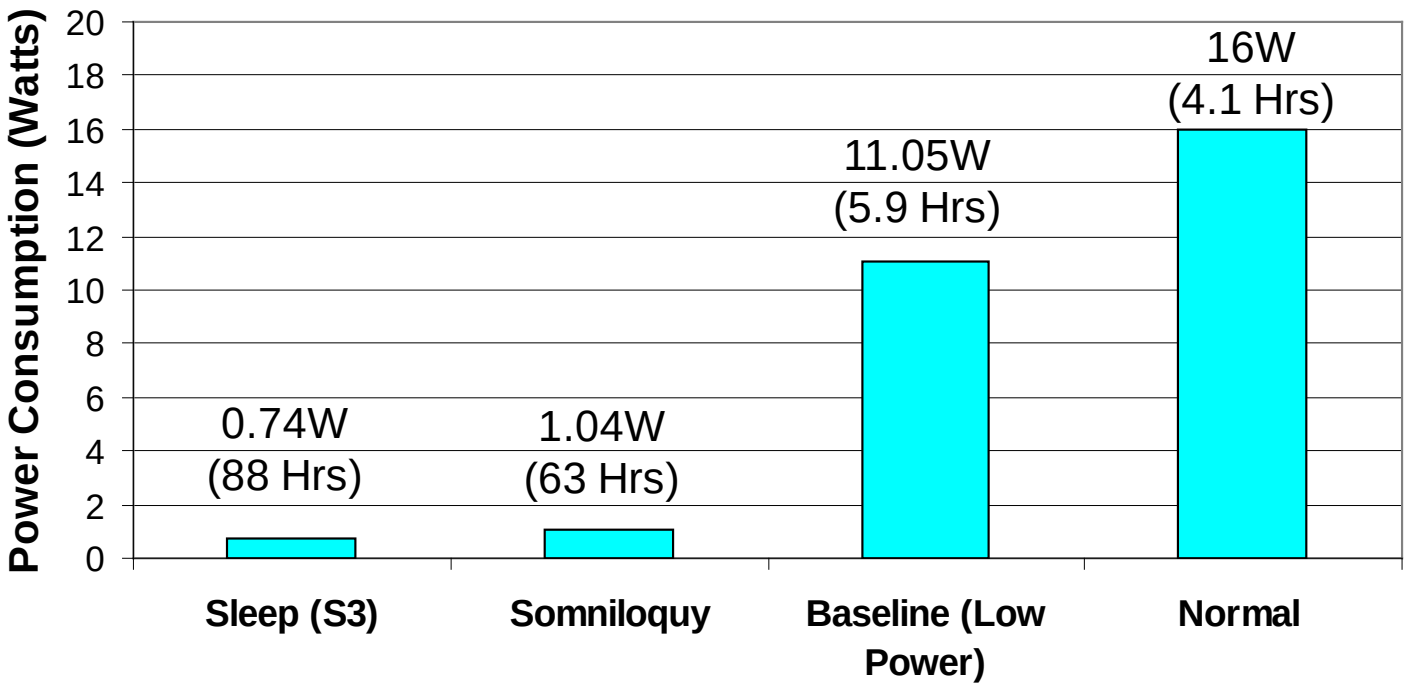
System Energy Efficiency Lab (seelab.ucsd.edu)
Prof. Tajana Šimunić Rosing, CSE, UCSD

