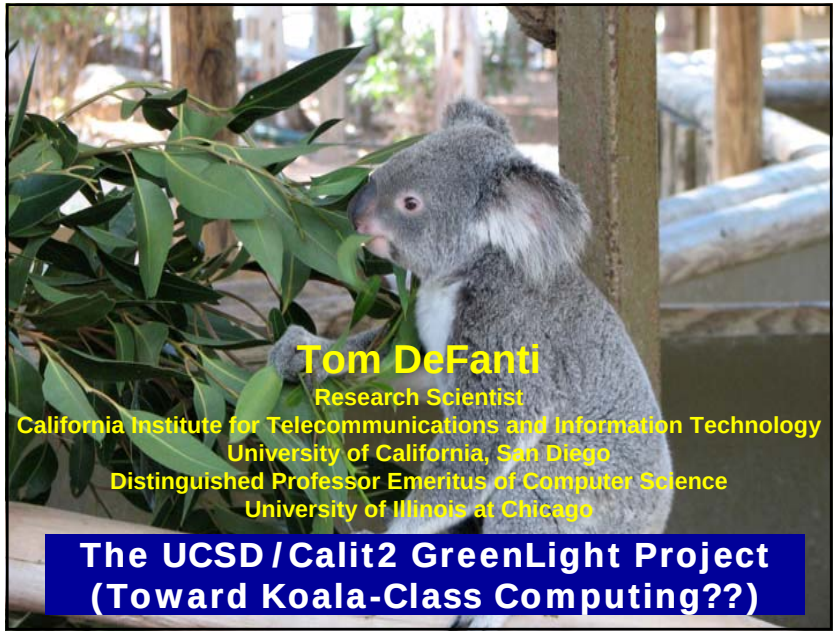
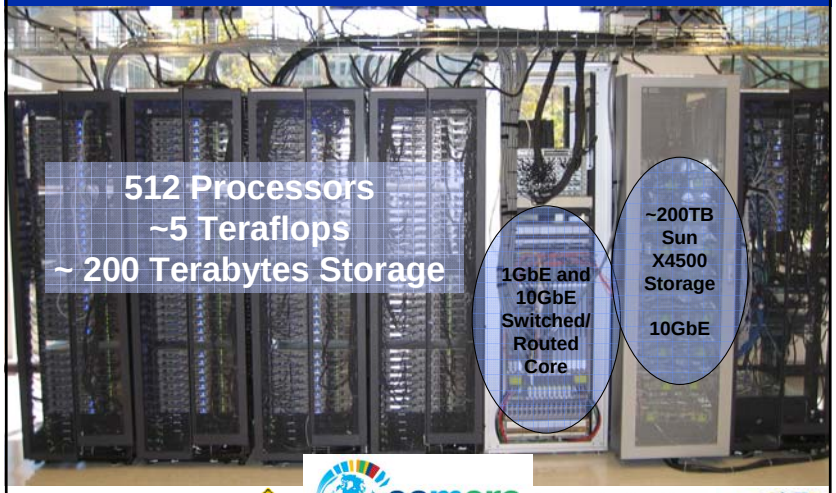


The Problem

- *Compute energy/rack : 2 kW (2000) to 30kW in 2010*
- *Cooling and power issues now a major factor in CI design*
- *IT industry is "greening" huge data centers*
- *But academic CI is often too small: departmental closets*
- ***Energy use of departmental facilities is exponentiating creating crises of space, power, and cooling***
- ***Unfortunately, almost nothing is known about how to make these shared virtual clusters energy efficient, since there has been no financial motivation to do so***

Example: Calit2 Microbial Metagenomics Cluster Production System--Single Problem Supercomputer



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

The GreenLight Solution: More Work/Watt

- *Measure then minimize energy consumption*
- *Develop middleware that automates optimal choice of compute/RAM power strategies*

