Restructuring Campus CI -- UCSD-A LambdaCampus Research CI and the Quest for Zero Carbon ICT

Invited Presentation to the
Net@EDU Campus Cyberinfrastructure Working Group

Tempe, AZ

February 3, 2009

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

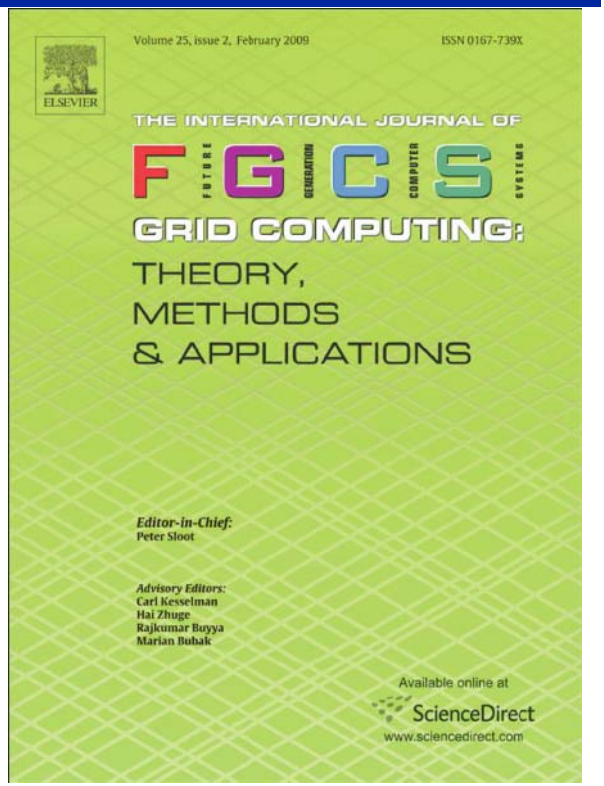
Jacobs School of Engineering, UCSD

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The OptIPuter Creates an Planetary Scale CI: Enabling Collaborative 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

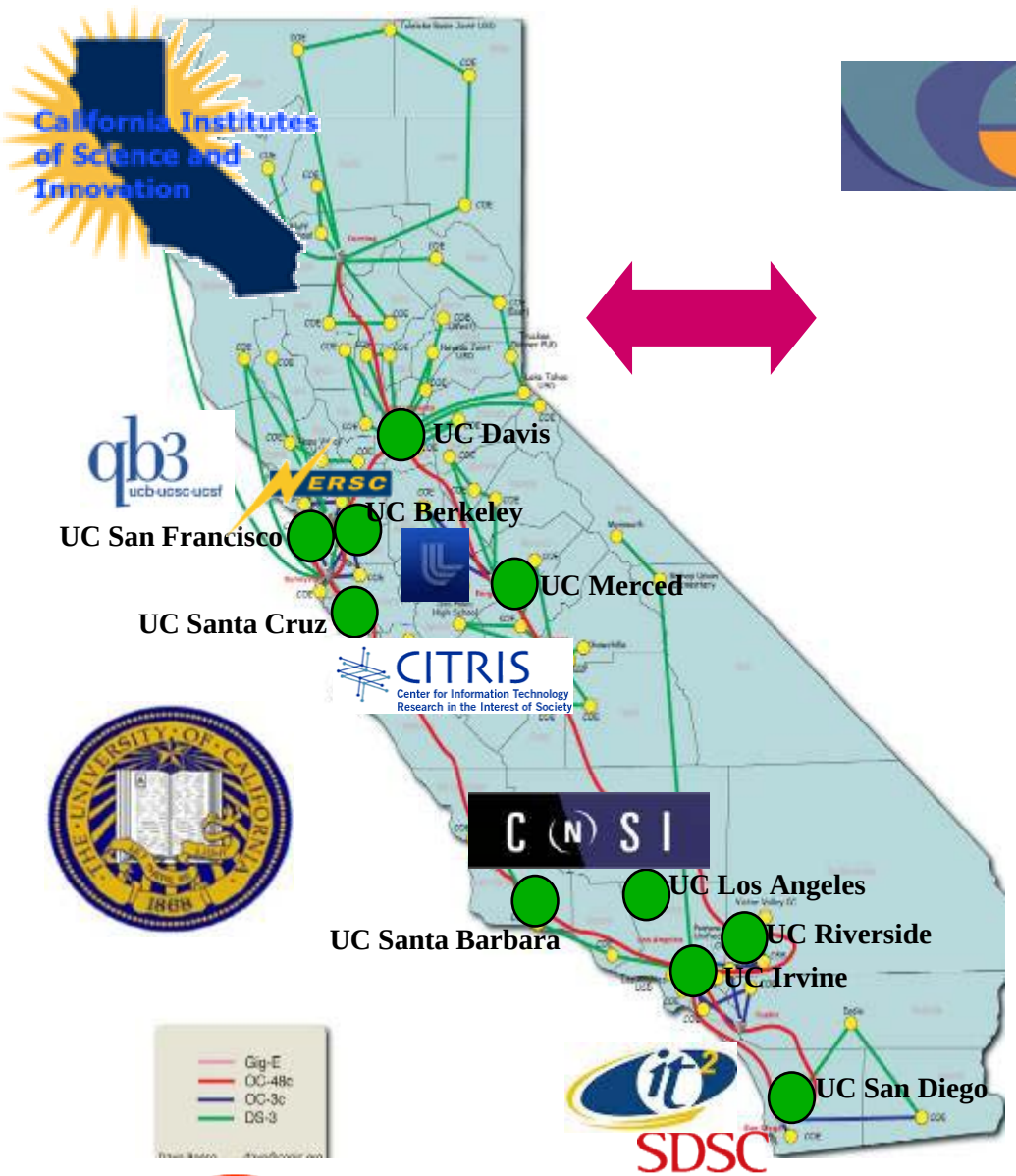
50 OptIPortals Worldwide -- Campus CI Now the Bottleneck

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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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Creating a California Cyberinfrastructure of OptIPuter "On-Ramps" to NLR, I2DC, & TeraGrid