GreenLight Project: Putting Machines To Sleep Transparently

Rajesh Gupta, UCSD CSE; Calit2



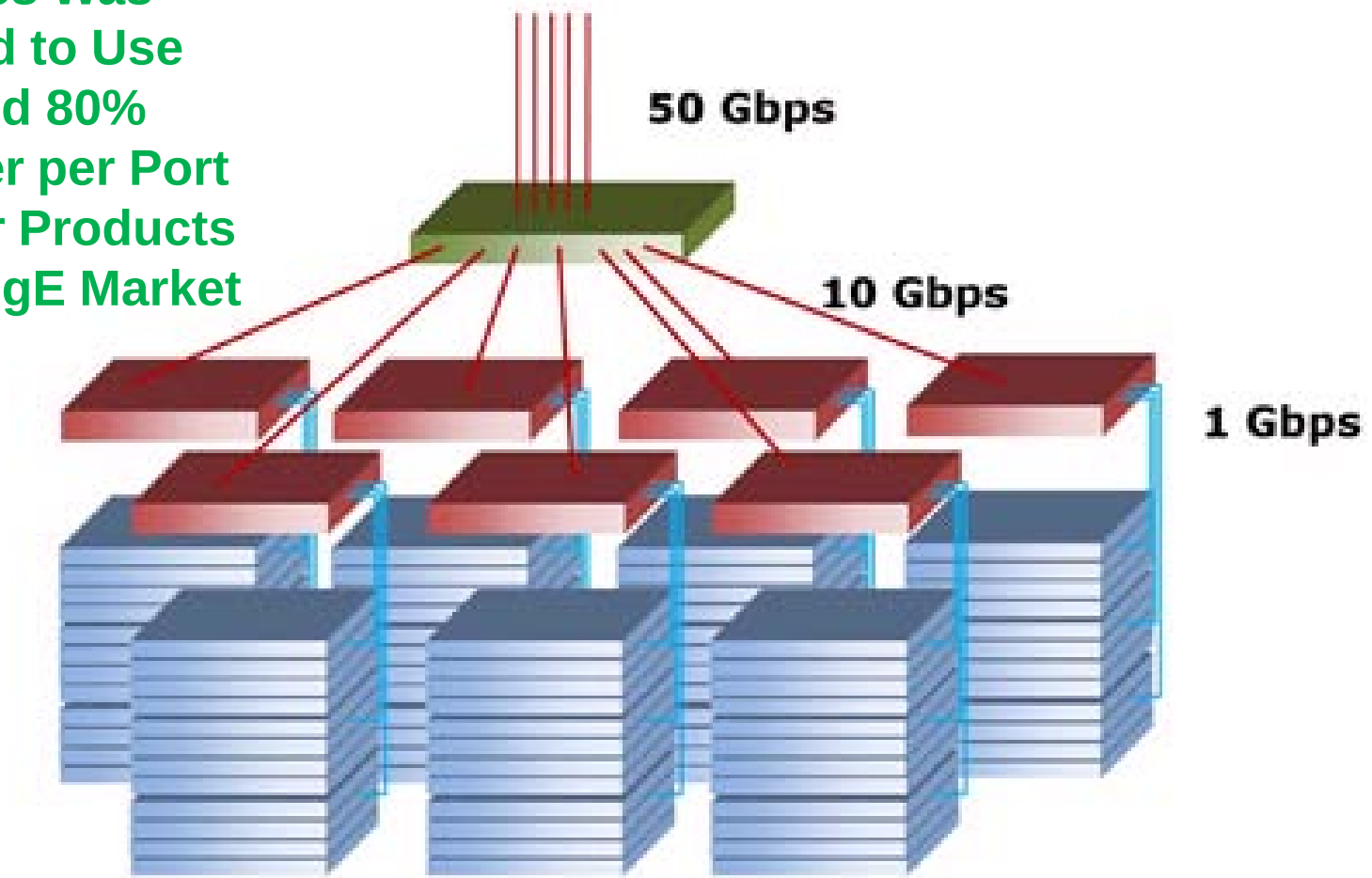
Somniloquy Enables Servers to Enter and Exit Sleep While Maintaining Their Network and Application Level Presence



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GreenLight Provides a Environment for Innovative "Greener" Products to be Tested

Quadrics Was Designed to Use 20% and 80% Less Power per Port Than Other Products in the 10 GigE Market