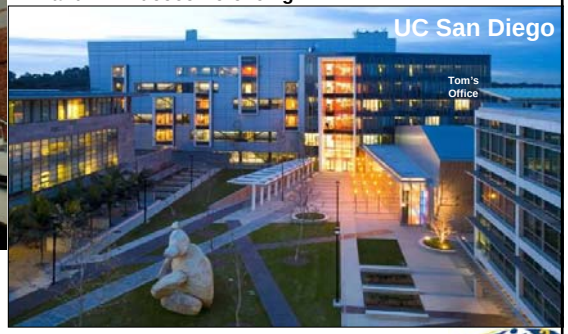
- *Discover better power efficiency configurations and architectures*
- *Teach the next generation of engineers who must scale from an education in Computer Science to a deep understanding in engineering physics*

- *Build a full-scale virtualized device, the GreenLight Instrument*
- *Measure, monitor, and make publicly available, via service-oriented architectures, real-time sensor outputs*
- *Focus on 5 communities: metagenomics, ocean observing, microscopy, bioinformatics, and digital media*
- *Allow researchers anywhere to study the energy cost of at-scale scientific computing*

it²

Calit2

- Over 1000 Researchers in Two Buildings Linked via Dedicated Optical Networks
- International Science, Art and Engineering via Telecommunications and Information Technology
- Nanotechnology to Wireless, Microbial Genomics to Earth Sciences, Virtual Reality to 4K Digital Cinema and HD videoconferencing



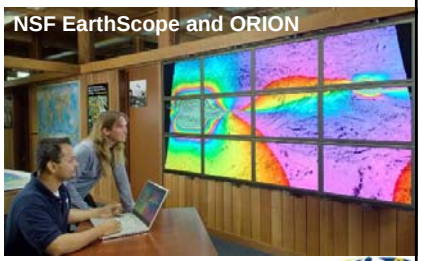
Preparing for a World in Which
Distance and Removing your Laptop, Shoes, and Belt are Eliminated…

The OptIPuter Project – Creating High Resolution Portals Over Dedicated Optical Channels to Global Science Data

- NSF Large Information Technology Research Proposal
  - Calit2 (UCSD, UCI) and UIC Lead Campuses
  - Partnering Campuses: SDSC, USC, SDSU, NCSA, NW, TA&M, UvA, SARA, NASA Goddard, KISTI, AIST, CRC(Canada), CICESE (Mexico)
- $13.5 Million Over 5 Years—Now In the 6th and Final Year