NLR NATIONAL LAMBDARAIL

TeraGrid

Internet2 Network
Dynamic Circuit Network

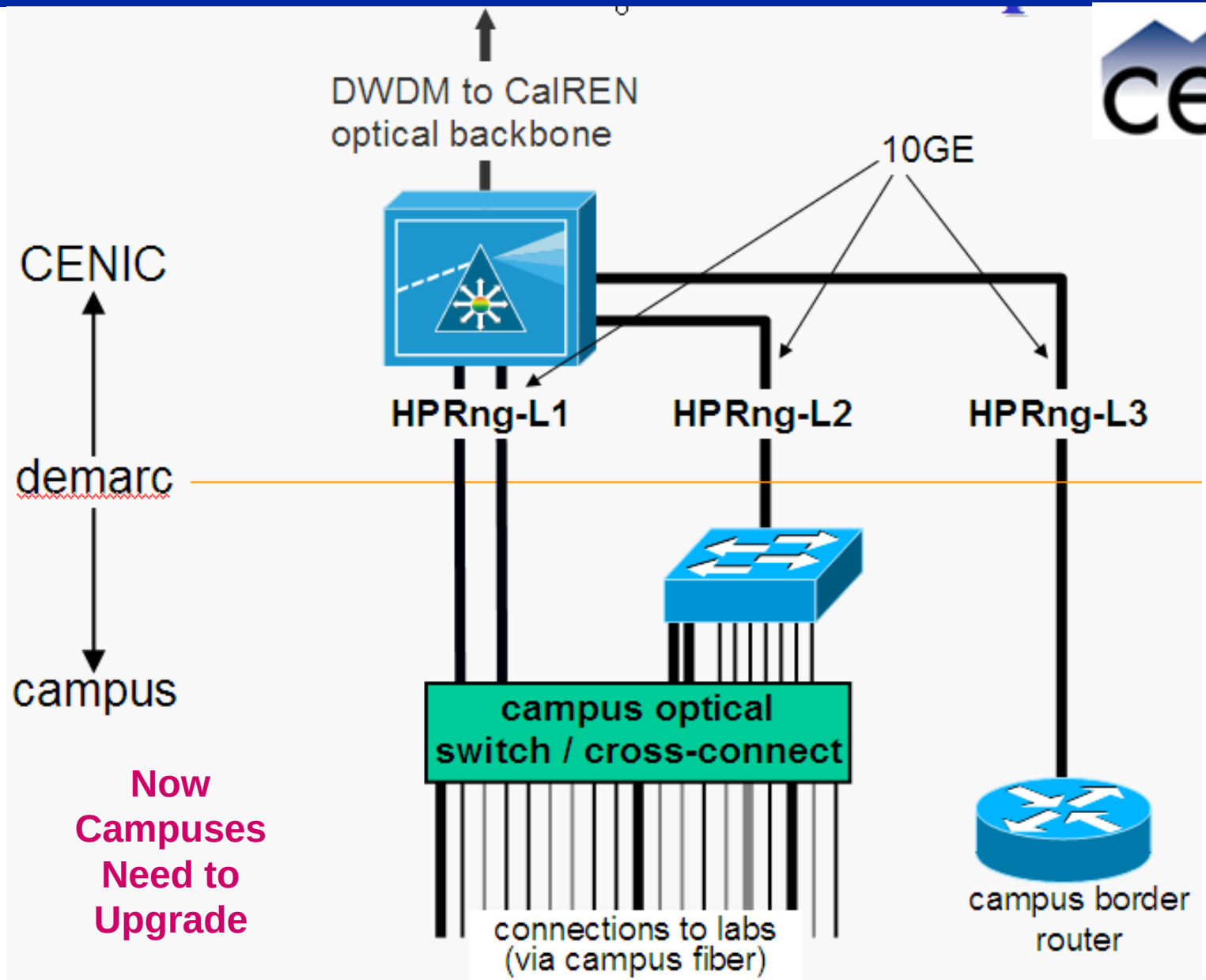
Creating a Critical Mass of OptIPuter End Users on a Secure LambdaGrid

CENIC Workshop at Calit2
Sept 15-16, 2008

OptIPuter

CENIC's New "Hybrid Network" - Traditional Routed IP and the New Switched Ethernet and Optical Services

~ $14M Invested in Upgrade



Now Campuses Need to Upgrade

Source: Jim Dolgonas, CENIC

The "Golden Spike" UCSD Experimental Optical Core: Ready to Couple Users to CENIC L1, L2, L3 Services



Goals by 2008:

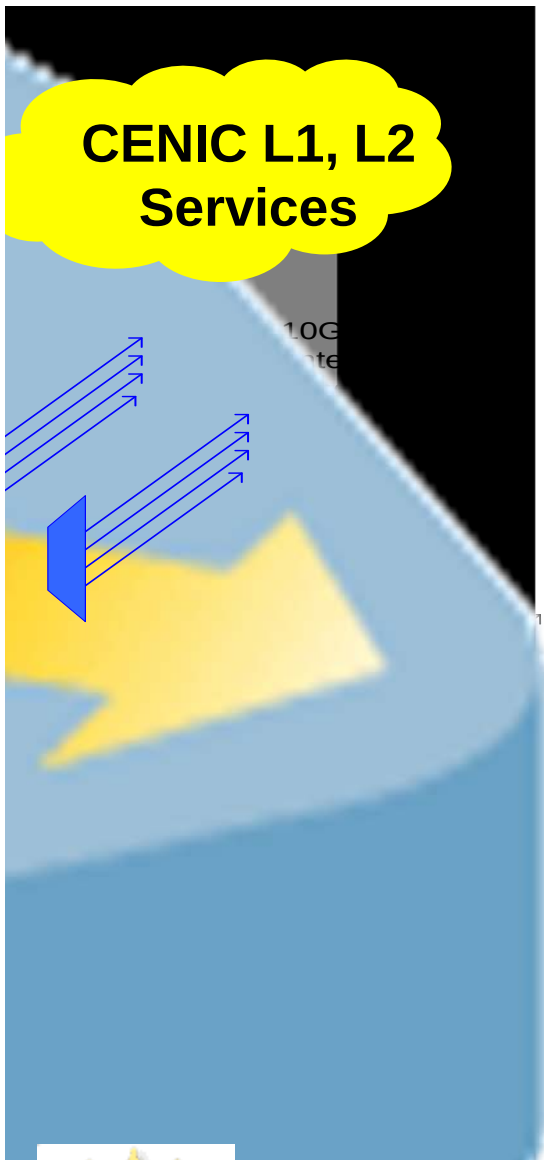
>= 60 endpoints at 10 GigE

>= 30 Packet switched

>= 30 Switched wavelengths

>= 400 Connected endpoints

Approximately 0.5 Tbps Arrive at the "Optical" Center of Hybrid Campus Switch



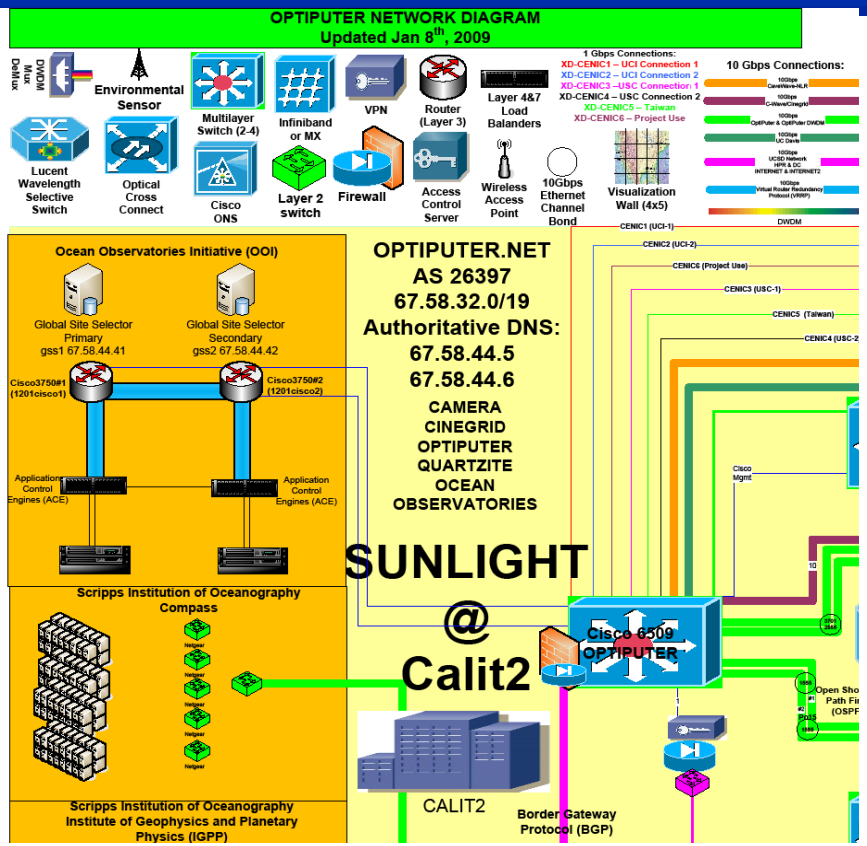
Funded by NSF MRI Grant

OptIPuter SDSC

Source: Phil Papadopoulos, SDSC/Calit2 (Quartzite MRI PI, OptIPuter co-PI)