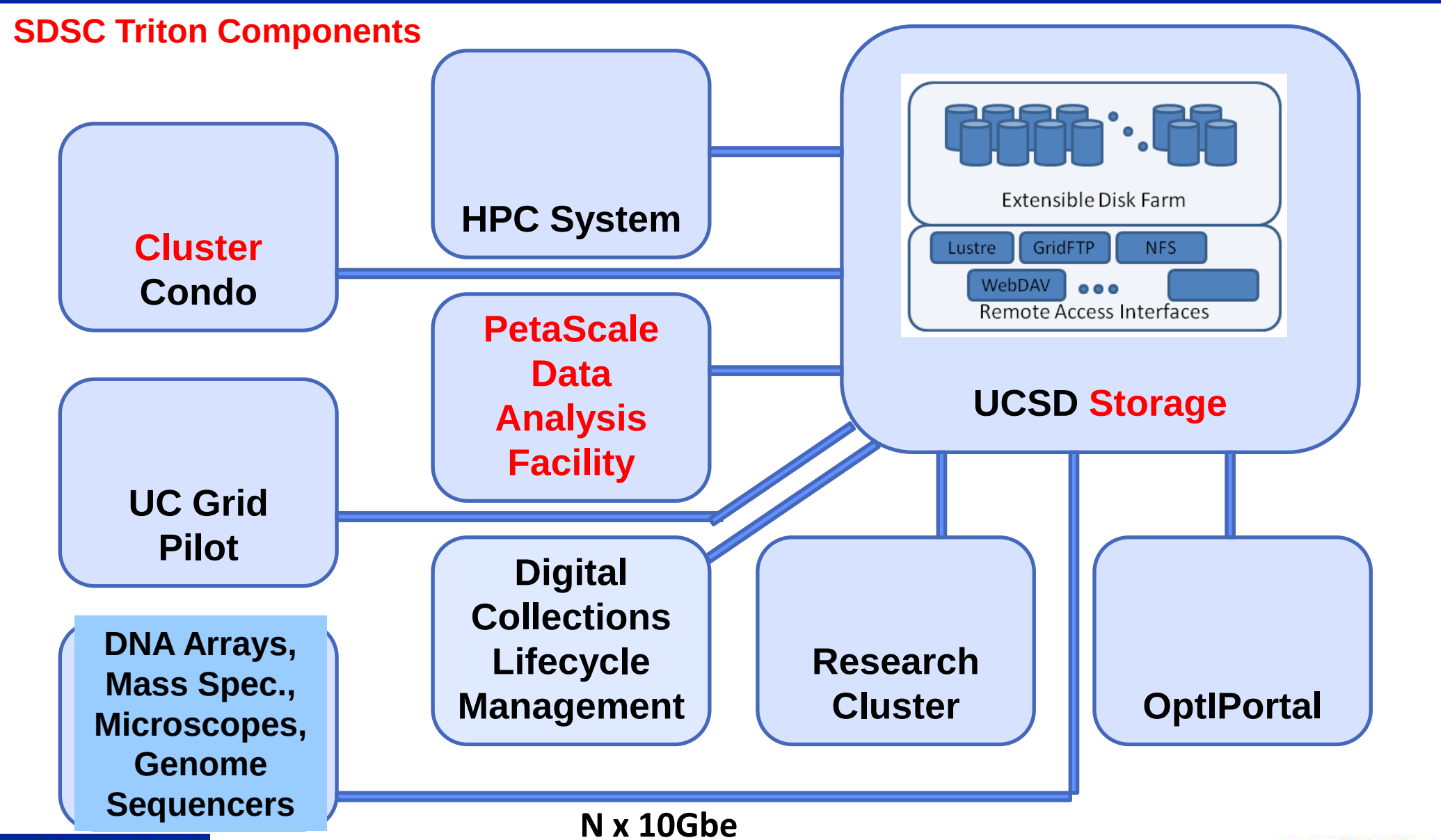


GreenLight topology for 10GE link aggregation: When complete, the servers (blue) will connect to edge switches (red) via 1 Gbps links, and the edge switches will connect to each other via the 10 Gbps links of the Quadrics TG201 switch (green).

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www.calit2.net/newsroom/article.php?id=1482

Consolidating Dispersed Faculty Clusters Over the Fiber Connected UCSD Campus Research CI



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Source: Phil Papadopoulos, SDSC/Calit2

Power Management in the Cellular Infrastructure: Calit2 Team Achieves 58% Power Amplifier Efficiency

Standard Commercial Base Station Power Amp is 10% Efficient

Calit2
High-Power
Amplifier Lab

freescale semiconductor

TriQuint SEMICONDUCTOR

HUAWEI

ERICSSON

Power Transistor Tradeoffs:

Si-LDMOS, GaN, & GaAs

Price & Performance

Eudyna

Power Amplifier Tradeoffs:

WiMAX & 3.9GPP LTE

Efficiency & Linearity

STMicroelectronics

Digital Signal Processing Tradeoffs:

Pre-Distortion, Memory Effects & Power Control

MIPS & Memory

NOKIA

QUALCOMM

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www.universityofcalifornia.edu/news/article/19058

Source: Don Kimball, Calit2; Peter Asbeck and Larry Larson, ECE

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Leading Edge Photonics Systems Laboratory Has Demonstrated Multiple World Records

- **Networking "Living Lab" Testbed Core**
  - **Terabit Networking**
  - **Micro LIDAR/Spectroscopy**
  - **Silicon Frequency Conversion**
  - **320Gbps Real Time Processing**
  - **Advanced Transmission Coding**

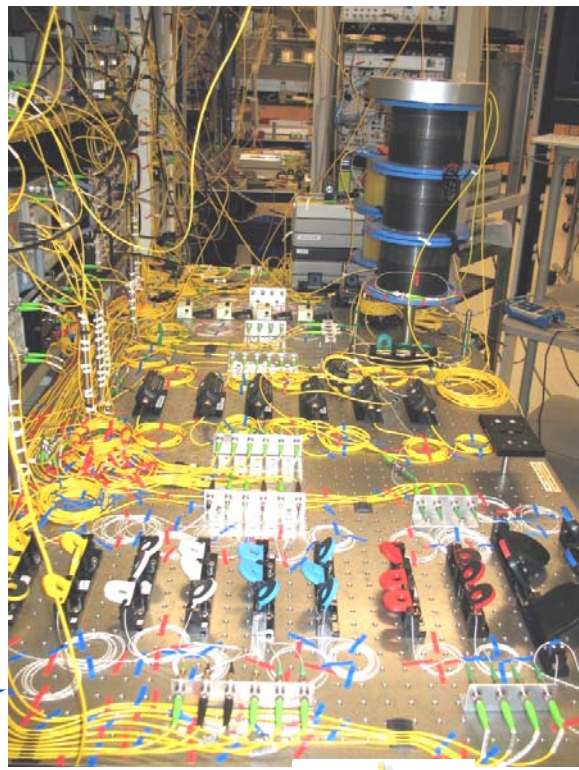
Alcatel·Lucent

AVANEX

ofs
A Furukawa Company

SUMITOMO ELECTRIC
LIGHTWAVE

LOCKHEED MARTIN



ECE Testbed Faculty



Stojan Radic
Optical communication networks; all-optical processing; parametric processes in high-confinement fiber and semiconductor devices.



George Papen
Advanced photonic systems including optical communication systems, optical networking, and environmental and atmospheric remote sensing.



Joseph Ford
Optoelectronic subsystems integration (MEMS, diffractive optics, VLSI); Fiber optic and free-space communications.



Shaya Fainman
Nanoscale science and technology; ultrafast photonics and signal processing



Shayan Mookherjea
Optical devices and optical communication networks, including photonics, lightwave systems and nano-scale optics.



