Data Intensive Applications at UCSD: Driving a Campus Research Cyberinfrastructure

Invited Talk

UCSD Administrative Computing and Telecommunications (ACT)

Strategic Planning Retreat

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



End User OptIPortal



Instruments

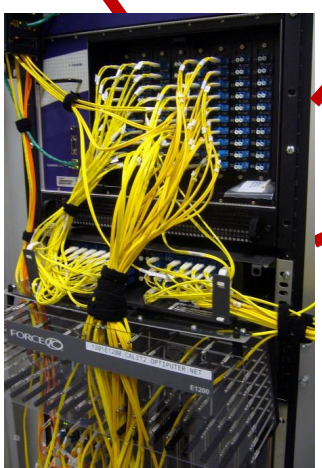


HD/4k Telepresence

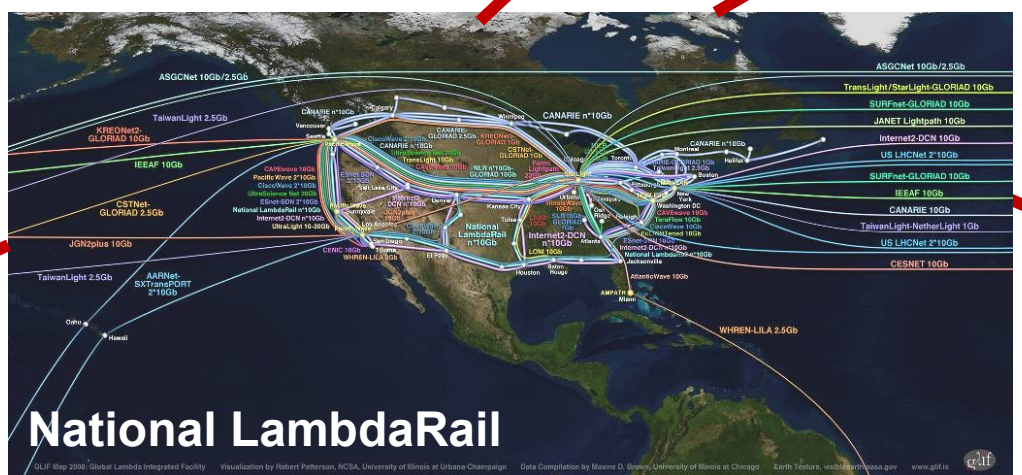


HD/4k Video Cams

HPC



10G Lightpath



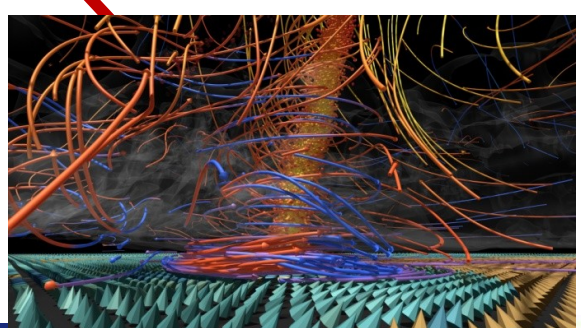
National LambdaRail

TeraGrid™

Campus Optical Switch



Data Repositories & Clusters



HD/4k Video Images

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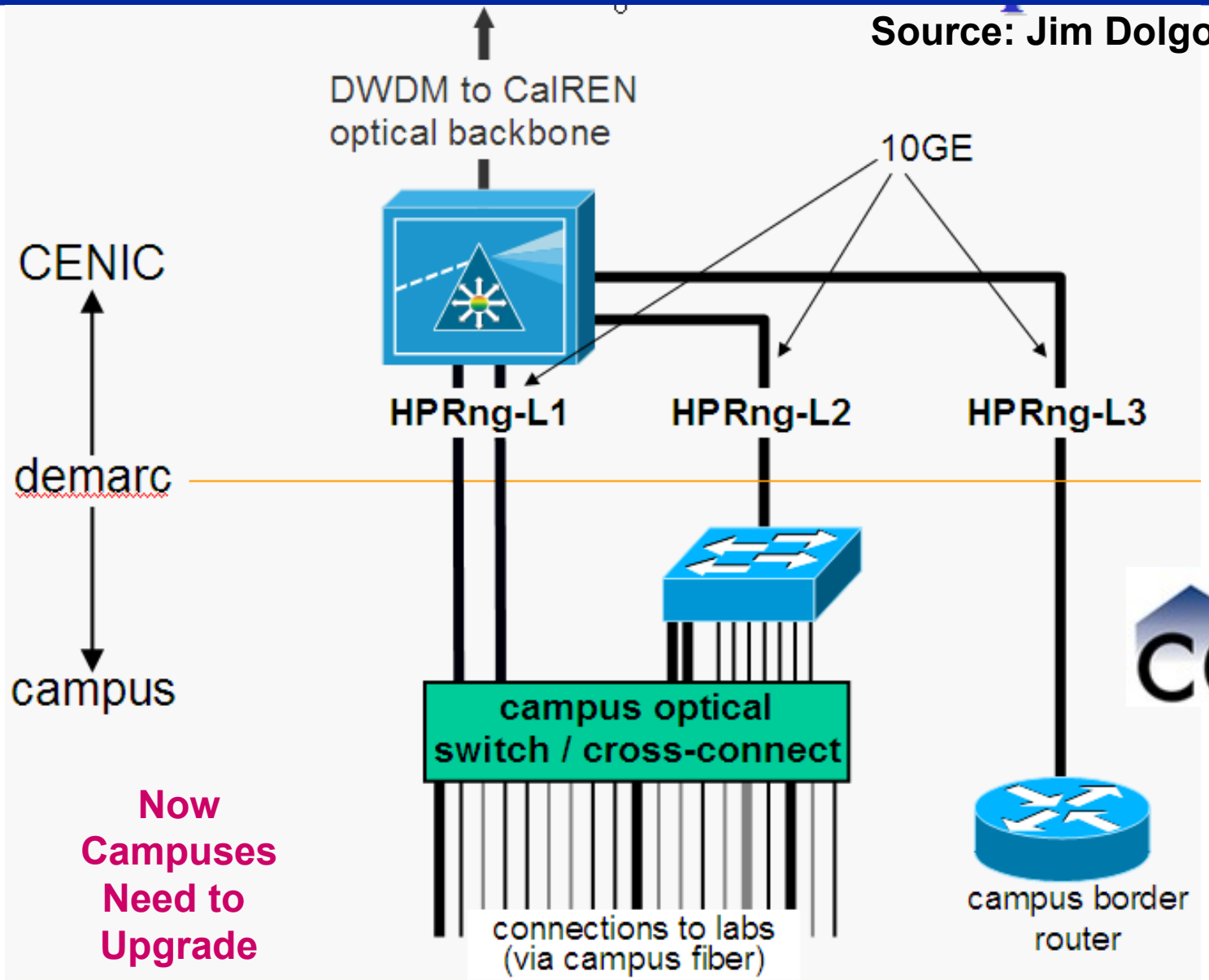
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CENIC's New "Hybrid Network" - Traditional Routed IP and the New Switched Ethernet and Optical Services