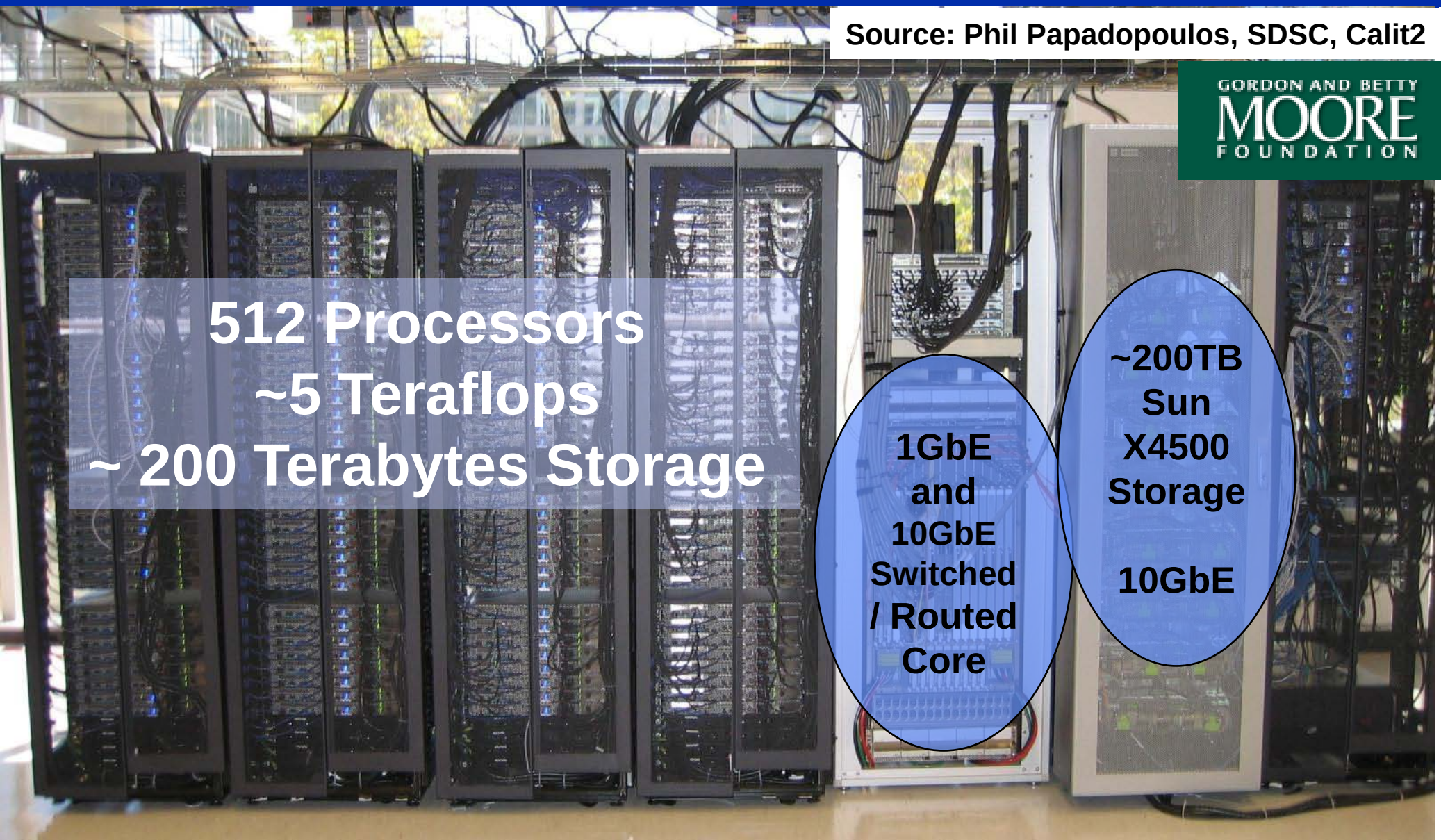
NSF it²

UCSD OptIPuter
a Dedicated 10Gbps LambdaCampus



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

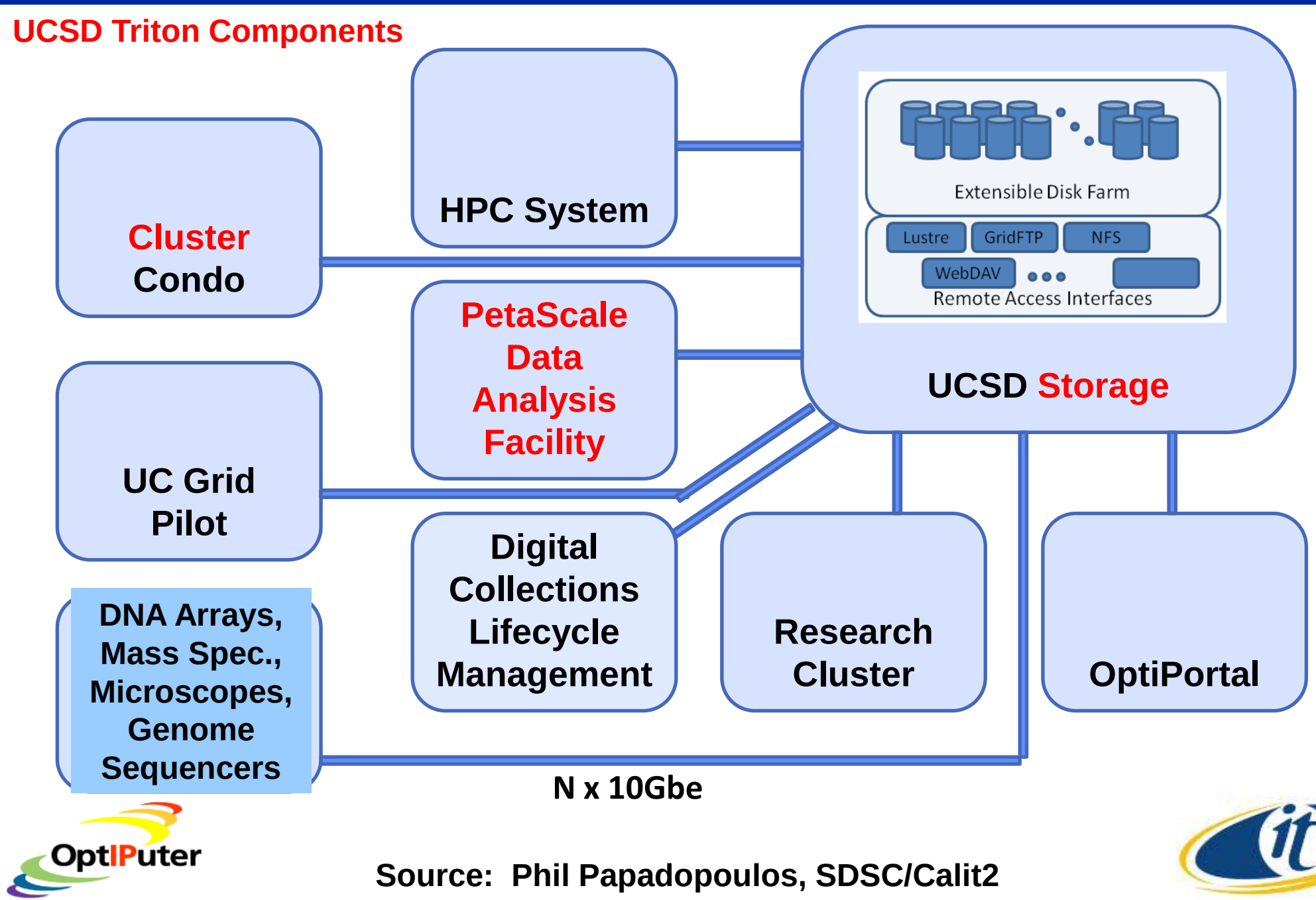
Source: Phil Papadopoulos, SDSC, Calit2



GORDON AND BETTY MOORE FOUNDATION

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

UCSD Campus Research CI: Design Team Architecture for Fiber Shared Resources



Source: Phil Papadopoulos, SDSC/Calit2

Current Planning for UCSD Triton
"OptIPuter on Steroids" *

Large Memory
PSDAF
- 256 GB/Node
- 8TB Total
- 128 GB/sec
- ~ 10 TF





Shared Resource
Cluster
- 16 – 32 GB/Node
- 4 - 8TB Total
- 256 GB/sec
- ~ 25 TF

SDSC



Large Scale Storage
- 2 – 4 PB
- 75 – 150 GB/sec
- 3000 – 6000 disks



UCSD Research Labs





Campus Research Network

TRITON RESOURCE

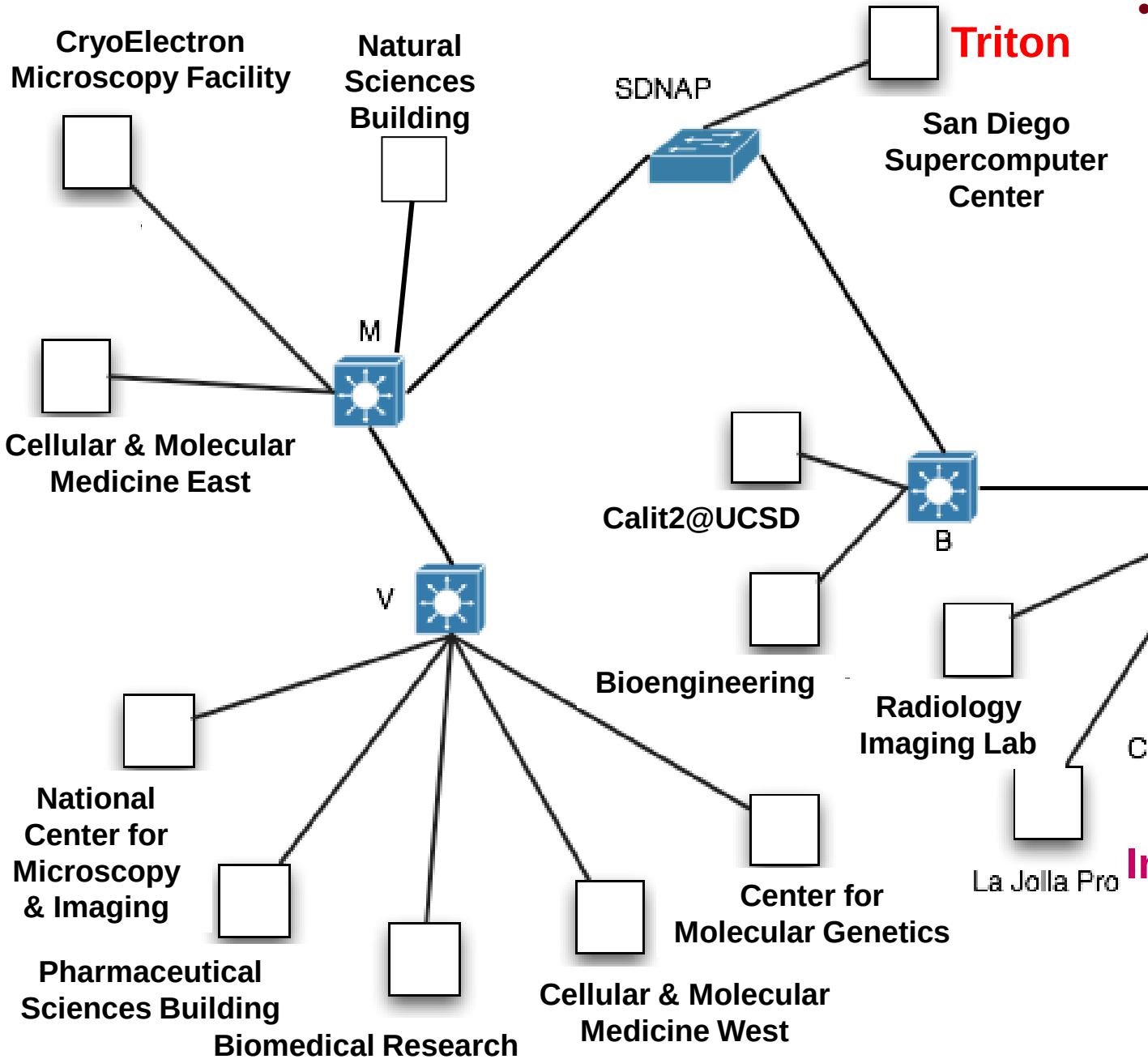


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Source: *Phil Papadopoulos, SDSC/Calit2

