Toward Greener Cyberinfrastructure

Invited Lecture to the
Green IT Workshop
Canada-California Strategic Innovation Partnership
September 19, 2008

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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An Inefficient Truth- ICT Is Major Contributor to CO_2 Emissions*

- **The ICT Industry Carbon Footprint is Equivalent to that of the Aviation Industry—But Doubling Every Two Years!**
- **Energy Usage of a Single Compute Rack is Measured in House-Equivalents**
- **ICT Emissions Growth is Fastest of any Sector in Society, Especially at Universities as Data-Intensive Research Spreads Across Disciplines**
- **Data Centers are a Unique Challenge**
  - **2008 50% have Insufficient Power and Cooling**
  - **2009 Energy Costs Second Highest Data Center Cost**

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Sources *An Inefficient Truth: http://www.globalactionplan.org.uk/event_detail.aspx?eid=2696e0e0-28fe-4121-bd36-3670c02eda49 and http://www.nanog.org/mtg-0802/levy.html

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U.S. Servers and Data Centers Use as Much Electricity as 5% of U.S. Housing

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

- **1.5% of Total U.S. Electricity Consumption**
  - **~ 61 Billion Kilowatt-Hours (kWh) in 2006**
  - **Total Electricity Cost of ~$4.5 Billion**

- **Federal Servers and Data Centers Alone Use:**
  - **~ 6 billion kWh**
  - **10% of electricity Used for Servers and Data Centers**
  - **Total Electricity Cost of ~$450 Million Annually**

EPA Report to Congress on Server and Data Center Energy Efficiency
Released On August 2, 2007 and in response to Public Law 109-431

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/)

3

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,

California's Universities are Engines for Green Innovation—Partnering with Industry

UCSD Structural Engineering Dept. Conducted Tests May 2007

Sun microsystems

UCSD Jacobs School of Engineering



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

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

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Calit2 GreenLight Project Enables Green IT Computer Science Research



- **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

Energy Efficiency by Exploiting Parallelism at the Processor Level

- **Multiprocessing as in Multiple Cores that can be Shutdown or Slowdown Based on Workloads**
- **Co-Processing that uses Specialized Functional Units for a Given Application**
- **The Challenge in Co-Processing is the Hand-Crafting that is Needed in Building such Machines**
  - **Application-Specific Co-Processor Constructed from Work-Load Analysis**
  - **The Co-Processor is Able to Keep up with the Host Processor in Exploiting Fine-Grain Parallel Execution Opportunities**

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Source: Rajesh Gupta, UCSD CSE; Calit2

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Algorithmically, Two Ways to Save Power Through Choice of Right System & Device States

- **Shutdown**
  - Multiple Sleep States
  - Also Known as Dynamic Power Management (DPM)
- **Slowdown**
  - Multiple Active States
  - Also Known as Dynamic Voltage/Frequency Scaling (DVS)
- **DPM + DVS**
  - Choice Between Amount of Slowdown and Shutdown

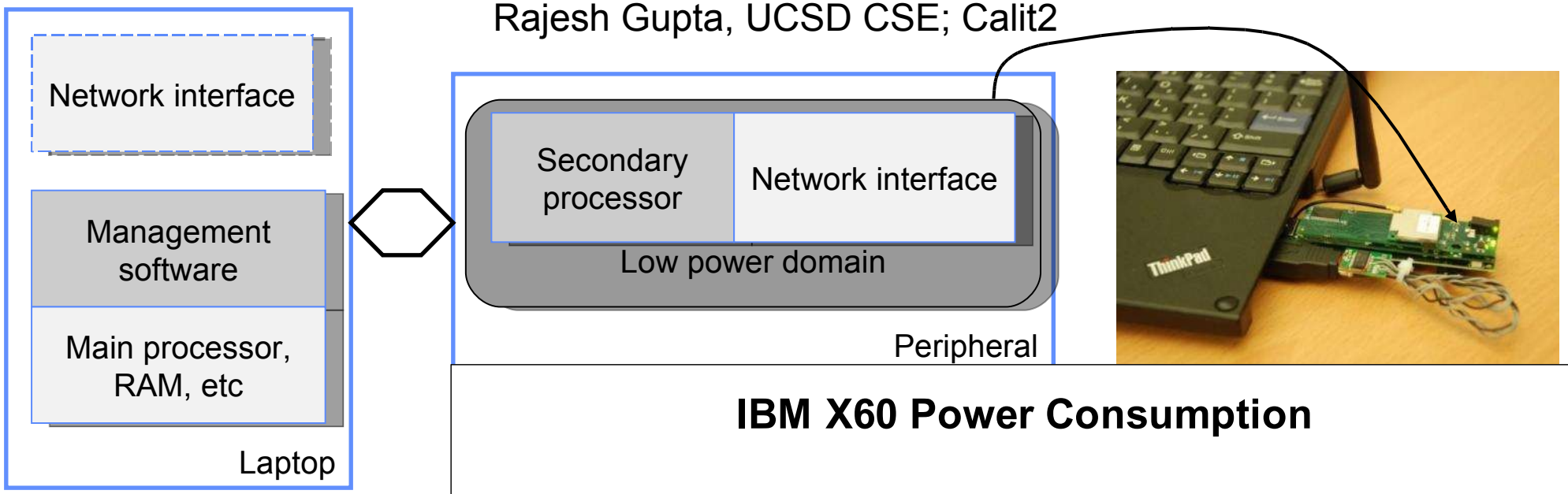
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Source: Rajesh Gupta, UCSD CSE; Calit2

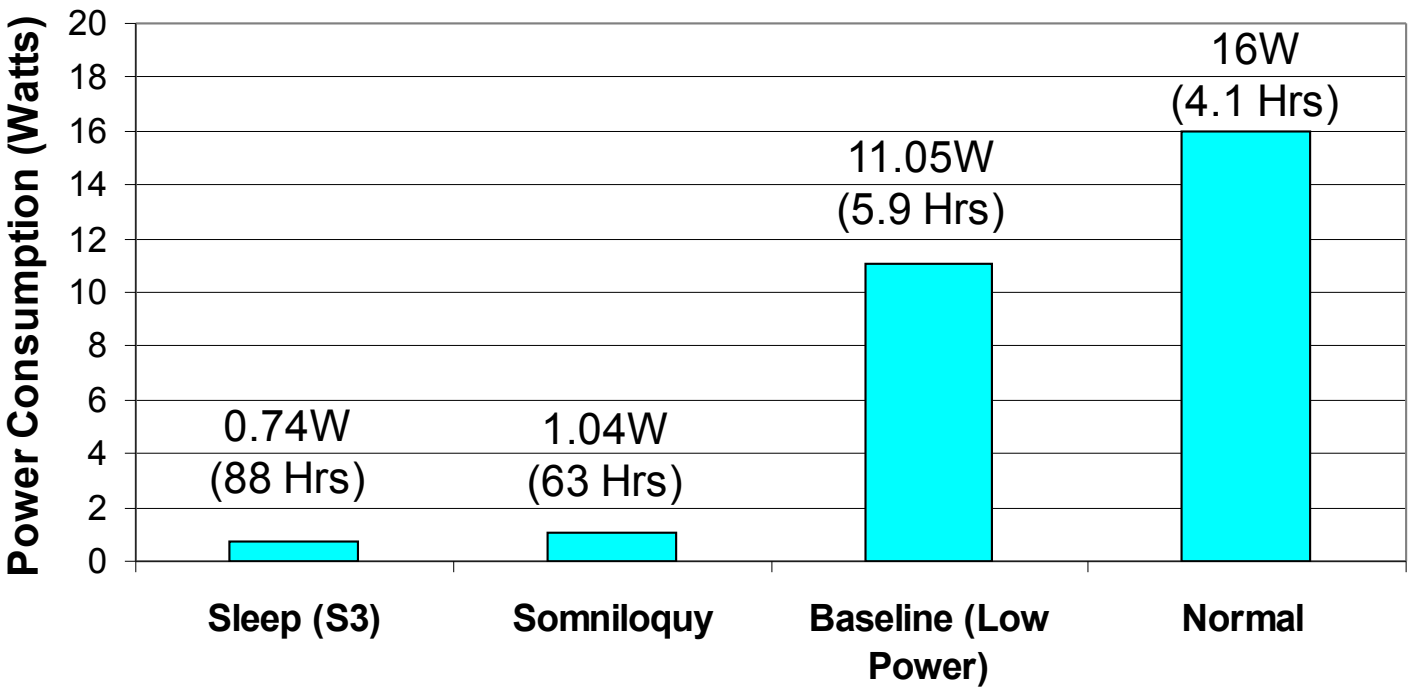
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GreenLight Project: Putting Machines To Sleep Transparently