Source: Jim Dolgonas, CENIC

CENIC has Invested ~ $14M in Upgrade

CENIC is Preparing $10M 14 Campus NSF-ARI Proposal



Now Campuses Need to Upgrade

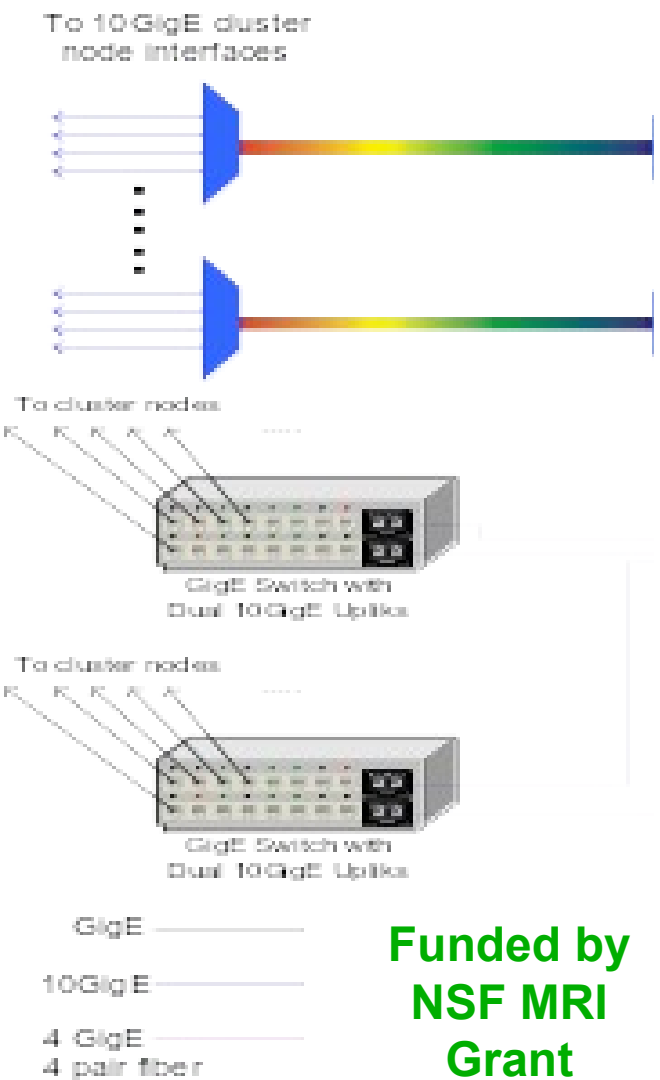
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The "Golden Spike" UCSD Experimental Optical Core: Ready to Couple Users to CENIC L1, L2, L3 Services



End State 2008:

>= 60 endpoints at 10 GigE

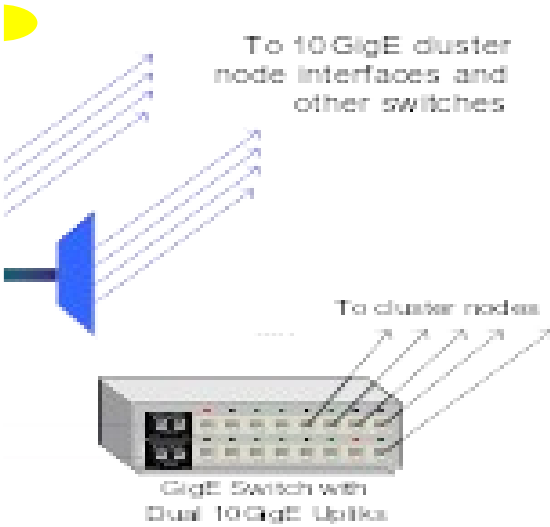
>= 30 Packet switched

>= 30 Switched wavelengths

>= 400 Connected endpoints

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

CENIC L1, L2 Services



CalREN-HPR Research Cloud

Campus Research Cloud

Funded by NSF MRI Grant

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

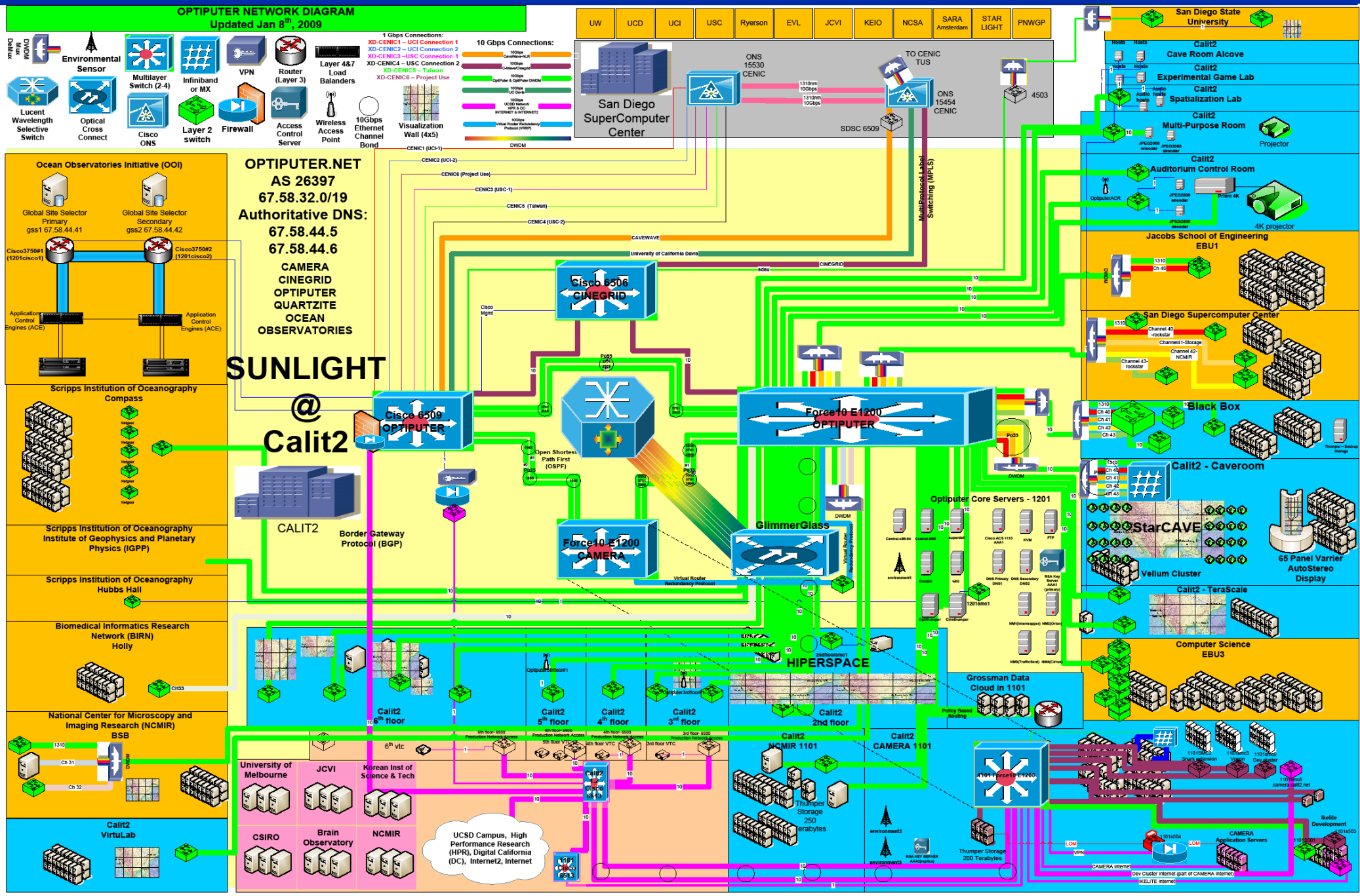
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UCSD OptIPuter
a Dedicated 10Gbps LambdaCampus



NSF GlassOwl MRI Proposal

Developing a Campus-Scale Instrument for Large-Scale Research Data Curation, Analysis, Discovery, Storage, and Publishing

- **PI--Philip Papadopoulos (PI of the previous Quartzite MRI)**
- **Co-PIs:**
  - **Mike Norman (Interim Director of SDSC),**
  - **Brian Schottlaender (University Librarian),**
  - **Larry Smarr (Director of Calit2)**
- **Mission: To Build Phase I of the Campus Research CI, Providing a "Data-intensive Optical Overlay" to the Conventional Campus Shared Internet, Connecting:**
  - **The Campus Data Generators with the Campus' Shared Triton Petabyte Storage and Data Analysis Facility (Located At SDSC);**
  - **The Libraries' Curation, Preservation, and Publishing Systems;**
  - **To State, National & Global Optical Nets (CENIC, NLR, I2DC, GLIF)**
  - **And Back to the Data Consumers in Their Labs for Discovery Using OptIPortals (Developed By Calit2)**