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UCSD Planned Optical Networked Biomedical Researchers and Instruments



- **Connects at 10 Gbps :**
  - **Microarrays**
  - **Genome Sequencers**
  - **Mass Spectrometry**
  - **Light and Electron Microscopes**
  - **Whole Body Imagers**
  - **Computing**
  - **Storage**

Creates Campus–Wide Instrument "Data Utility" - Lab Portals to Triton

ICT is a Key Sector in the Fight Against Climate Change

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.

THE CLIMATE GROUP

GeSI GLOBAL e-SUSTAINABILITY INITIATIVE

OptIPuter

www.smart2020.org

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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

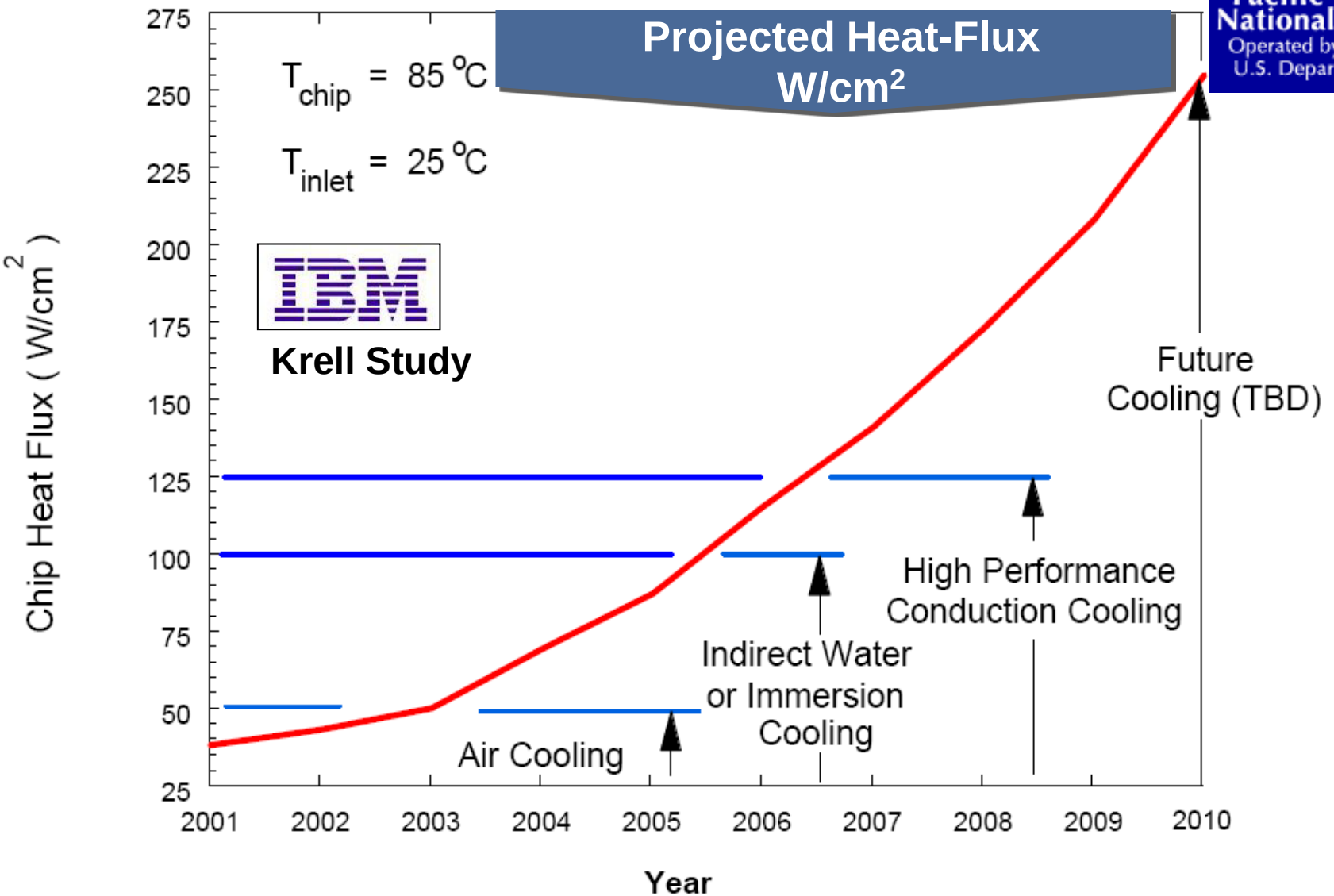
IBM Project Big Green

Big Green Banner

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

Data Centers Will Require Advanced Cooling Environments

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

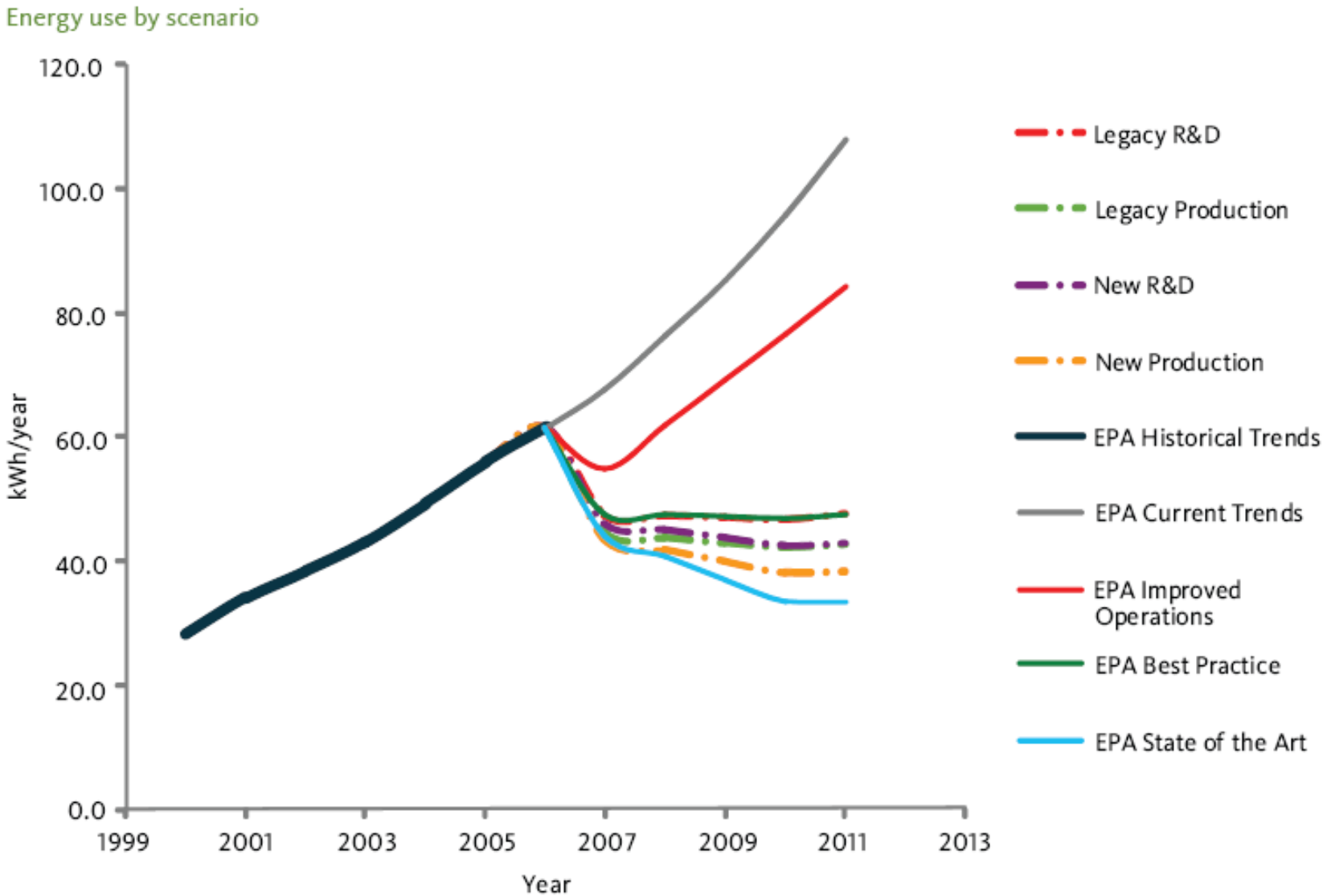


Source: PNNL Smart Data Center-Andrés Márquez, Steve Elbert, Tom Seim, Dan Sisk, Darrel Hatley, Landon Sego, Kevin Fox, Moe Khaleel (http://esdc.pnl.gov/)

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

UCSD Structural Engineering Dept. Conducted Tests May 2007



7 Racks plus Network



Takes up 2 Parking Spaces



Data Power Cooling

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



$2M NSF-Funded GreenLight Project

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