NIH Biomedical Informatics Research Network

NSF EarthScope and ORION

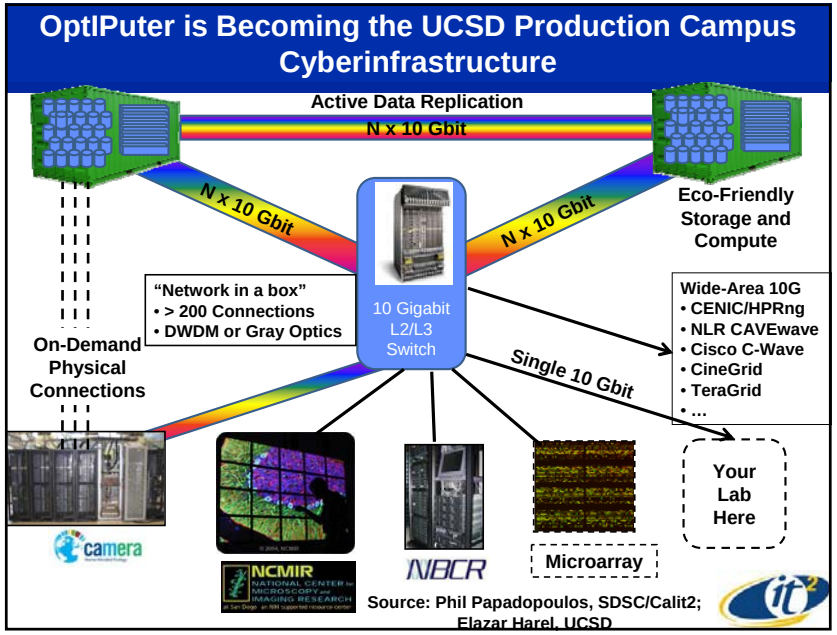


SCRIPPS INSTITUTION OF OCEANOGRAPHY

Calit2 SunLight Quartzite Optical Exchange

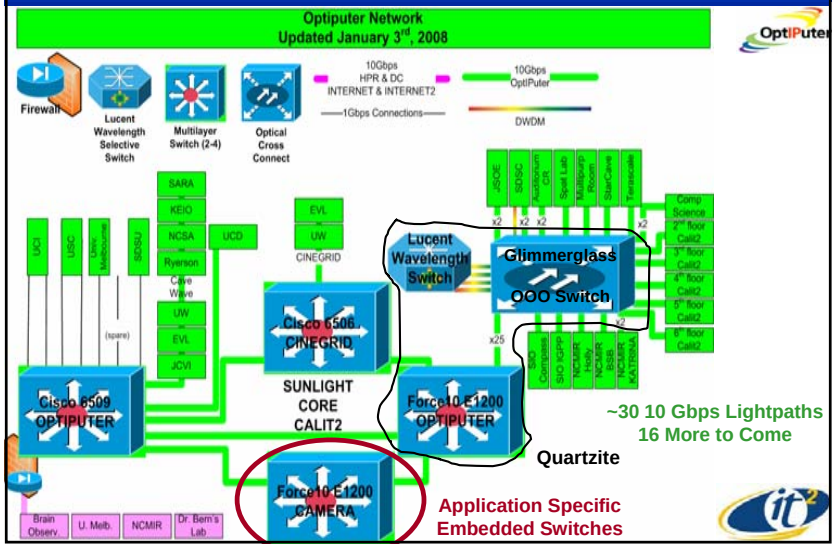
10:45 am
Feb. 21, 2008

OptIPuter is Becoming the UCSD Production Campus Cyberinfrastructure

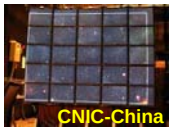


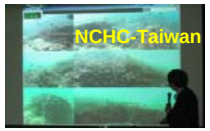
Source: Phil Papadopoulos, SDSC/Calit2; Elazar Harel, UCSD

Block Layout of OptIPuter BackPlane Network



OptIPortals Are Being Adopted Globally



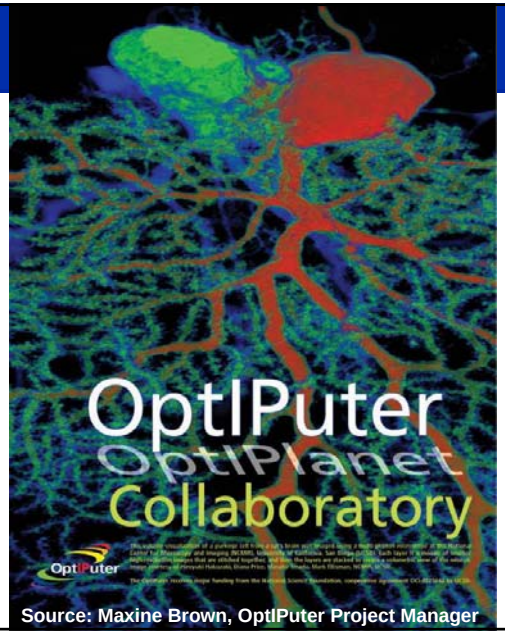


Powered by Rocks ROCKS

evl electronic visualization laboratory

CGLX Downloads

Source: Falko Kuester



Source: Maxine Brown, OptIPuter Project Manager

Green Initiative:

Can Optical Fiber Replace Airline Travel for Continuing Collaborations ?