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PARAMETRIC OPTICAL PROCESSES & SYSTEMS

DARPA

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UCSD Photonics

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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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Real-Time Monitoring of Building Energy Usage: UCSD Has 34 Buildings On-Line



Import/Production
Meter Reads
Vista

UCSD MAP | HOUSING

Real Time Cost Per Hour $ 2,570
Real Time kW Usage 30,238 kW

	SIO	UCSD Medical Center La Jolla	Warren Campus University Center	East Campus	Muir Campus
Current Month:					
Monthly Cost ($)	66,121	64,277	138,097	18,564	67,143
kWh del	777,893 kWh	756,204 kWh	1,624,674 kWh	218,400 kWh	789,923 kWh
Previous Month:					
Monthly Cost ($)	149,881	148,692	320,149	42,478	157,613
kWh del	1,763,309 kWh	1,749,312 kWh	3,766,459 kWh	499,744 kWh	1,854,266 kWh
Realtime Values:					
kW inst	2,546 kW	2,665 kW	5,475 kW	638 kW	2,404 kW

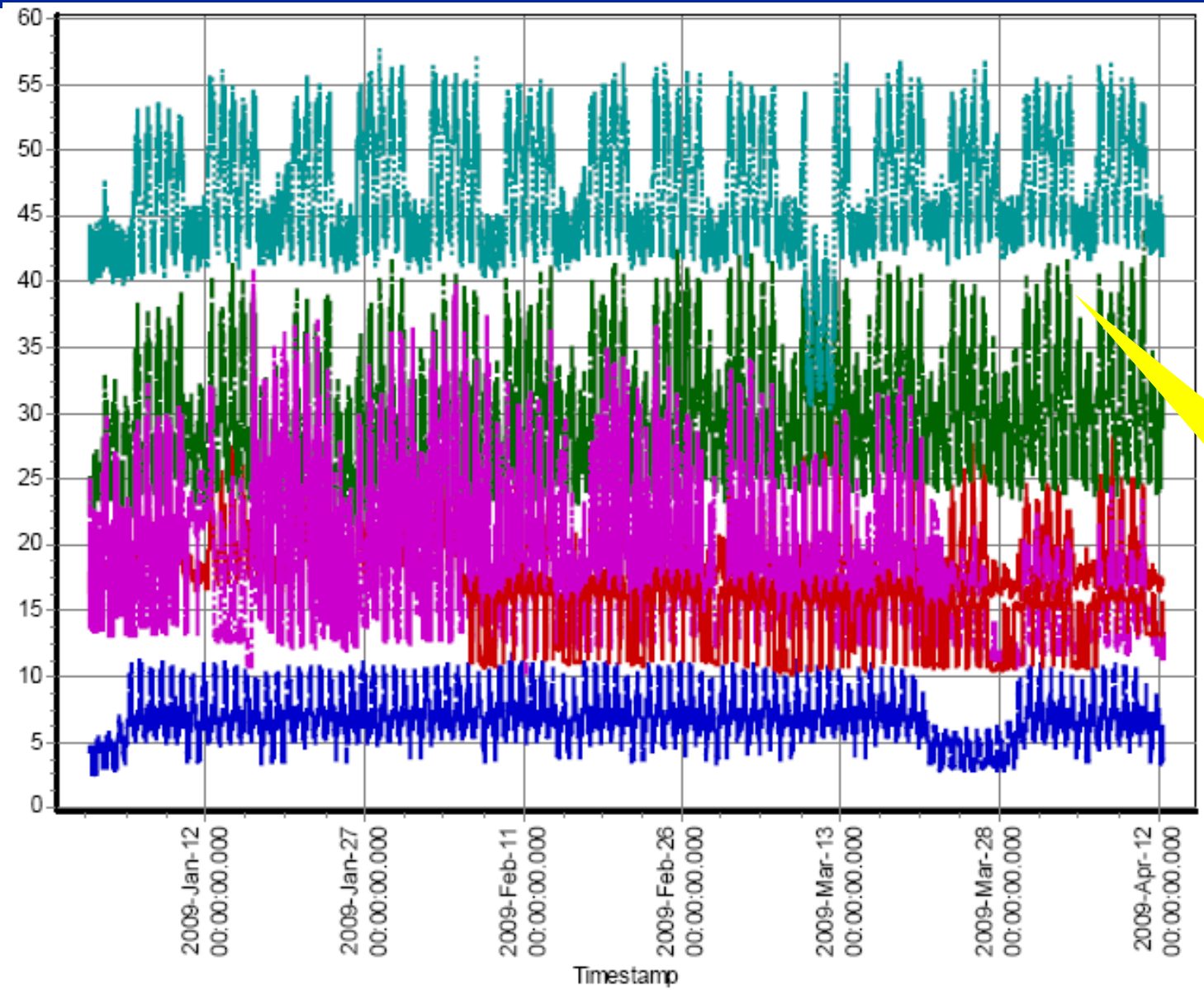
	SOM	North Campus	Revelle Campus	Central Plant	UCSD Total
Current Month:					
Monthly Cost ($)	19,075	30,163	236,794	93,913	734,148
kWh del	224,414 kWh	354,860 kWh	2,785,807 kWh	1,104,854 kWh	8,637,030 kWh
Previous Month:					
Monthly Cost ($)	45,133	67,085	557,638	184,830	1,673,499
kWh del	530,982 kWh	789,230 kWh	6,560,443 kWh	2,174,474 kWh	19,688,219 kWh
Realtime Values:					
kW inst	715 kW	1,022 kW	8,777 kW	3,947 kW	30,238 kW