Rajesh Gupta, UCSD CSE; Calit2



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



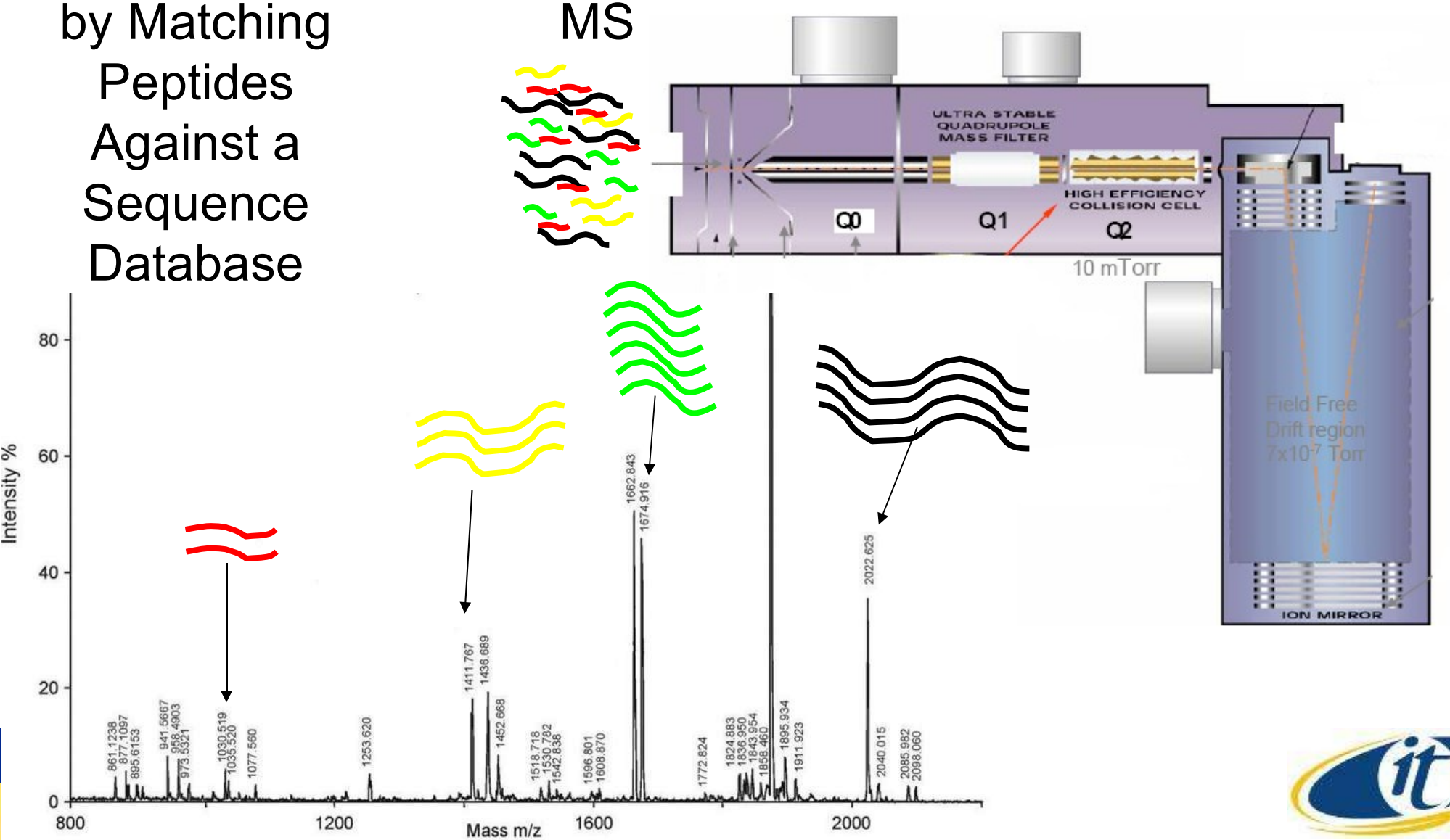
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Mass Spectrometry Proteomics: Greening Application by Speedup in Algorithm

Source: Sam Payne, UCSD CSE

Proteins are then Identified by Matching Peptides Against a Sequence Database

Peptides Serve as Input to the MS



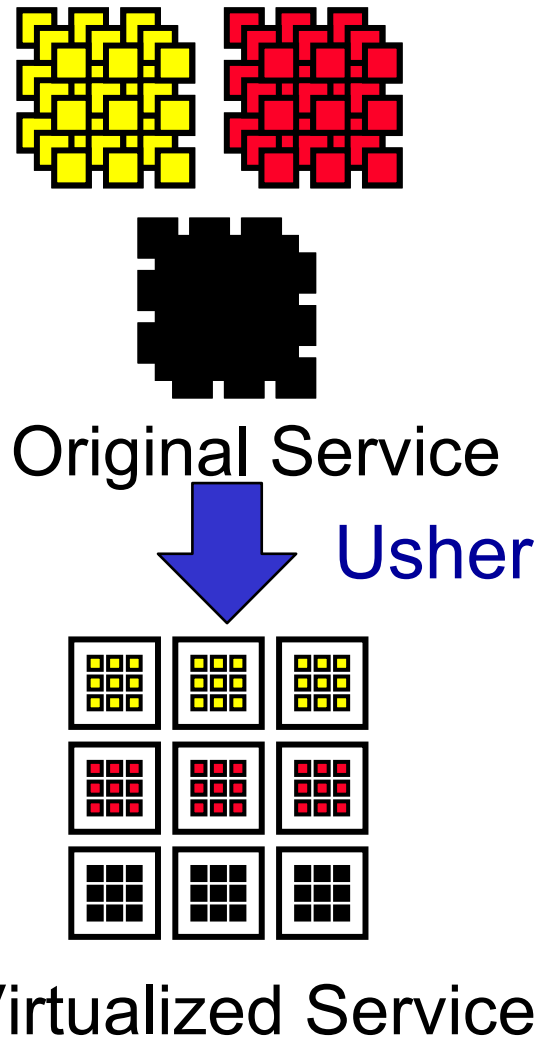
Improve Mass Spectrometry's Green Efficiency By Matching Algorithms to Specialized Processors

- **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**

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Virtualization at Cluster Level for Consolidation and Energy Efficiency