Source: Tom DeFanti, Calit2; GreenLight PI

The 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**
  - **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

Threat to CI Deployment—CSE 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

http://greenlight.calit2.net

Source: Tom DeFanti, Calit2; GreenLight PI

Improve Mass Spectrometry's Green Efficiency By Matching Algorithms to Specialized Processors

- **Inspect Implements the Very Computationally Intense MS-Alignment Algorithm for Discovery of Unanticipated Rare or Uncharacterized Post-Translational Modifications**
- **Solution: Hardware Acceleration with a FPGA-Based Co-Processor**
  - **Identification and Characterization of Key Kernel for MS-Alignment Algorithm**
  - **Hardware Implementation of Kernel on Novel FPGA-based Co-Processor (Convey Architecture)**
- **Results:**
  - **300x Speedup & Increased Computational Efficiency**

Large Savings in Energy Per Application Task

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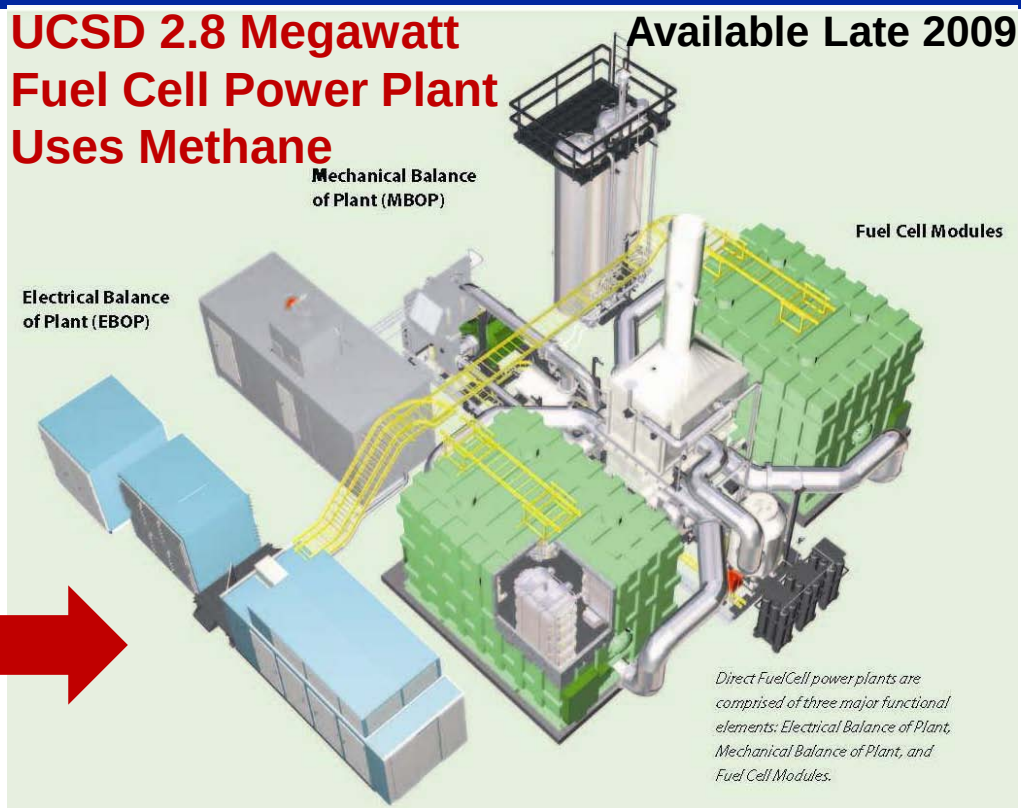
UCSD is Installing Zero Carbon Emission Solar and Fuel Cell DC Electricity Generators

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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Zero Carbon GreenLight Experiment: DC-Powered Modular Data Center

- **Concept—Avoid DC to AC to DC Conversion Losses**
  - Computers Use DC Power Internally
  - Solar and Fuel Cells Produce DC
  - Both Plug into the AC Power Grid
  - Can We Use DC Directly (With or Without the AC Grid)?