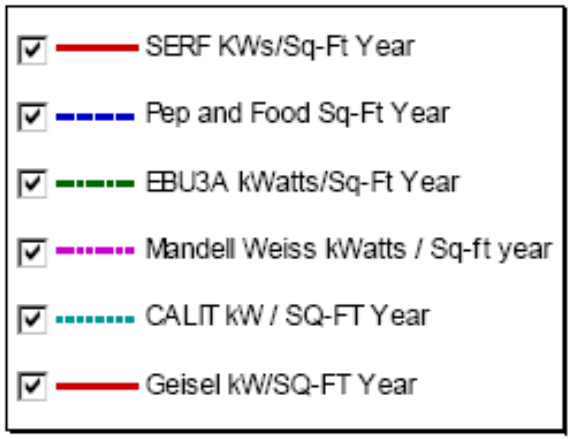
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http://mscada01.ucsd.edu/ion/

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Comparision Between UCSD Buildings: kW/sqFt Year Since 1/1/09





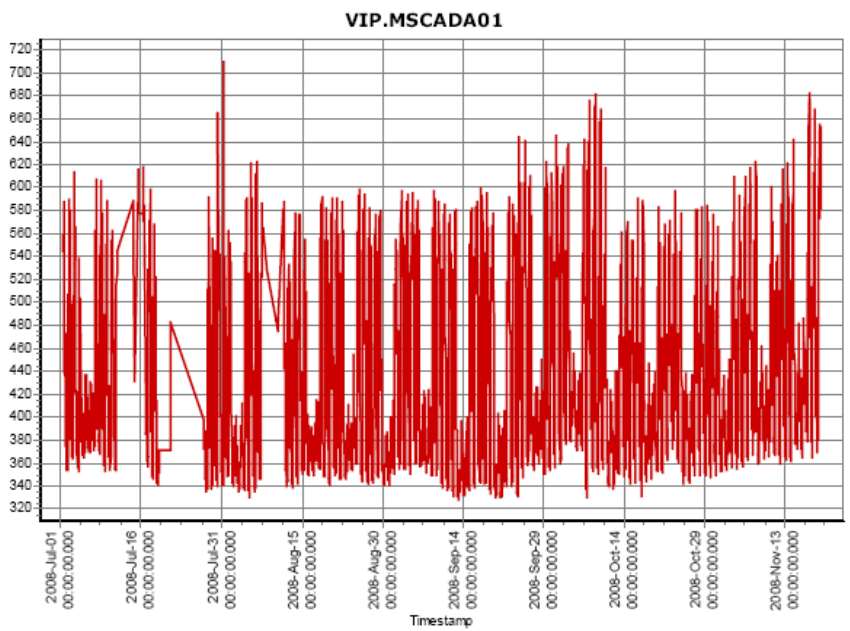
Calit2 and CSE are Very Energy Intensive Buildings

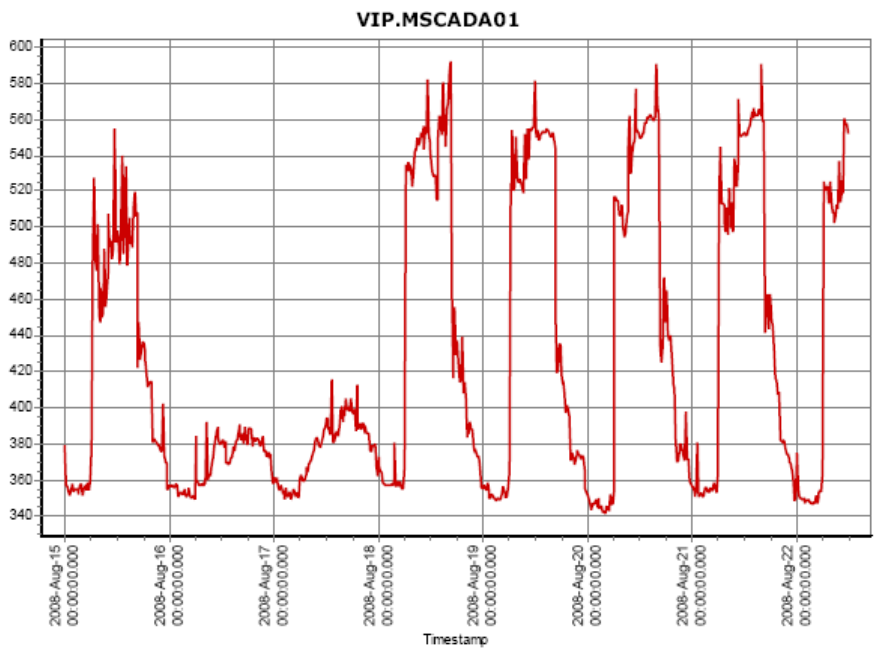
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Power Management in Mixed Use Buildings: The UCSD CSE Building is Energy Instrumented