Source: Amin Vadhat, CSE, UCSD



- **Fault Isolation and Software Heterogeneity, Need to Provision for Peak Leads to:**
  - **Severe Under-Utilization**
  - **Inflexible Configuration**
  - **High Energy Utilization**
- **Usher / DieCast enable:**
  - **Consolidation onto Smaller Footprint of Physical Machines**
  - **Factor of 10+ Reduction in Machine Resources and Energy Consumption**

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cns center for networked systems

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The GreenLight Project Focuses on Minimizing Energy for Key User Communities

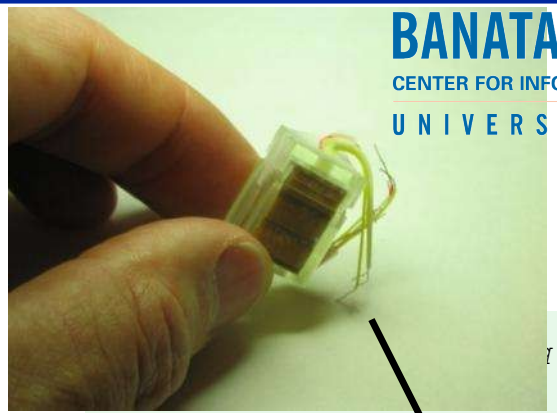


- Microbial Metagenomics
- Ocean Observing
- Microscopy
- Bioinformatics
- Digital Media—CineGrid Project
  - Calit2 will Host TB of Media Assets in GreenLight CineGrid Exchange to Measure and Propose Reductions in the "Carbon Footprint" Generated by:
    - File Transfers and
    - Computational Tasks
  - Required for Digital Cinema and Other High Quality Digital Media Applications

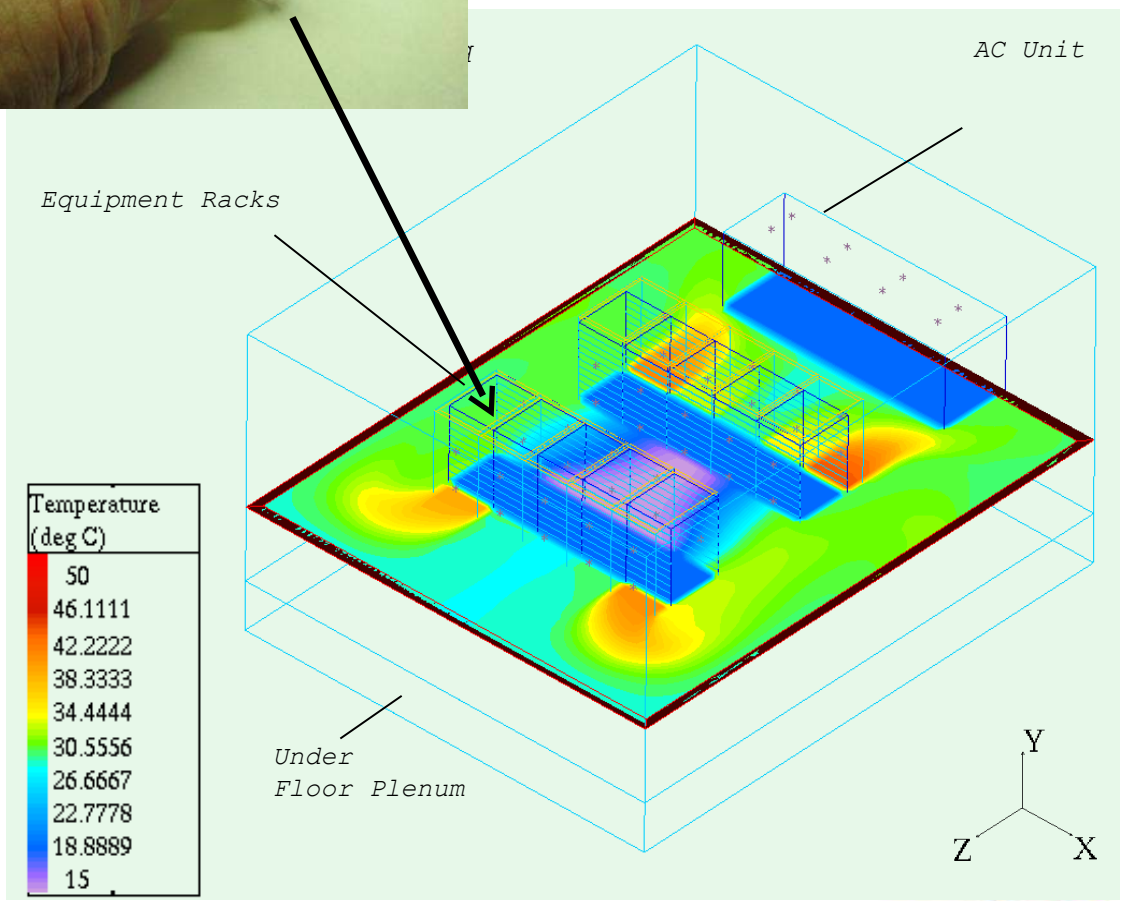
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Business Impact: Energy Aware Design and Control

- **Wireless Sensor Networks @ CITRIS**
  - **"Micro-climate" and Use at Each Blade in the Server Farm**
- **CITRIS/HP Redesign and Sensing Saves Up to 45% of Cooling Power Use**
- **Saving ~$400K/yr in Typical Center**



BANATAO INSTITUTE @ iTRIS
CENTER FOR INFORMATION TECHNOLOGY RESEARCH IN THE INTEREST OF SOCIETY
UNIVERSITY OF CALIFORNIA • BERKELEY



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Source: Paul Wright CITRIS, Profs Van Carey and David Auslander

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The Department of Energy's PNNL Energy Smart Data Center Testbed

Strategy

Develop a Testbed Datacenter Facility to Promote Energy Efficiency in Collaboration with other National Labs, industry leaders, and Energy-Focused Organizations

Objectives

- Demonstrate and Compare Innovative Cooling Technologies
- Research Potential Savings in Power Conversion
- Partner with Vendors and Chip Manufacturers to Mature New Technologies in a Operational Datacenter Environment
- Promote Power Aware Computing