Sun Box <200kWatt

- **DC Generation Can Be Intermittent**
  - Depends on Source
    - Solar, Wind, Fuel Cell, Hydro
  - Can Use Sensors to Shut Down or Sleep Computers
  - Can Use Virtualization to Halt/Shift Jobs
- **Experiment Planning Just Starting**
  - Collaboration with Sun and LBNL
  - NSF GreenLight Year 2 and Year 3 Funds



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Source: Tom DeFanti, Calit2; GreenLight PI

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The GreenLight Project Focuses on Minimizing Energy for Key User Communities

- Microbial Metagenomics
- Ocean Observing
- Microscopy
- Bioinformatics
- Digital Media—CineGrid Project

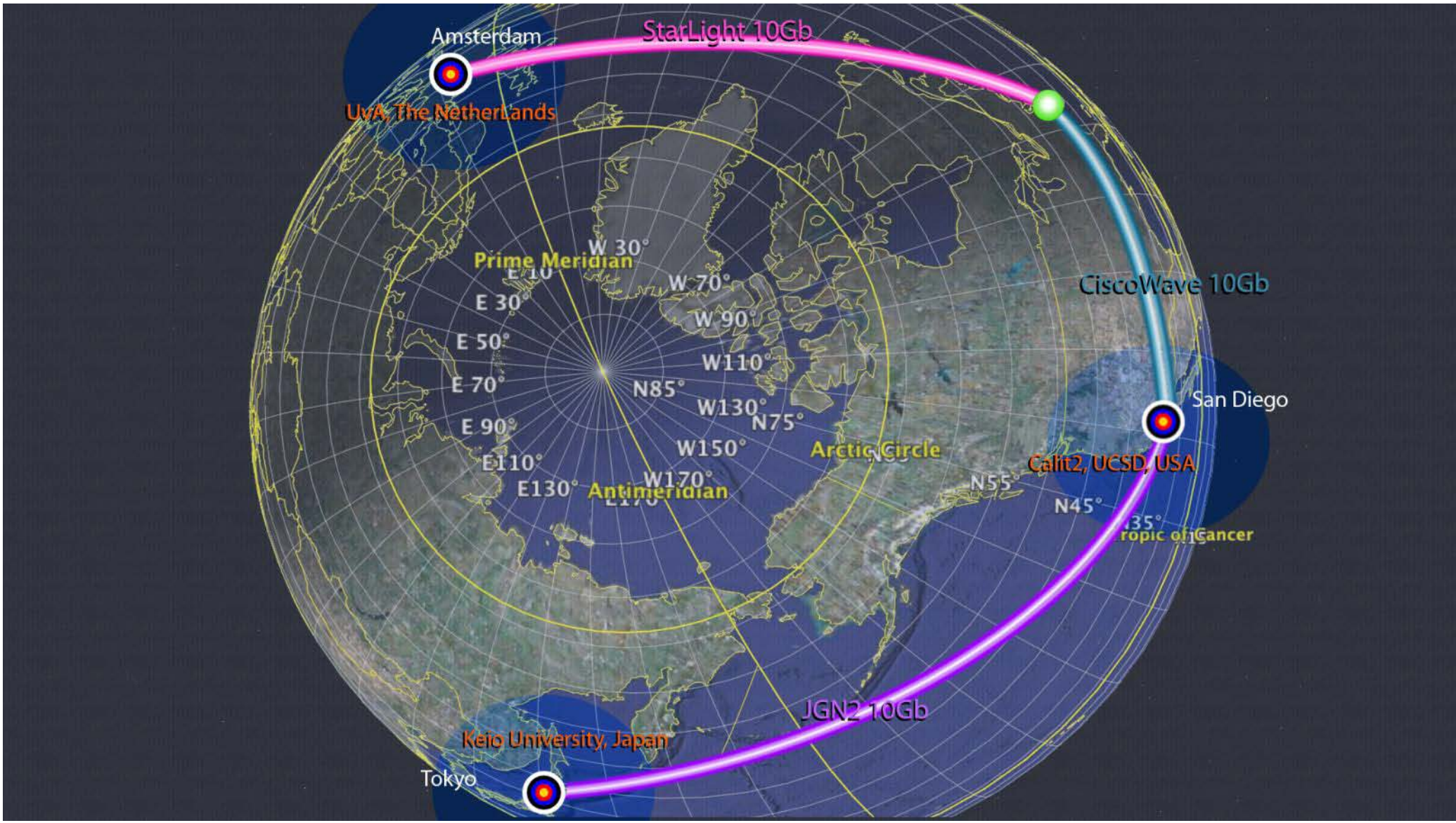


  - Calit2 will Host TB of Media Assets in GreenLight CineGrid Exchange to Measure and Propose Reductions in the “Carbon Footprint” Generated by:
    - File Transfers and
    - Computational Tasks
  - Required for Digital Cinema and Other High Quality Digital Media Applications