- **500 Occupants, 750 Computers**
  - **More Computers Than Humans!**
- **Detailed Instrumentation to Measure Macro and Micro-Scale Power Use**
  - **39 Sensor Pods, 156 Radios, 70 Circuits**
  - **Subsystems: Air Conditioning & Lighting**







Calit2 is Being Re-Designed as an "Internet of Things" Building

Source: Rajesh Gupta, CSE, Calit2

Making Cars Greener Requires Software Engineering--Calit2 Established the Automotive Software Workshop

Source: Ingolf Krueger, Calit2



AUTOMOTIVE SOFTWARE WORKSHOP SAN DIEGO 2006

90 % of all Auto Innovations are Now Software-Driven

- Over 10 Million Lines of Code in Your Car!
- Sponsors: Calit2, NSF, EU, DFG
- 50:50 Participation Industry/Academia
- Next Instance Planned For 2009
- Industry Participants Include:

vector

Ford

BMW

TOYOTA InfoTechnology Center, U.S.A., Inc.

DAIMLER

VALIDAS validated quality

TOYOTA

GM

BOSCH

AbsInt Angewandte Informatik

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SAINT Software & Systems Architecture & Integration Team

S3EL Service-Oriented Software & Systems Engineering Lab

UCSD

California Institute for Telecommunications and Information Technology : Computer Science and Engineering, University of California, San Diego

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

San Diego
(866) 500 0977



LA & OC
(888) 9 CALIT2



Bay Area
(888) 4 CALIT2



http://traffic.calit2.net

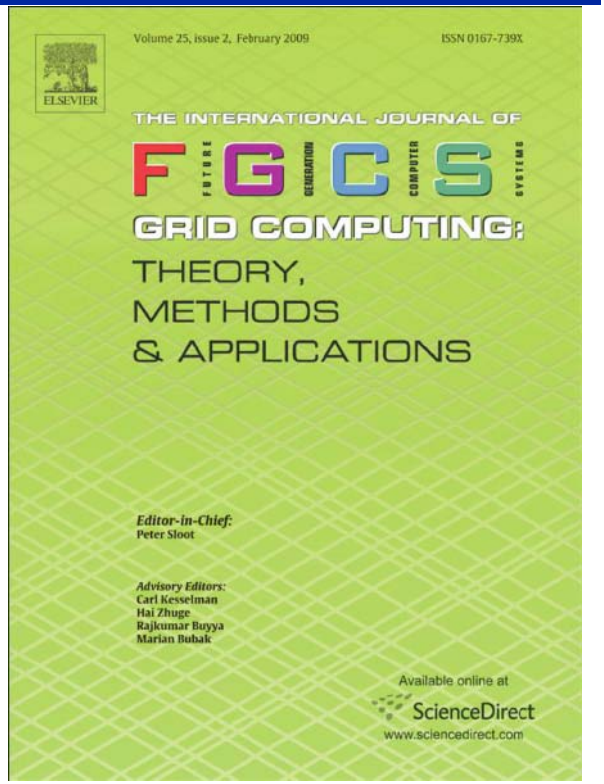
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Source: Ganz Chockalingam, Calit2

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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

Over 50 OptIPortals Worldwide

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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

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Room-to-Room Telepresence on a Global Scale