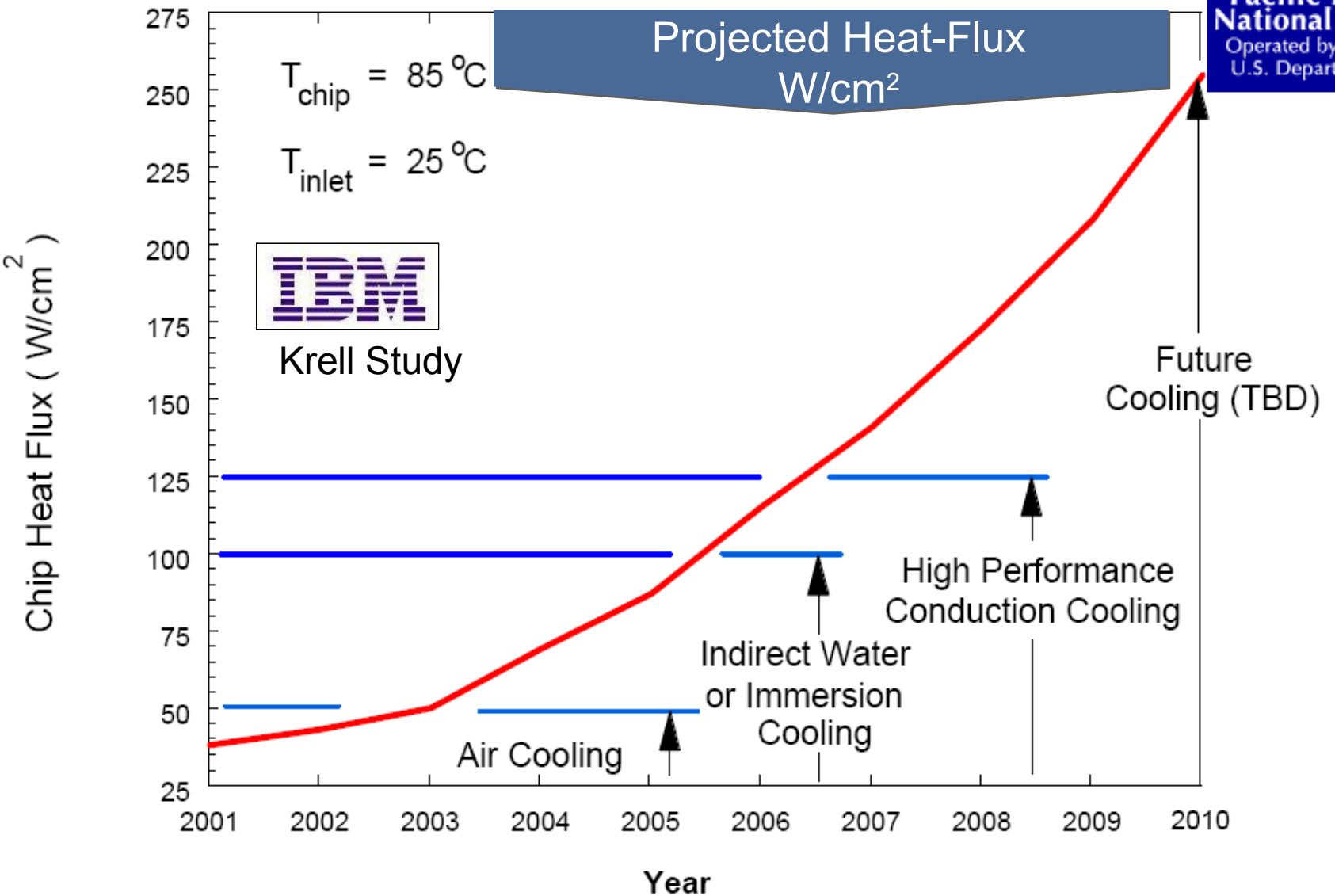
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

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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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Data Centers Will Require Advanced Cooling Environments



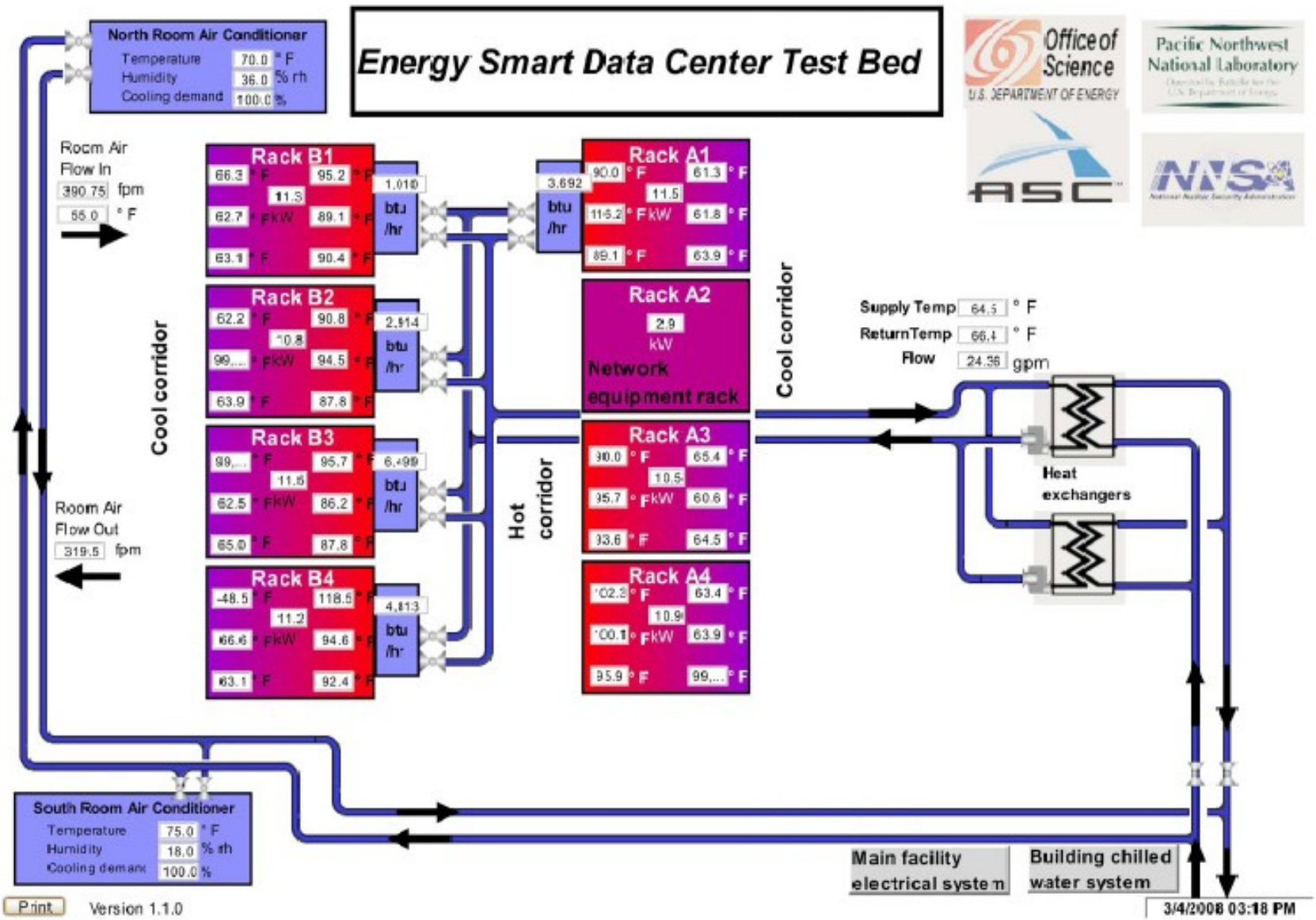
Source: PNNL Smart Data Center-Andrés Márquez, Steve Elbert, Tom Seim, Dan Sisk, Darrel Hatley, Landon Sego, Kevin Fox, Moe Khaleel (http://esdc.pnl.gov/)

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Fundamental Research of Efficient Datacenters (FRED)