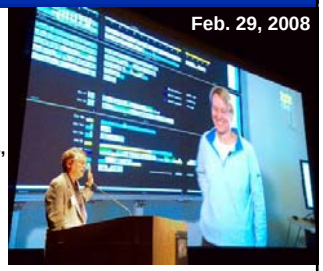
Bernard Pailthorpe will give stats on the Access Grid in Qld

OptIPlanet Collaboratory Persistent Infrastructure Between Calit2 and U Washington

OptIPuter

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

ROCKS



UW's Research Channel Michael Wellings

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

ROCKS

January 15, 2008

OptIPuter

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

Protein Visualizations on OzIPortal
Created with Covise Software Displayed with CGLX

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

Victoria Premier and Australian Deputy Prime Minister Asking Questions

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

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

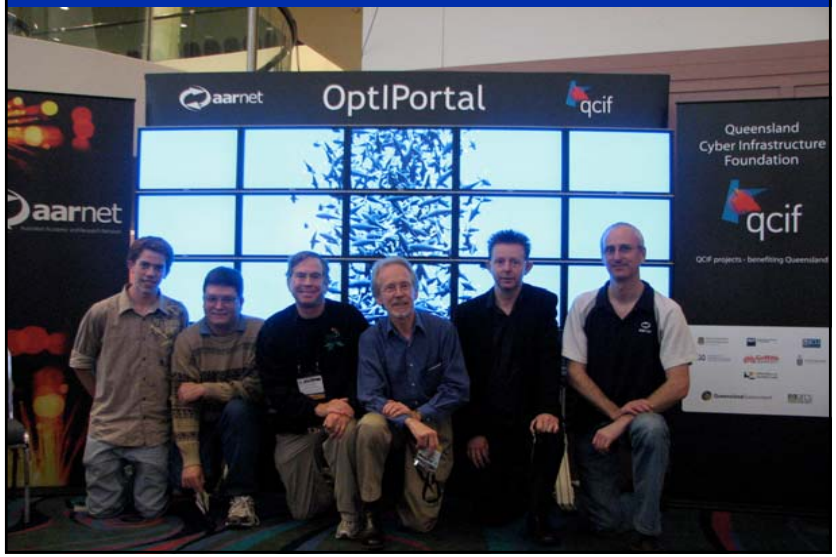
"Real TelePresence: Using the Link to Build the Link" Being Extended to Monash Univ., UQ, CSIRO…

No Calit2 Person Ever Physically Flew to Australia Build OptIPortals

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

UQ OptIPortal

At QUESTnet too!



Energy Metrics – on the AARNet CORE

Shipping in 1Q2008	M320	Cisco 12416	Juniper MX240	Cisco 7604
Slot Capacity, Gpbs	20	10 (SIP-601)	40	20 (ES-20)
System Capacity	320 Gbps	280 Gbps	240 Gbps	80 Gbps
Rack Space (height)	1/2 rack	Full rack	8.71"	8.75"
Max System Draw	2.78 KW	5.58 KW	1.42 KW	1.30 KW
Energy Efficiency (EER)	58 Gbps/KW	25 Gbps/KW	85 Gbps/KW	31 Gbps/KW
ECR, Watts/10Gbps	173.75	398.57	118.33	325.00
Feature Set	Multiservice edge		Carrier Ethernet	