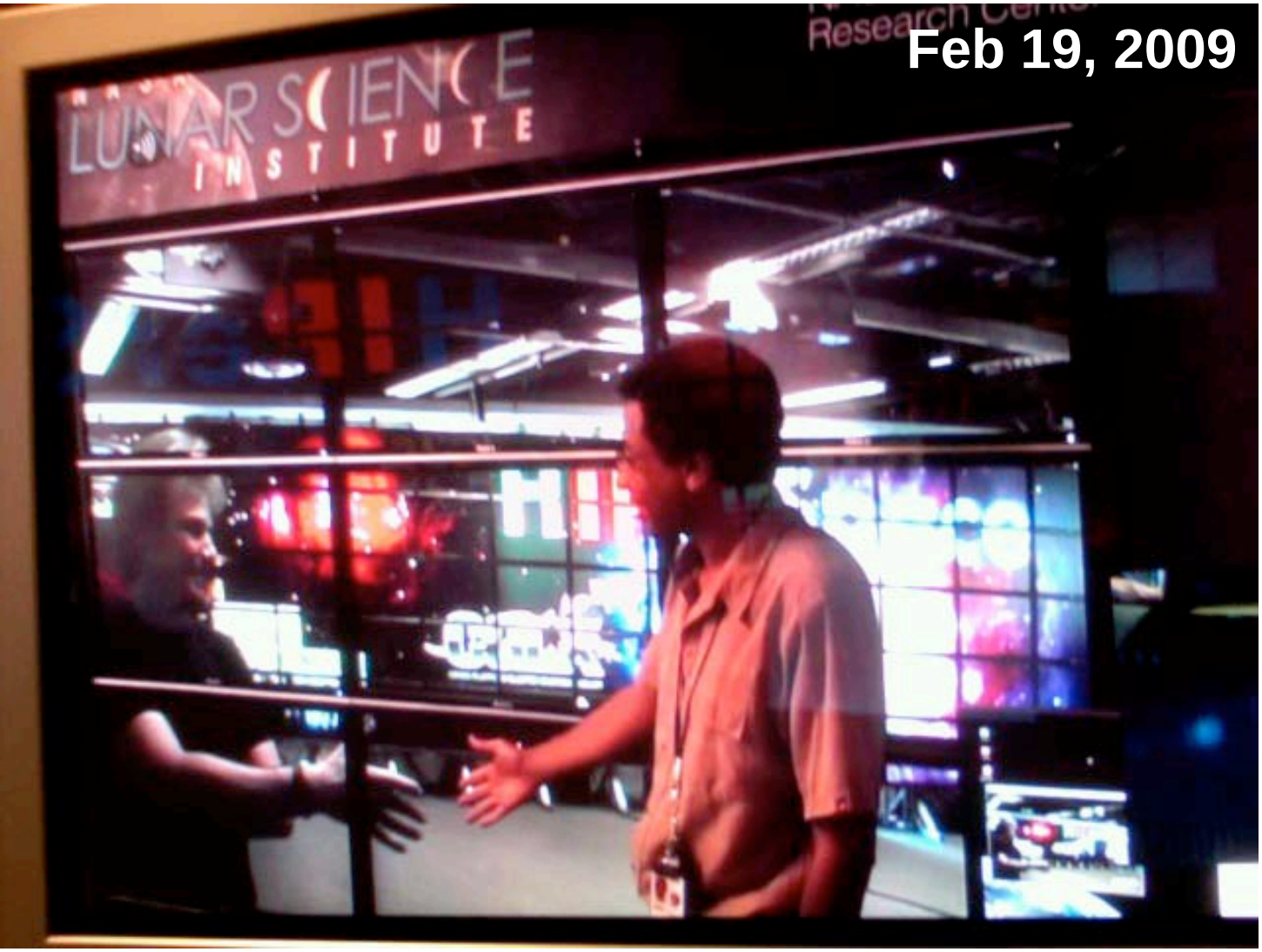
No Calit2 Person Physically Flew to Australia to Bring This Up!

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Covise, Phil Weber, Jurgen Schulze, Calit2
CGLX, Kai-Uwe Doerr , Calit2
www.calit2.net/newsroom/release.php?id=1219

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Just in Time OptIPlanet Collaboratory: Live Session Between NASA Ames and Calit2@UCSD



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

NASA Interest in Supporting Virtual Institutes

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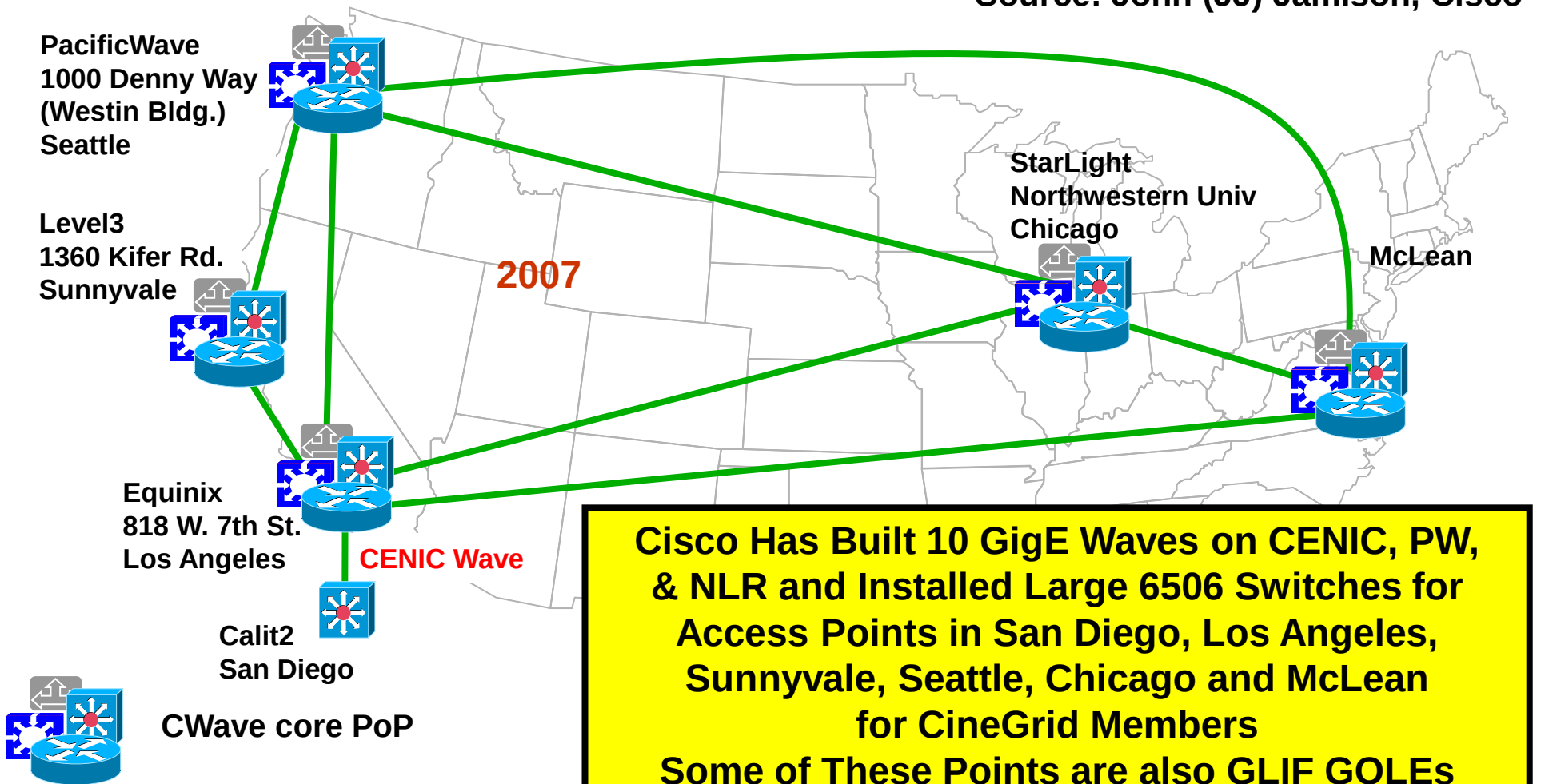
CGLX