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

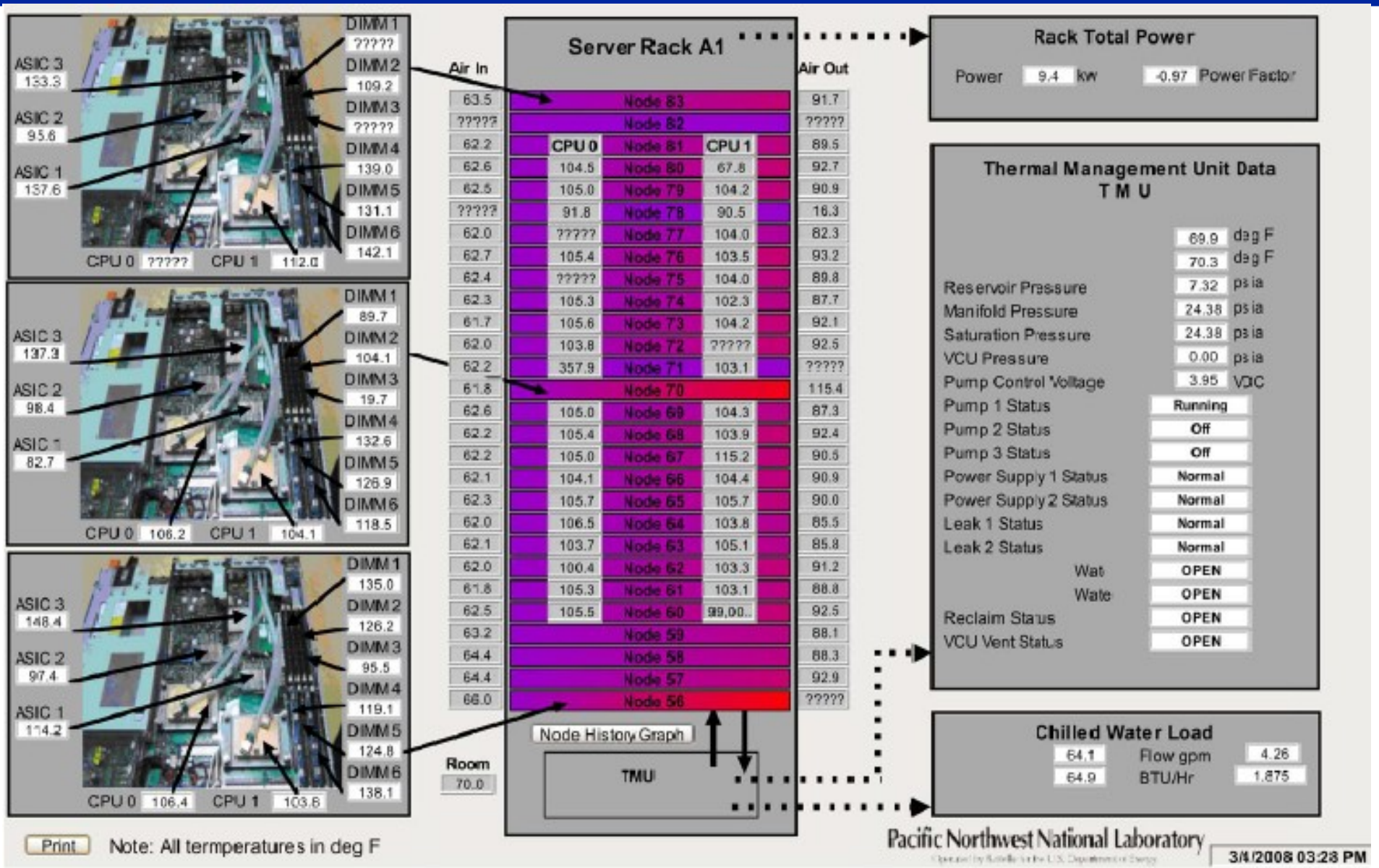


http://esdc.pnl.gov/

Interactive GUI to Extensive Sensornet

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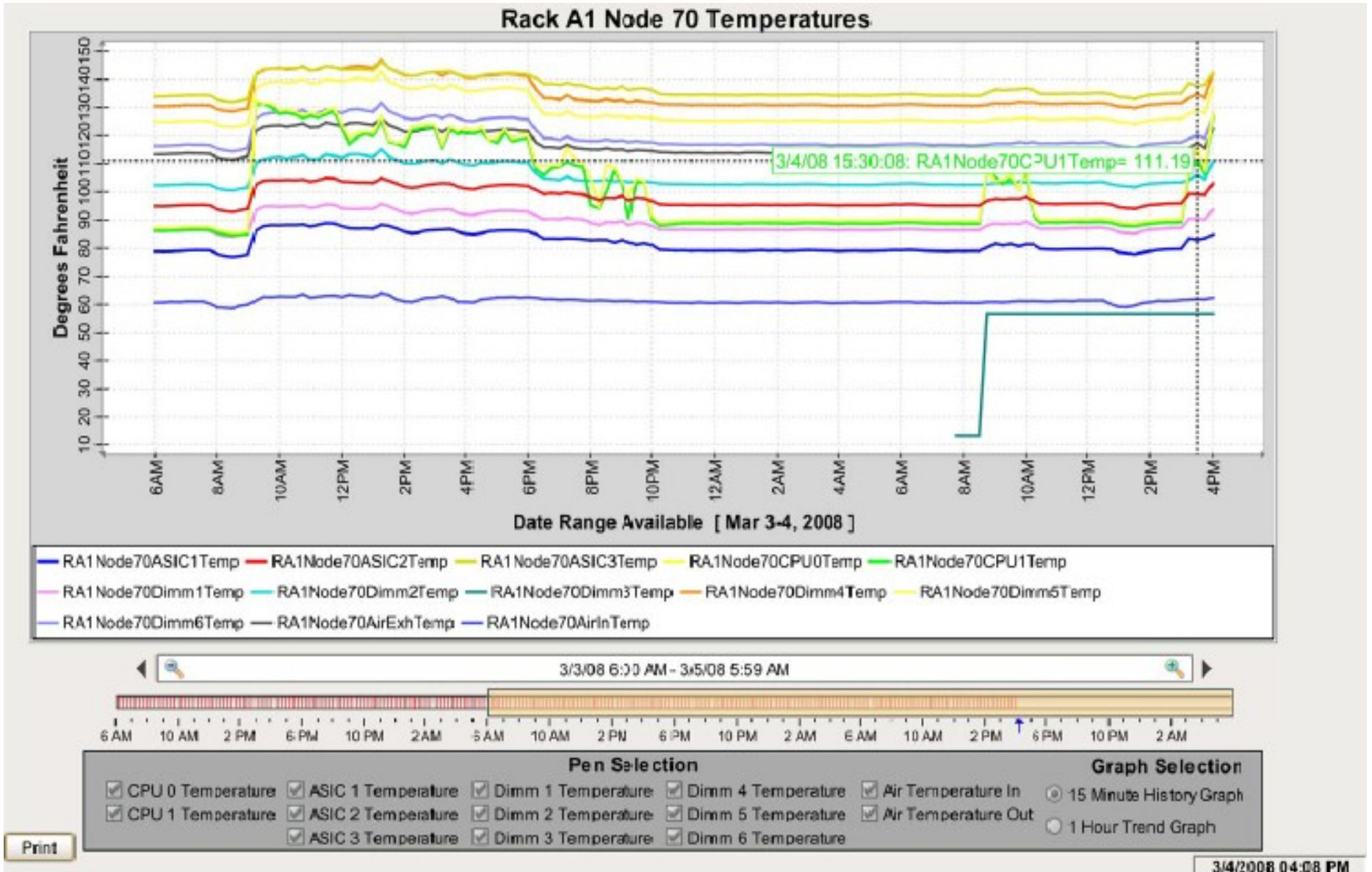
FRED Real-Time: SprayCooled Rack



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/)