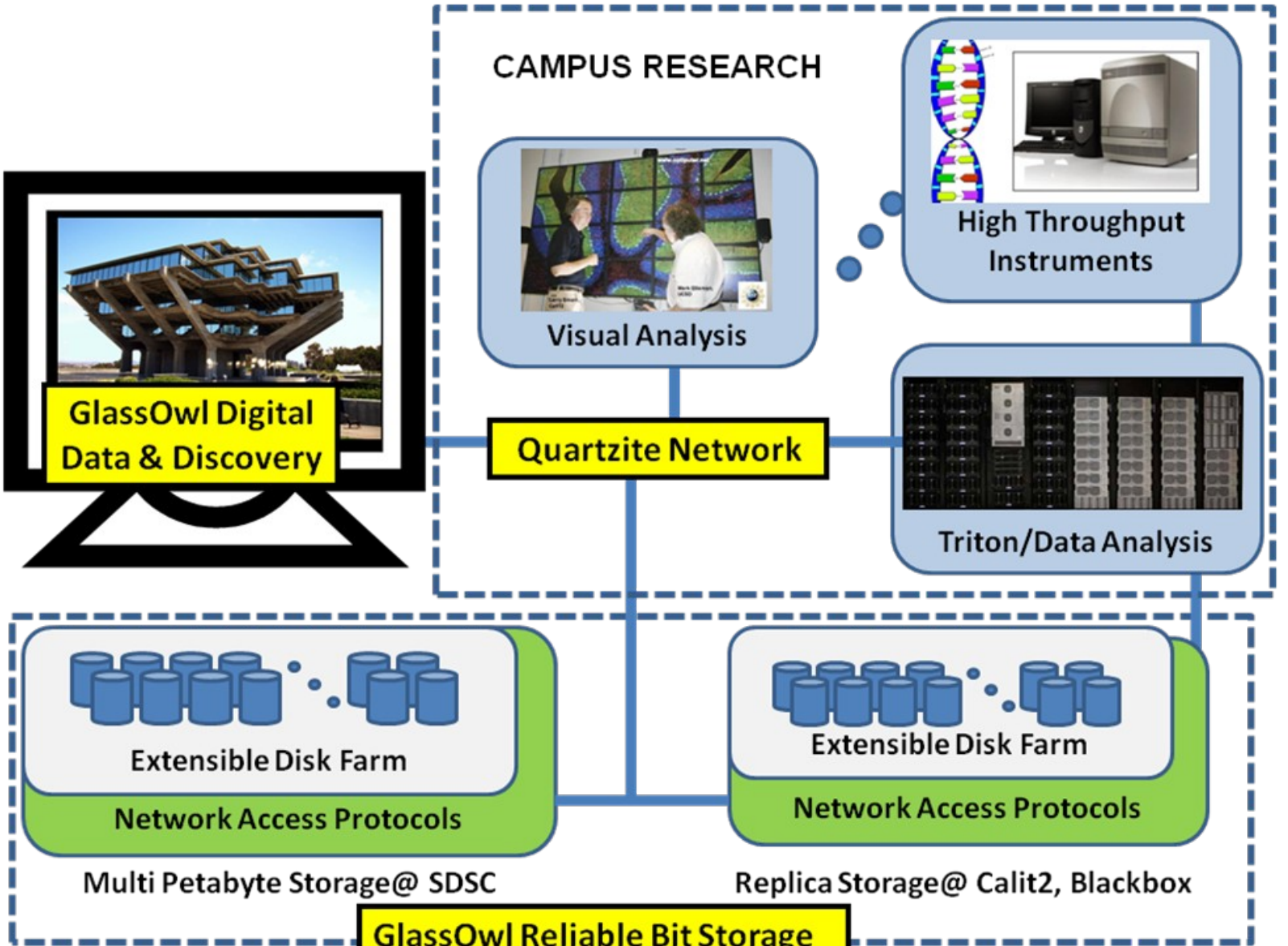
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GlassOwl Conceptual Architecture Diagram:

Triton Extension of Replicated Data Caches for Scientific Instruments & Faculty Projects Plus a New Digital Data and Discovery Capability in the UCSD Libraries



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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

Source: Falko Kuester, Calit2; Michael Sims, NASA

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CGLX CROSS-PLATFORM CLUSTER GRAPHICS LIBRARY

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While MRI Supplies Equipment, Even with Campus Cost Sharing It is Short on Staff

- **NSF MRI Resources~$4.5M (If Funded):**
  - Highly-Reliable, Replicated, High-BW Bit Storage for Applications ~ $3M
  - Data Preservation Hardware ~ $1M
  - Additional Quartzite Optical Connections ~ $200K
  - Specialized Analysis Engines~ $200K.
  - End-User OptIPortals ~$200k
  - Partial Salaries for SDSC and Calit2 Existing Personnel ~$200k
  - Campus Cost Sharing: $360k/yr for 4 Years for Staff
- **GlassOwl Staff Requirements Estimate (8.25 FTE):**
  - Design/Implementation of the Storage/Data Preservation Systems ~ 3FTE
  - Connections to Campus Labs, Building OptIPortals, and Integrating Data Feeds ~ 2FTE
  - Data Curation, Preservation, Publishing ~ 2FTE
  - Project Management, Reporting – 1 FTE
  - PI Oversight – 0.25 FTE

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UCSD GlassOwl Application Drivers

- **Large Compute and Storage Clusters:**
  - NSF Frontiers of Science Center for Theoretical Biological Physics,
  - NSF Math MRI for Acquisition of a Parallel Computing and Visualization Facility to Enable Integrated Research and Training in Modern Computational Science, Mathematics, and Engineering;
  - The NSF Cluster at the SIO Center for Observations, Modeling and Prediction at Scripps (COMPAS)
  - Moore Foundation Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis (CAMERA)
  - Calit2 CineGrid Project
  - GreenLight Modular Data Centers
  - SDSC Track 2D Flash Gordon
  - UC South Compute Cluster
- **Remote Environmental Observatories**
  - NSF High Performance Wireless Research and Education Network
  - SIO California Real Time (GPS) Network (CRTN)
  - SIO Ocean Observatories Initiative (OOI)