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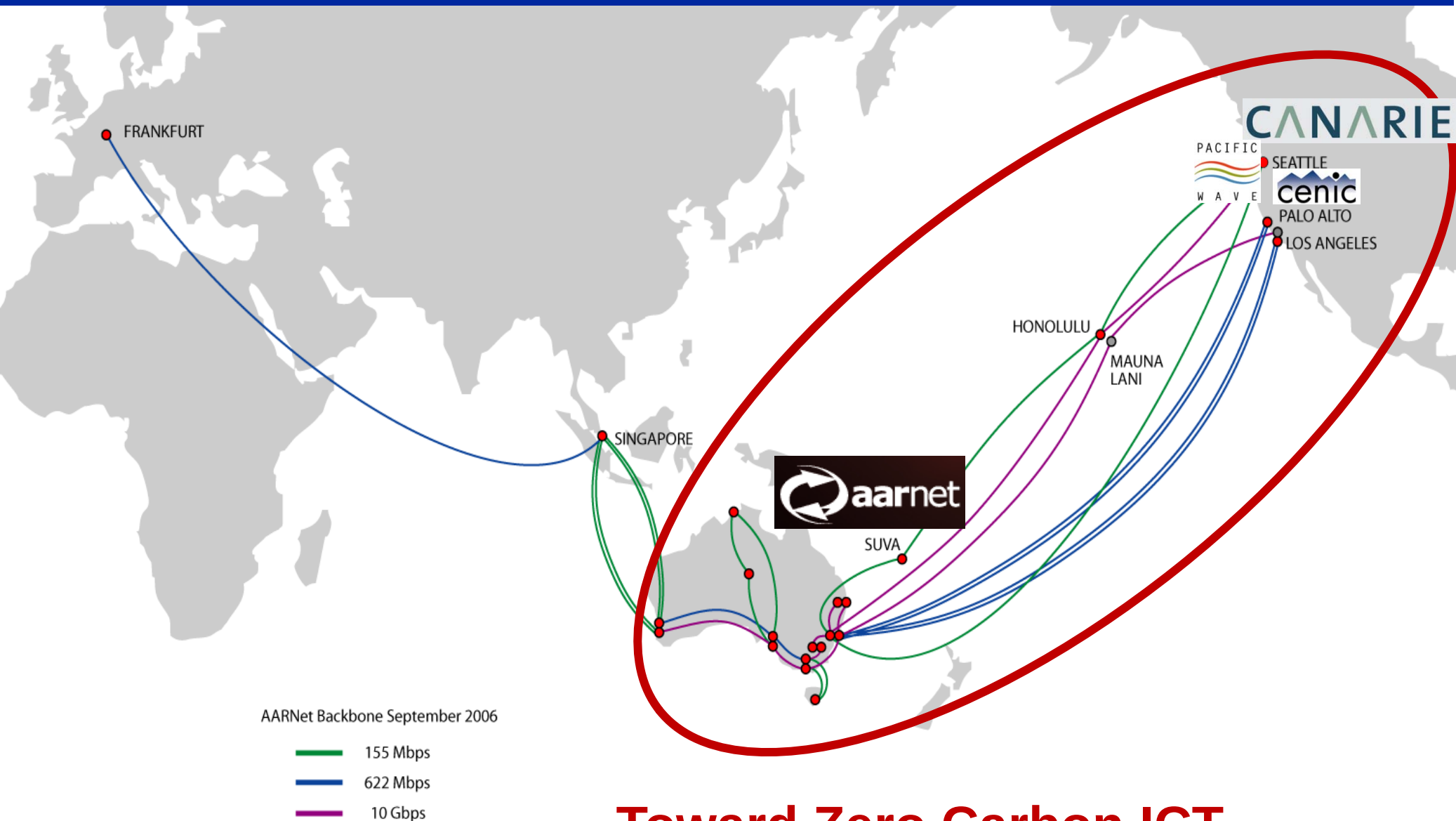
it²

CineGrid Exchange:
Using Optical Fibers to Create Remote Storage



Global Warming will Drive Cloud Computing!

Coupling AARNet - CENIC/PW - CANARIE Optical Nets: An Australian-U.S.-Canada Green Cloud Testbed



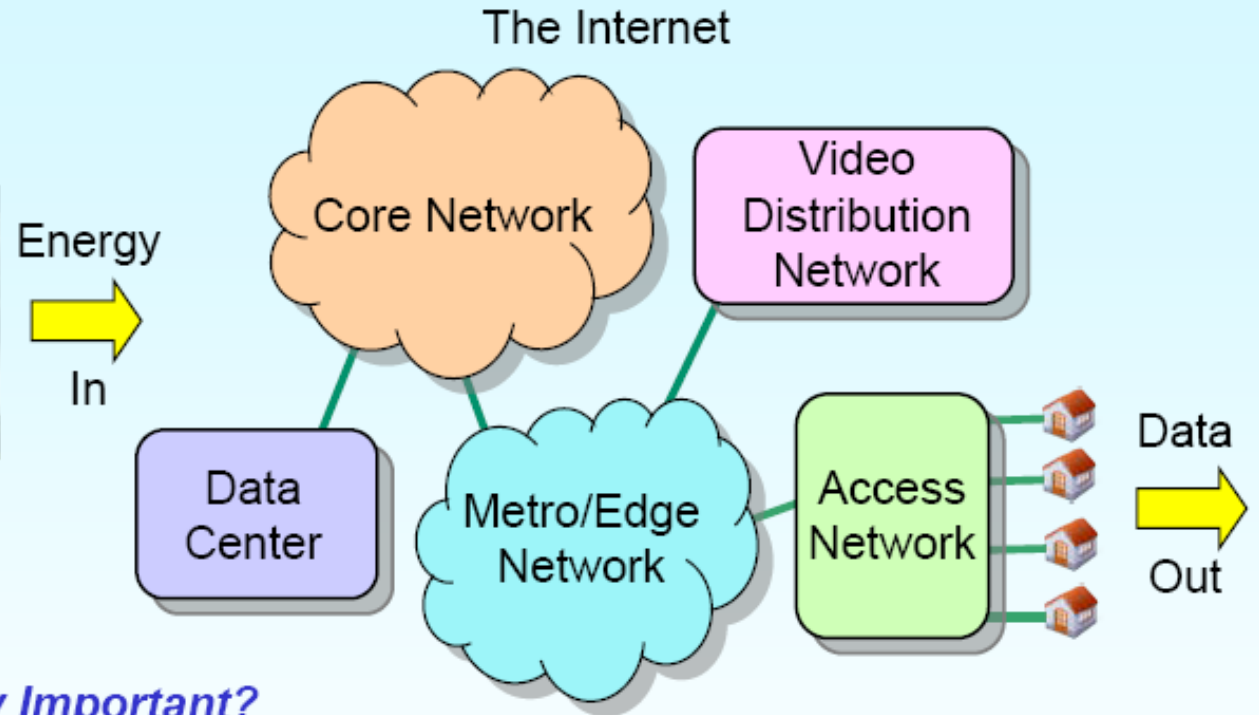
Toward Zero Carbon ICT

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A System Approach is Required to Reduce Internet's Greenhouse Gas Emissions





Why is Energy Important?

- OPEX
- Greenhouse Impact
- Energy-limited capacity bottlenecks ("hot spots")
- Enabling energy efficiencies in other sectors

Source: Rod Tucker, U Melbourne

Green ICT MOU Between
UCSD, Univ. British Columbia, and PROMPT



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

January 22-23, 2009



California Public Utilities Commission

Calit2

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Co-Hosted By Calit2 & CPUC

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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Next Stage: Developing Greener Smart Campuses Calit2 (UCSD & UCI) Prototypes

- **Coupling the Internet and the Electrical Grid**
  - Multiple Time Varying Sources--GHG Emitting + Renewable
  - Measuring Demand at Sub-Building Levels
  - Make Local Energy Usage Explicit Over Web
- **Transportation System**
  - Campus Wireless GPS Fleet with Renewable Fuels
  - Freeway-Scale Measurements
  - Driver Level Cell Phone Traffic Awareness
- **Travel Substitution**
  - Commercial Teleconferencing
  - Next Generation Global Telepresence

Student Video -- UCSD Living Laboratory for Real-World Solutions
www.gogreentube.com/watch.php?v=NDc4OTQ1 on UCSD

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UCI Named 'Best Overall' in Flex Your Power Awards
www.today.uci.edu/news/release_detail.asp?key=1859

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