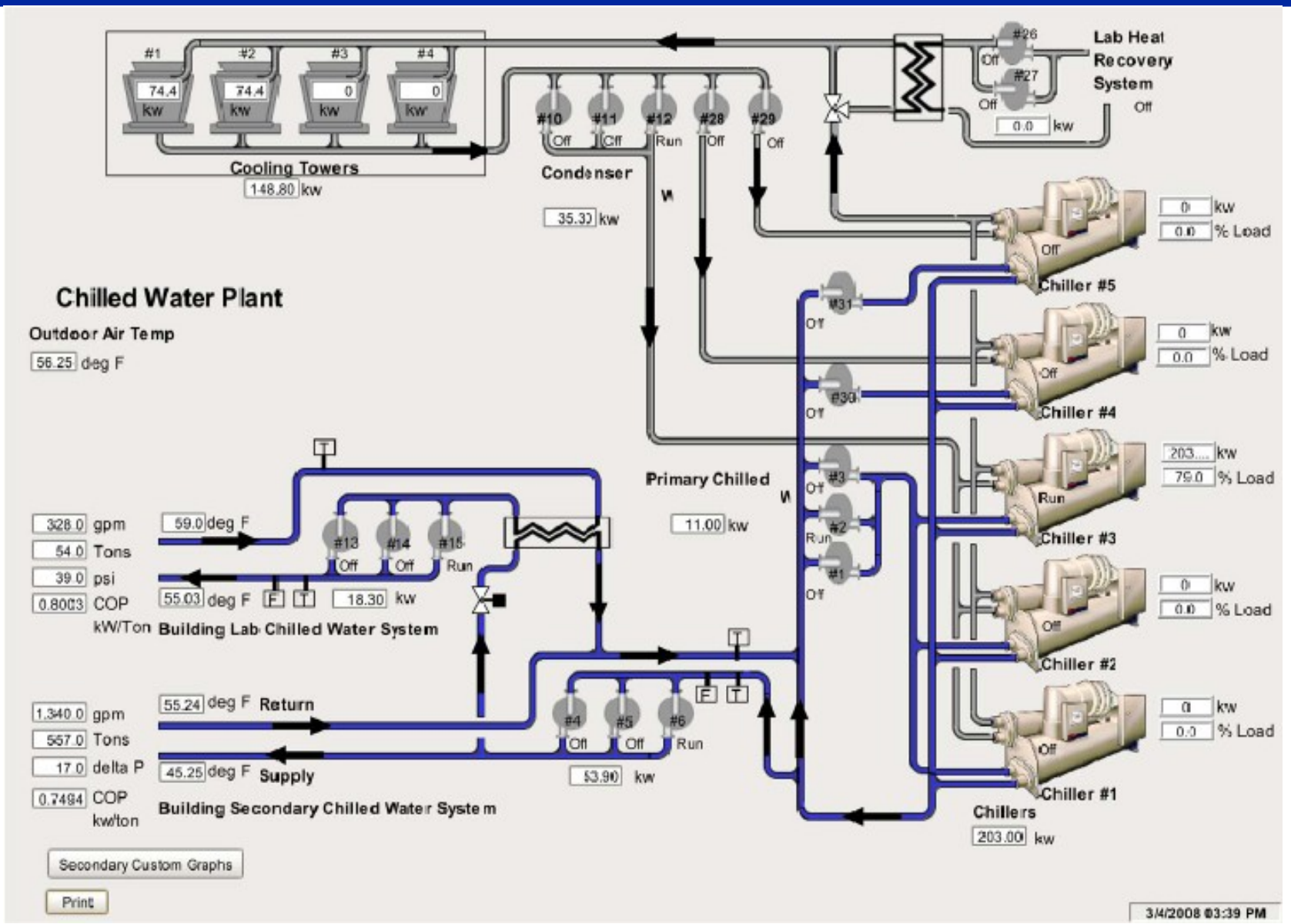
FRED Real-Time Read-Outs: Server Temperatures

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/)

FRED Real-Time: Monitoring Chilled Water



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/)

Cisco Telepresence Provides Leading Edge Commercial Video Teleconferencing

- **191 Cisco TelePresence in Major Cities Globally**
  - **US/Canada: 83 CTS 3000, 46 CTS 1000**
  - **APAC: 17 CTS 3000, 4 CTS 1000**
  - **Japan: 4 CTS 3000, 2 CTS 1000**
  - **Europe: 22 CTS 3000, 10 CTS 1000**
  - **Emerging: 3 CTS 3000**
- **Overall Average Utilization is 45%**

- 85,854 TelePresence Meetings Scheduled to Date
  - Weekly Average is 2,263 Meetings
- 108,736 Hours
  - Average is 1.25 Hours

- 13,450 Meetings Avoided Travel
  Average to Date
  (Based on 8 Participants)

  ~$107.60 M To Date
- Cubic Meters of Emissions Saved 16,039,052 (6,775 Cars off the Road)

Uses QoS Over Shared Internet ~ 15 mbps

Cisco Bought WebEx





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Source: Cisco 3/22/08

Using High Definition to Link the Calit2 Buildings: Living Greener



une 2, 2008

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HD Talk to Australia's Monash University from Calit2: Reducing International Travel



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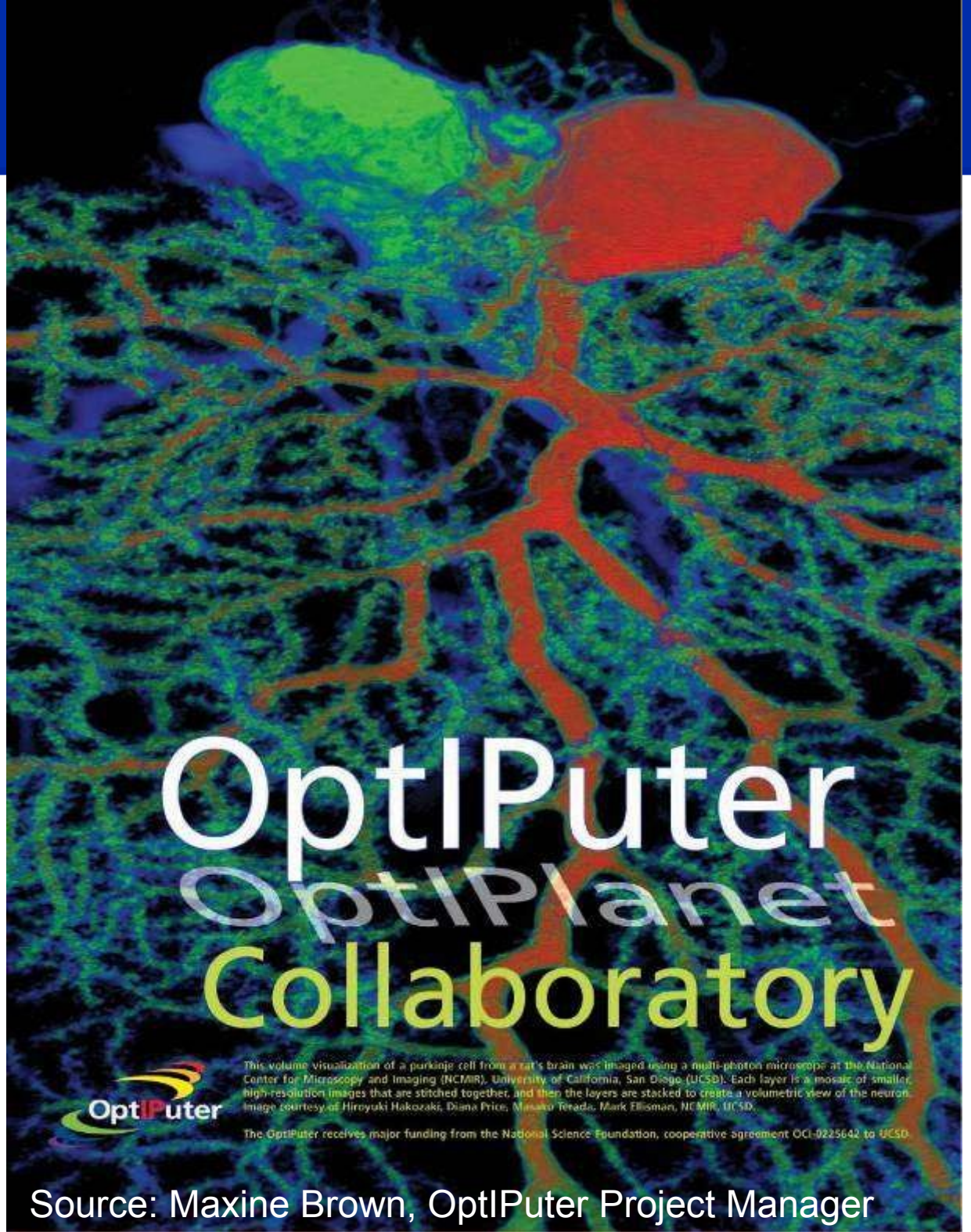
EVL's SAGE VisualCasting Multi-Site OptIPuter Collaboratory