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UCSD GlassOwl Application Drivers

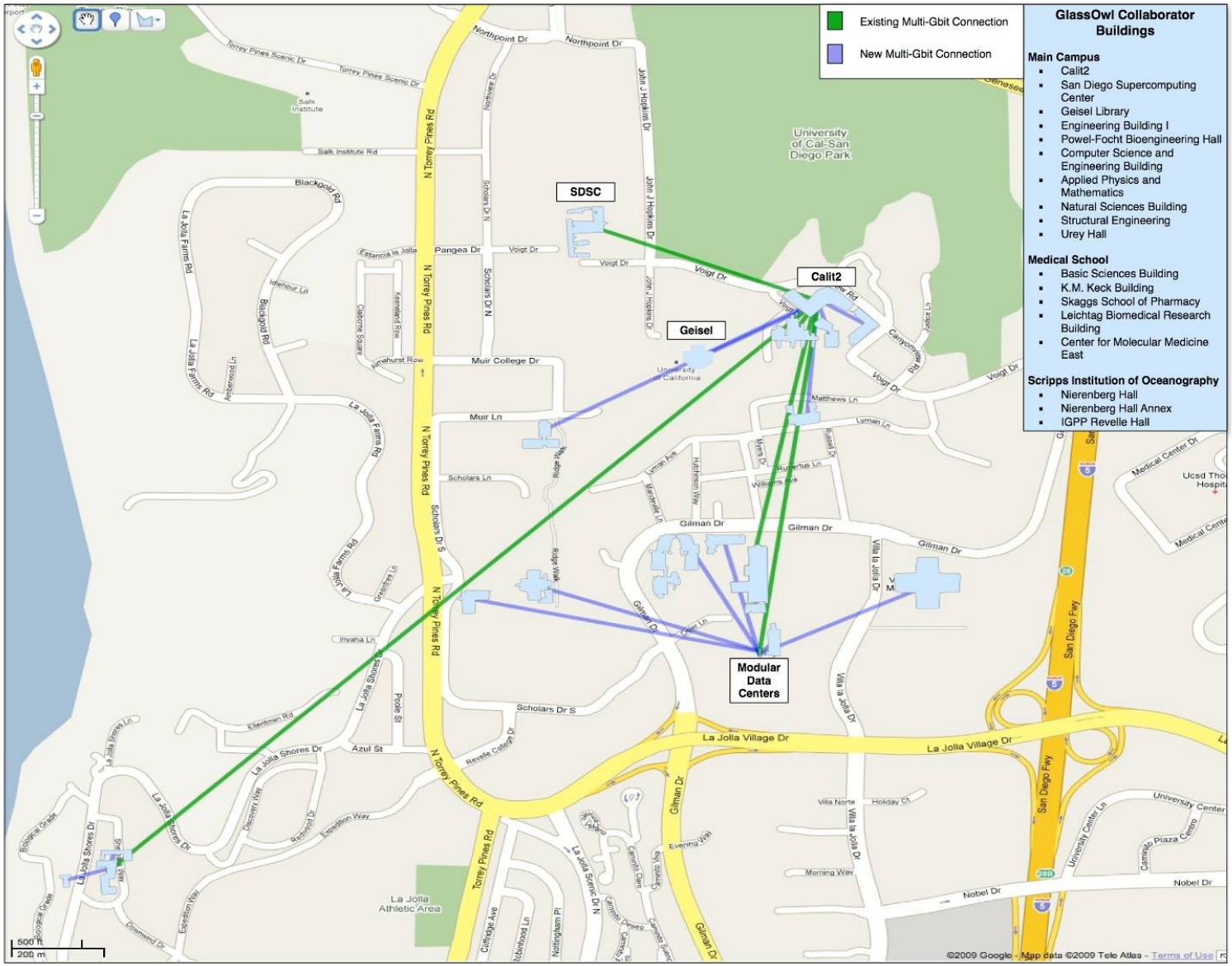
- **Data Analysis Centers**
  - Laboratory for Computational Genomics
  - NSF-funded Laboratory for Computational Astrophysics
  - NIH-funded Center for Computational Mass Spectrometry
  - NIH-funded National Biomedical Computation Resources (NBCR)
  - Trey Ideker NSF grant: Biological Data Integration Using Large-Scale Molecular Interaction Networks
  - Scripps component of the California Climate Change Center (CCCC)
- **Scientific Instruments**
  - NIH-funded Brain Observatory
  - NIH-funded National Center for Imaging and Microscopy Research
  - Core Facilities:
    - Mass Spectrometers (Chem/Pharma/Bio/SOM)
    - Sequencing and Microarray Cores (Biogem and VA)
    - Microscopy Core (CMME Building)
    - fMRI center

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GlassOwl MRI Campus Collaborator Connectivity: Existing (Green) and New (Blue) 10Gps Optics



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

- **Coupling the Internet and the Electrical Grid**
  - Choosing non-GHG Emitting Electricity Sources
  - Measuring Demand at Sub-Building Levels
  - Reducing Local Energy Usage via User Access Thru Web
- **Transportation System**
  - Campus Wireless GPS Low Carbon Fleet
  - Green Software Automobile Innovations
  - 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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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
  - Enable Scientists To Explore Tactics For Maximizing Work/Watt
- **Develop Middleware that Automates Optimal Choice of Compute/RAM Power Strategies for Desired Greenness**
- **Partnering With Minority-Serving Institutions Cyberinfrastructure Empowerment Coalition**

Source: Tom DeFanti, Calit2; GreenLight PI

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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