it²

Source: Falko Kuester, Calit2; Michael Sims, NASA

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

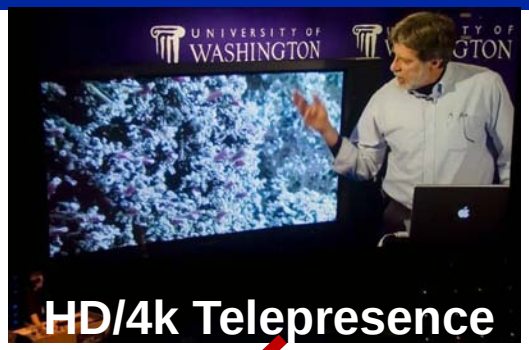
Academic Research "OptIPlatform" Cyberinfrastructure: A 10Gbps Lightpath Cloud



End User OptIPortal



Instruments



HD/4k Telepresence

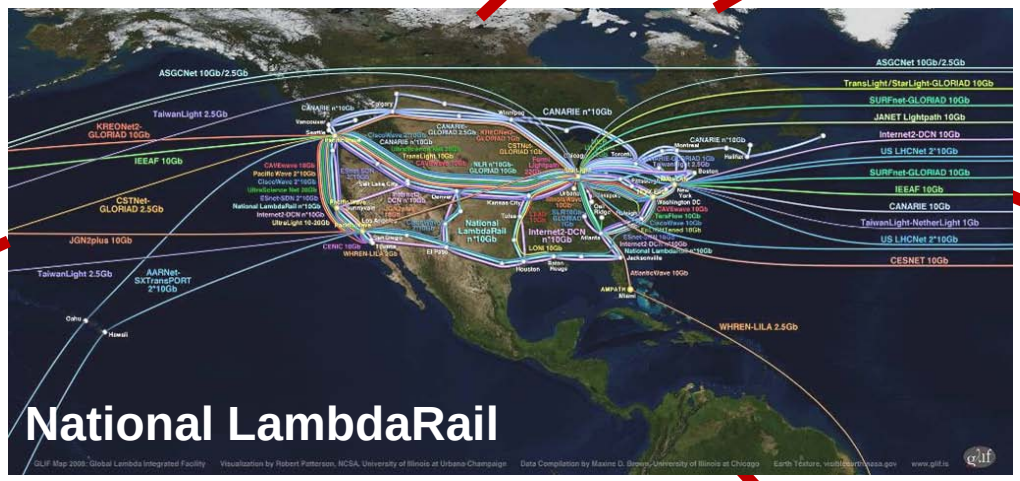


HD/4k Video Cams

HPC



10G Lightpath



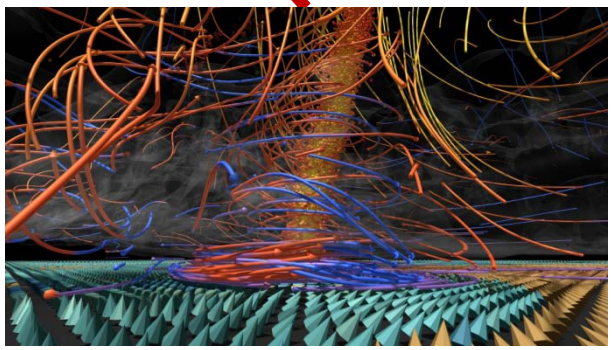
National LambdaRail

TeraGrid

Campus Optical Switch



Data Repositories & Clusters



HD/4k Video Images

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International Symposia on Green ICT: Greening ICT and Applying ICT to Green Infrastructures

CUBIN

Symposium on Sustainability of the Internet and ICT

THE UNIVERSITY OF MELBOURNE

November 25 & 26, 2008, The University of Melbourne

Webcasts Available at:
www.calit2.net/newsroom/article.php?id=1456

Greening the Internet Economy

ICT & GLOBAL CHANGE

California Public Utilities Commission

Calit2

Co-Hosted By Calit2 & CPUC

January 22-23, 2009



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