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

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Source: Maxine Brown, OptIPuter Project Manager

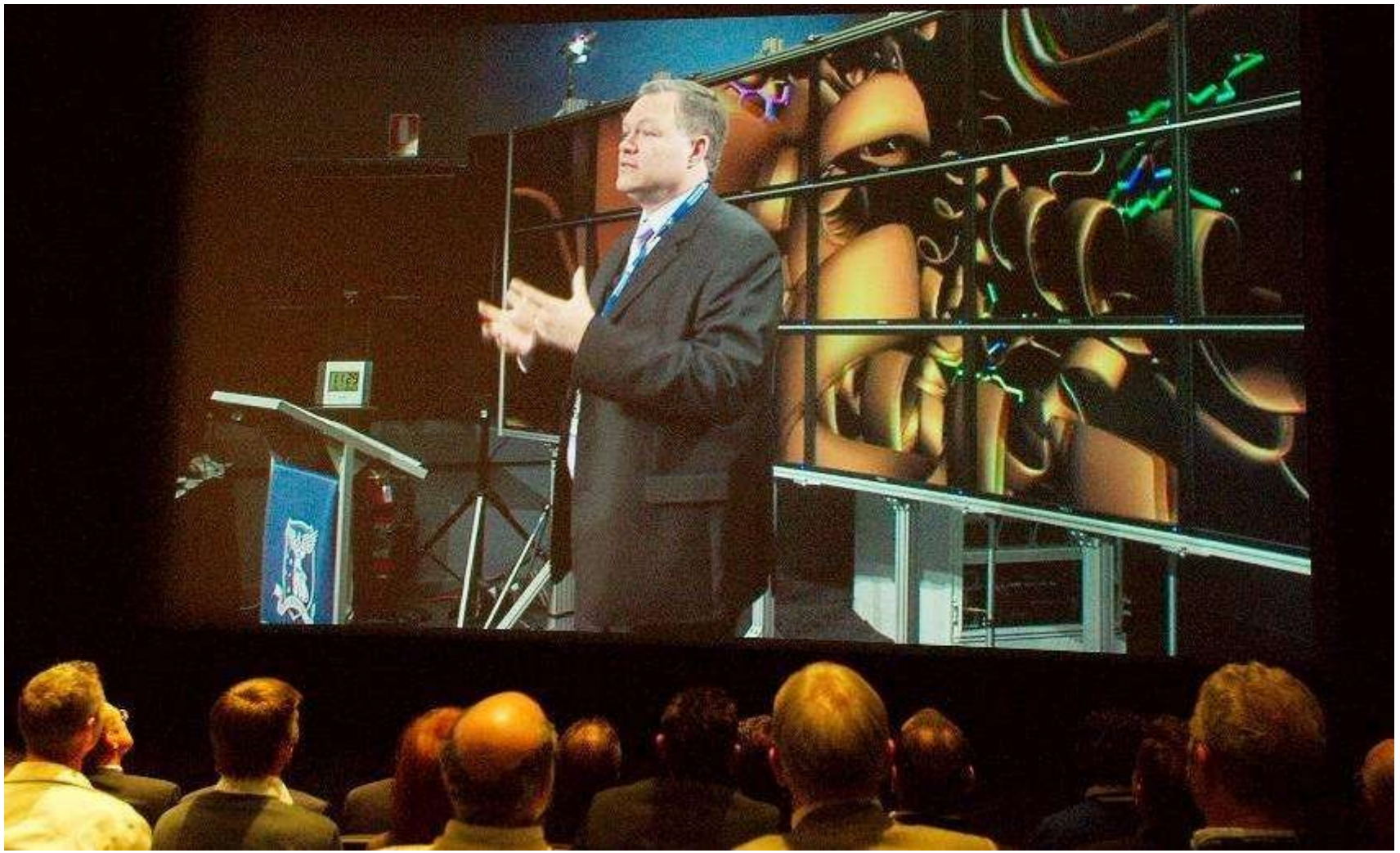
Green Initiative:

Can Optical Fiber Replace Airline Travel for Continuing Collaborations?

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Launch of the 100 Megapixel OzIPortal Over Qvidium Compressed HD on 1 Gbps CENIC/PW/AARNet Fiber

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



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

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Victoria Premier and Australian Deputy Prime Minister Asking Questions



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www.calit2.net/newsroom/release.php?id=1219

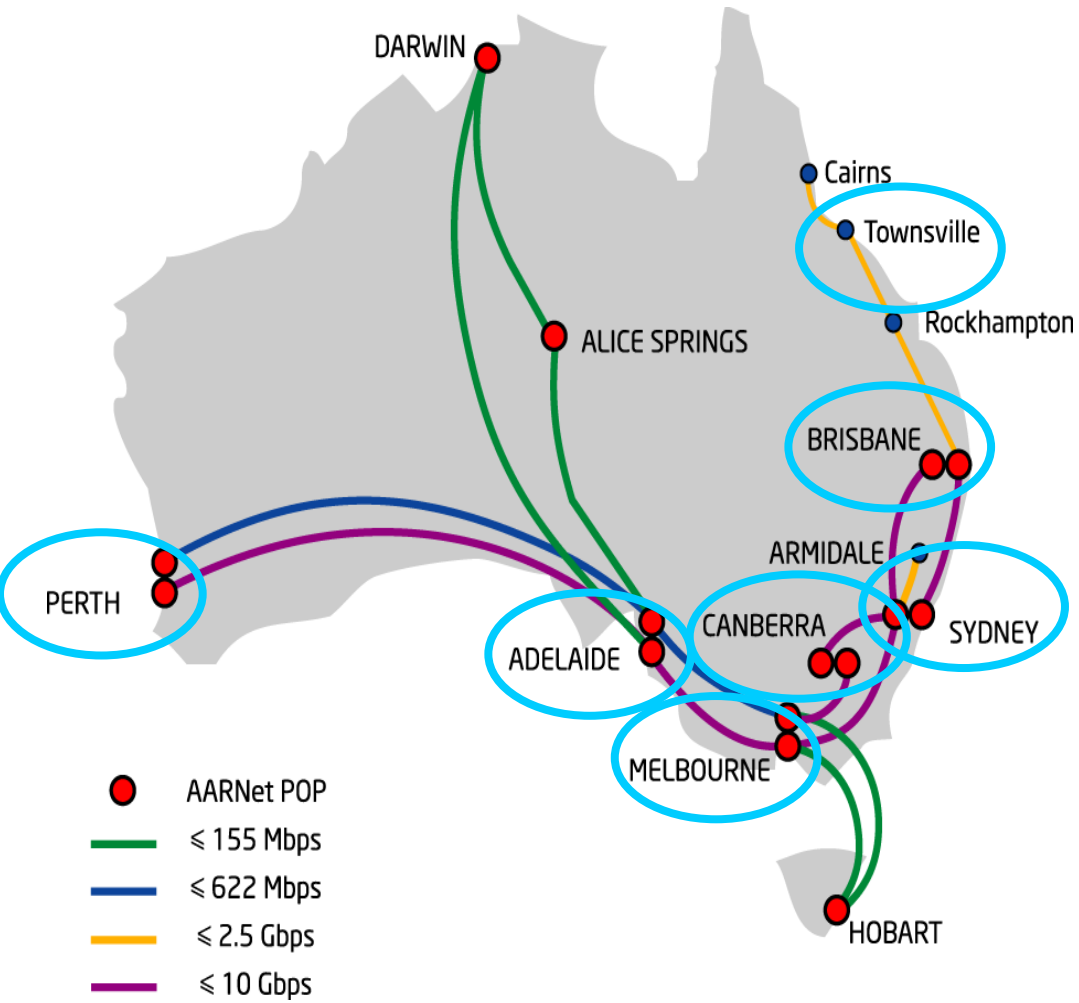
University of Melbourne Vice Chancellor Glyn Davis in Calit2 Replies to Question from Australia