Prof. Tajana Šimunić Rosing, CSE, UCSD

hp invent
Sun microsystems
Texas Instruments Inc.
YAHOO!
CISCO
NSF
DARPA
SRC Semiconductor Research Corporation
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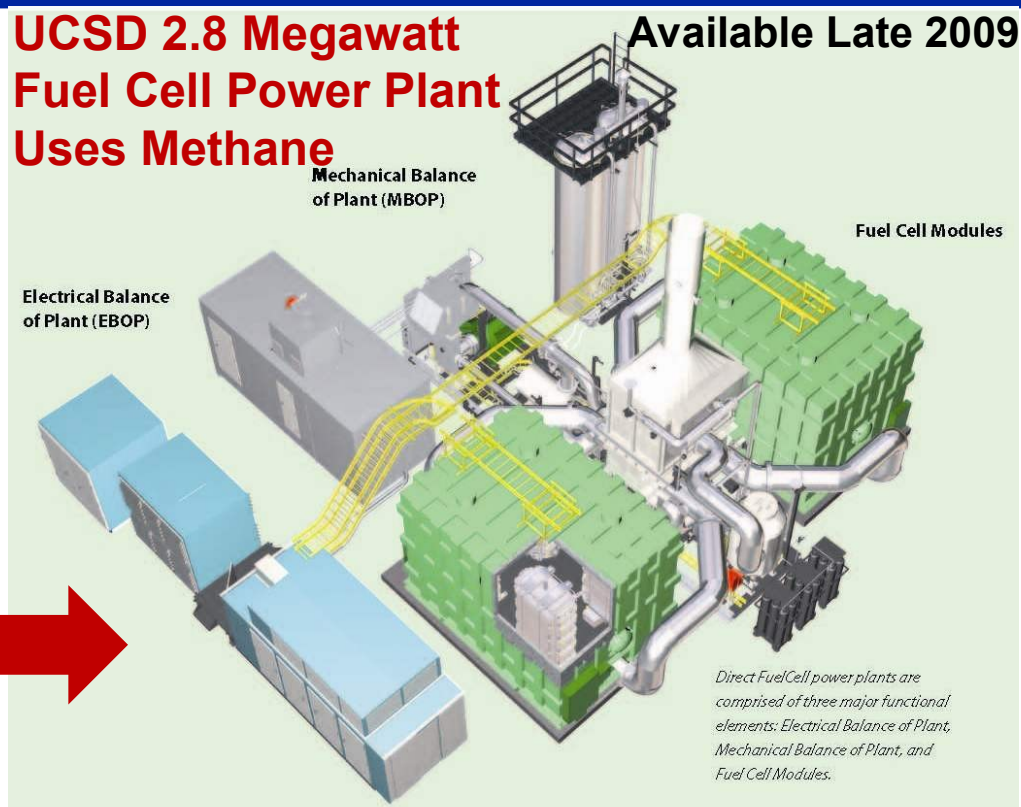
UCSD is Installing Zero Carbon Emission Solar and Fuel Cell DC Electricity Generators

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: Direct 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)?

DC Fuel Cell 2800kWatts
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

Source: Tom DeFanti, Calit2; GreenLight PI

- **Experiment Planning Just Starting**
  - Collaboration with Sun and LBNL
  - NSF GreenLight Year 2 and Year 3 Funds