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A Continent Preparing for Green Telepresence

AARNet National Network

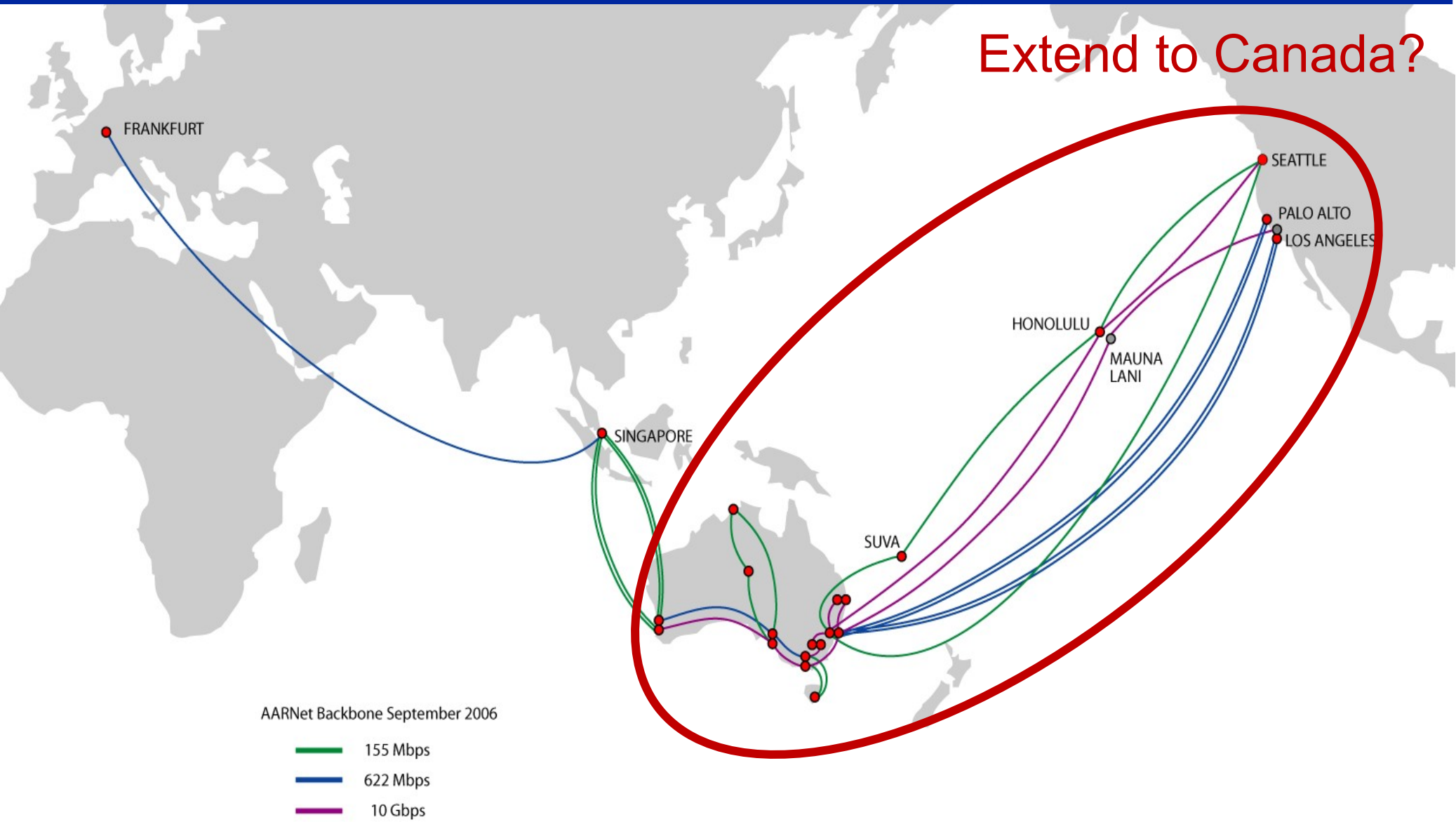


Smarr American Australian Leadership Dialogue OptIPlanet Collaboratory Lecture Tour October 2008

- Oct 2—University of Adelaide
- Oct 6—Univ of Western Australia
- Oct 8—Monash Univ.; Swinburne Univ.
- Oct 9—Univ. of Melbourne
- Oct 10—Univ. of Queensland
- Oct 11—AIMS, James Cook Univ., Townsville
- Oct 13—Univ. of Technology, Sydney
- Oct 14—Univ. of New South Wales
- Oct 15—Leadership Dialogue Scholar Oration, Canberra
- Oct 16—CSIRO OptIPortal Dedication; ANU; AARNet
- Oct 16—Sydney Univ.

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Coupling CENIC/PW to AARNet International Network: The Core of the OptIPlanet Collaboratory



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It's Not Easy Being Green





- **EPA Energy Star Report to Congress 2007**
  - **Lack of Public and Open Data on Energy Consumption**
  - **Calls on New Efforts to Create and Make Available Data Sets on Energy Usage, Usage, and Physical Characteristics**
- **Green is Newest "Marketing" Spin**
- **Gartner Concludes: "Users Are Increasingly Confused About the Issues and Solutions Surrounding Green IT"**

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Greening Can Be Economically Beneficial to California





- **California Air Resources Board Recently (Sept 17th) Released Their Economic Analysis of the Impact of AB32**
- **Based on Macroeconomic Modeling* Implementation of Preliminary AB32 Plans can Result in Significant Economic Benefit--Increasing:**
  - **Production Activity by $27B**
  - **Overall Gross State Product by $4B**
  - **Overall Personal Income by $14B**
  - **Per Capita income by $200**
  - **Jobs by More then 100,000**

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* Environmental Dynamic Revenue Assessment Model &
Berkeley Energy and Resources Model

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