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ARRA Funding Opportunity

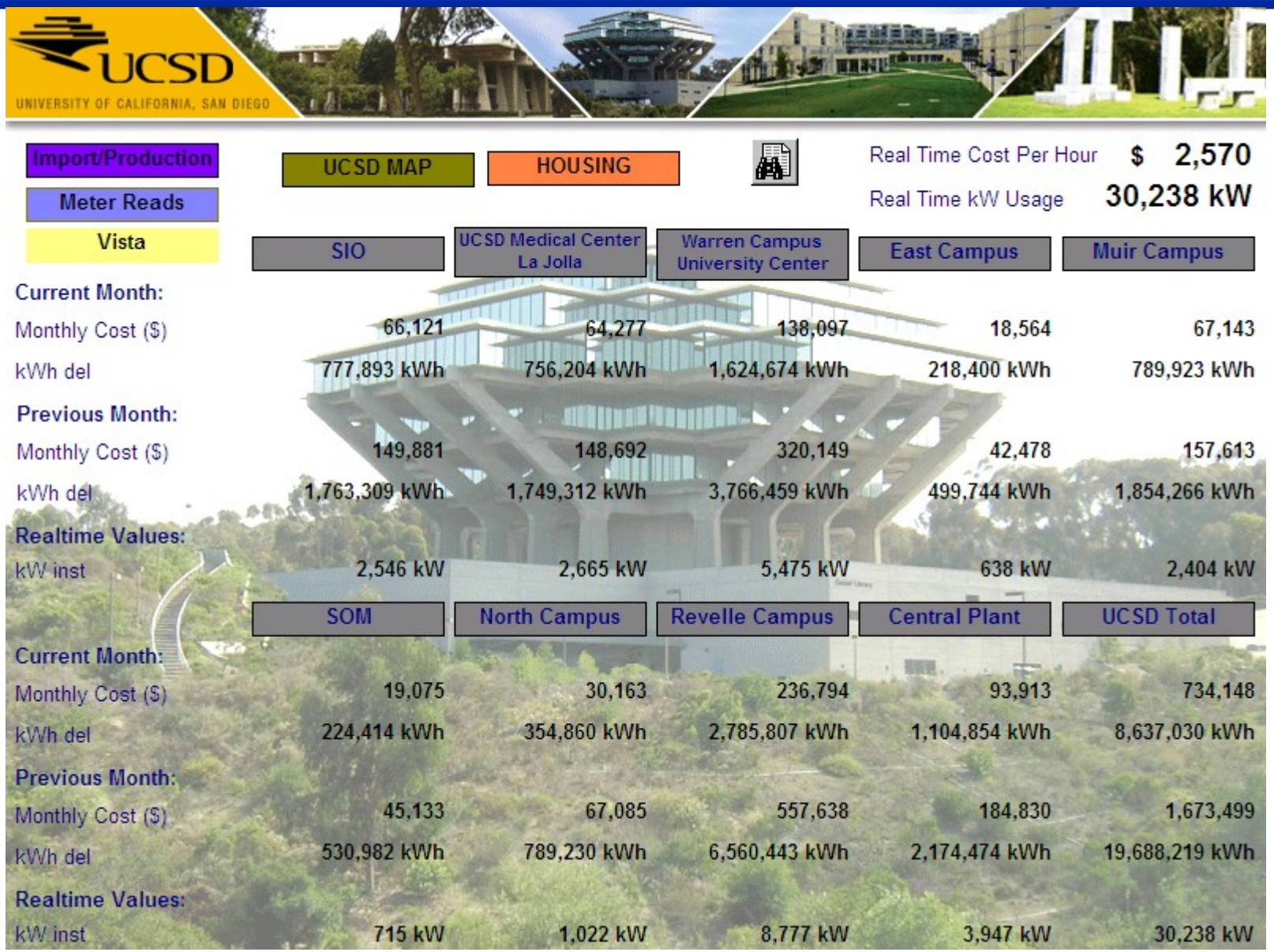
- Recovery Act: Energy Efficient Information and Communication Technology
- UCSD Proposal: Renewable, Bio-Fueled 400 VDC Modular Data Center
  - PI Tom DeFanti, UCSD, Calit2
  - CoPIs Rajesh Gupta, Tajana Rosing, Greg Hidley
  - Partners
    - NSF funded GreenLight investigators
    - Lawrence Berkeley National Laboratory
    - Sun Microsystems, Intel, Delta
    - EPRI, Direct Power Technologies
  - Coordination with UCSD Strategic Initiatives Office and Facilities Management
- Goals: At UCSD East Campus Utility Plant
  - Establish renewable energy facility with Fuel Cell, Biomass generator, and PVs
  - Develop Smart Grid distribution of above DC sources providing 5 9's reliability
  - Develop all DC Sun MD with DC powered computers and networking equipment
  - Develop novel cooling improvements using reduced loads and virtualization
  - Develop novel energy efficiency improvements using reduced loads and virtualization

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



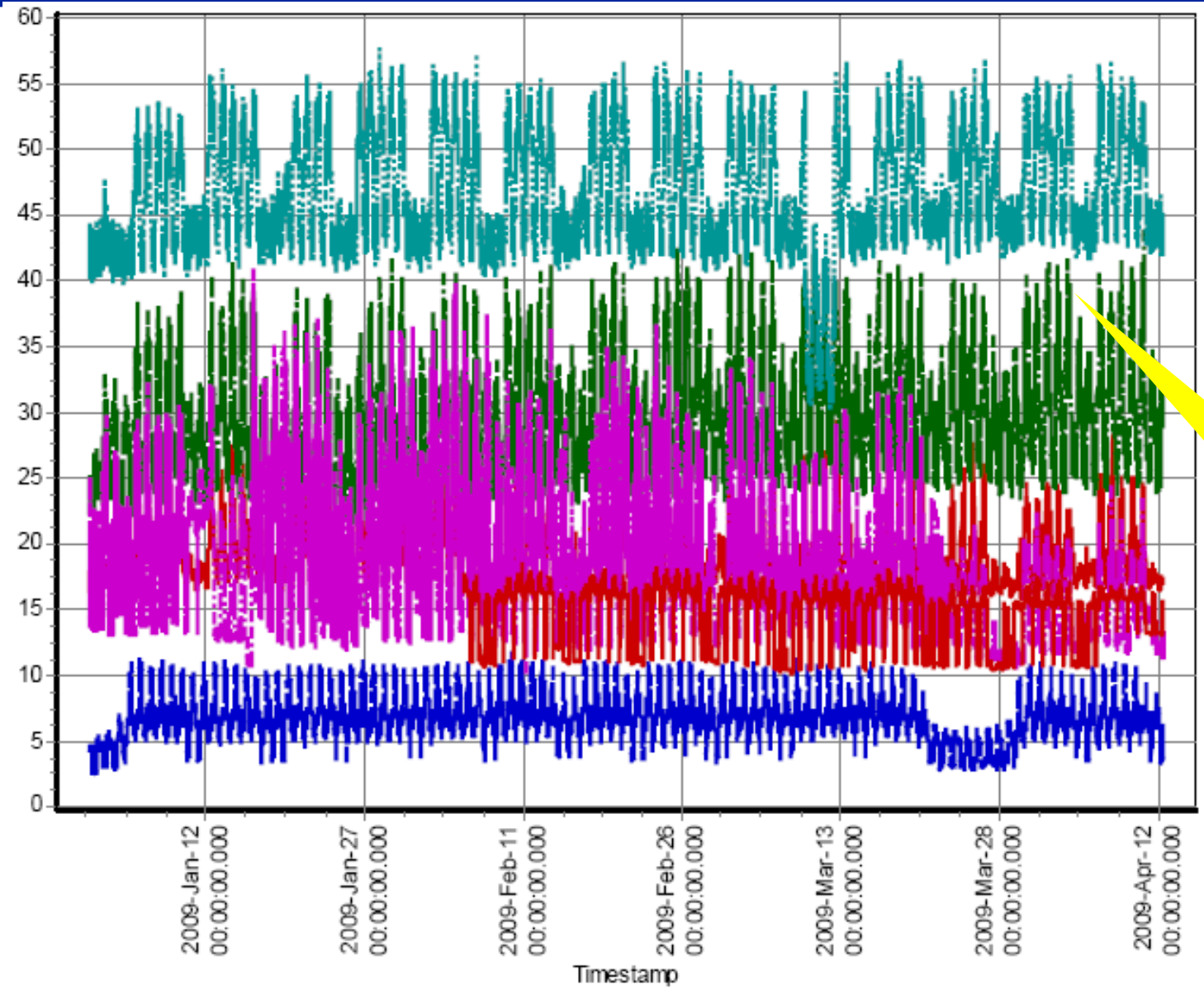
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http://mscada01.ucsd.edu/ion/

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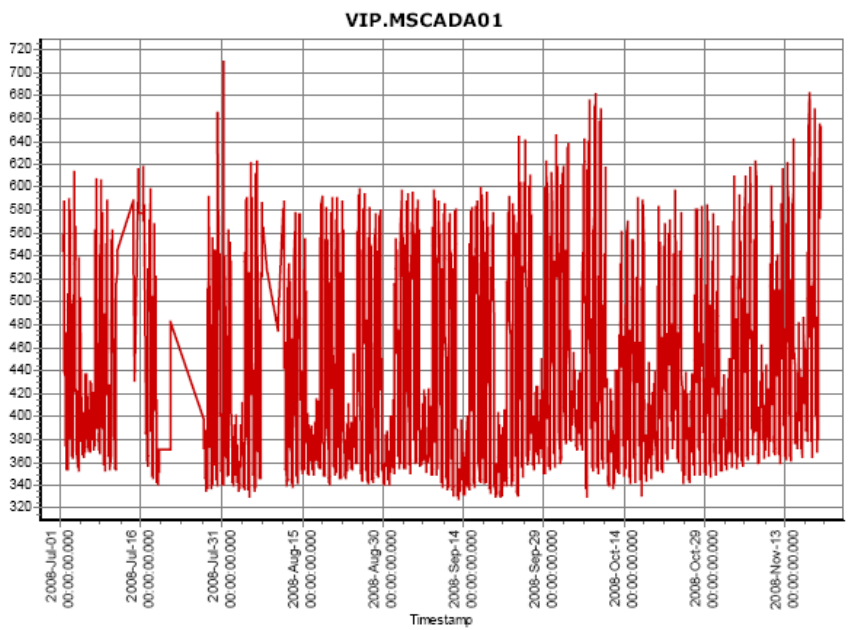
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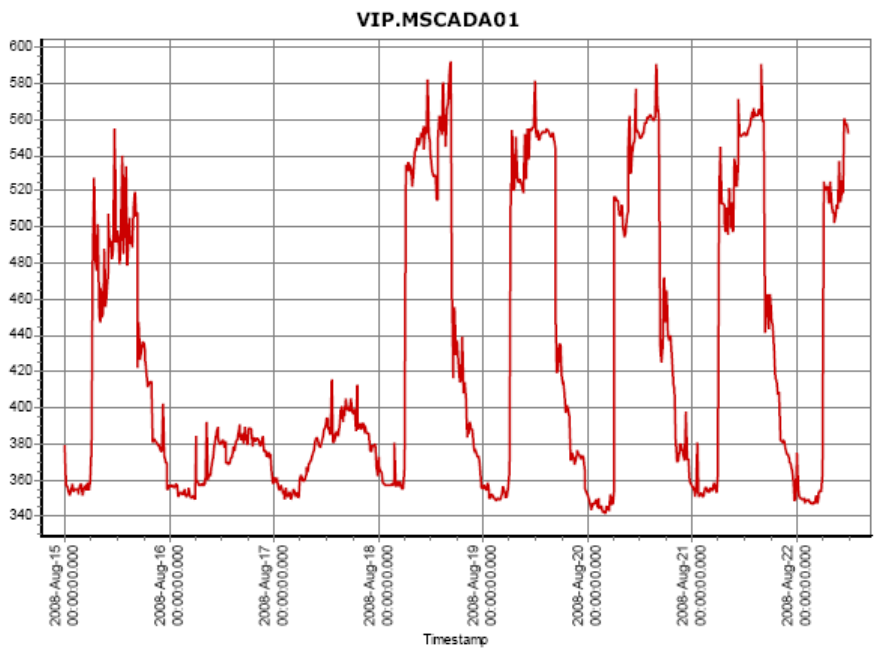
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Power Management in Mixed Use Buildings: The UCSD CSE Building is Energy Instrumented

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







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Source: Rajesh Gupta, CSE, Calit2

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Possible Wireless Innovations On Campus

- Cell Phone Use as _Alternative_ to Desktop Phone. Right Now Cell Phones are Treated as a Special Privilege…
- Smooth Handoffs Between Cell and WiFi/WiMax
- Pico Cells with Tens to Hundreds of Mbps
- Broadband Coverage on Campus That will Allow for Dense Deployments of Networked Sensors
- Holistic Architecture for Licensed Band Systems That Ensures Coverage in All Campus Buildings Including Relays and Repeaters
- A Comprehensive Framework for Managing Interference
- Location Based Services to Track Inventory and Moving Assets as a Campus Wide Service
- Security Services That Keep Up with the Growing Threats

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Source: Ramesh Rao, Calit2

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