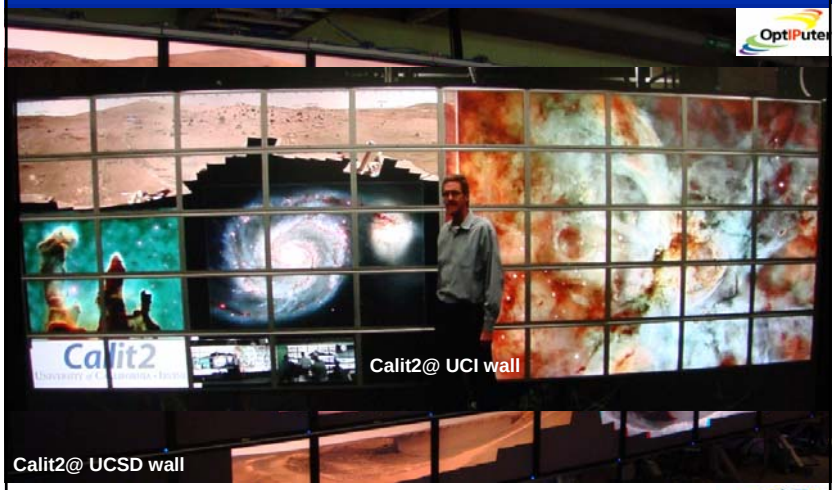
Source: Chris Hancock

Back to Conspicuous Consumption: Interactive Exploration of Marine Genomes Using 100 Million Pixels

camera

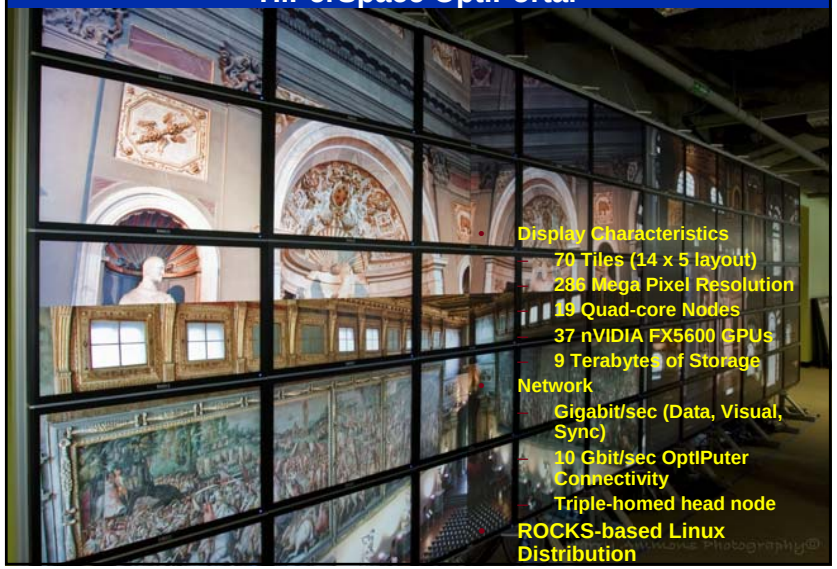
Ginger Armburst (UW), Terry Gaasterland (UCSD SIO)

The Calit2 Great Walls at UCSD and UCI Use CGLX and Are Now a 1 Gbit/s HD Collaboratory



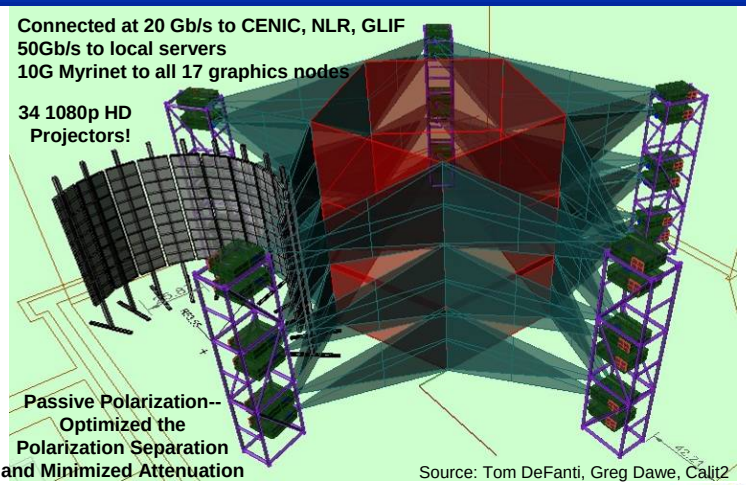
OptIPortals Used to Visually Study Very Large Collages from NASA Space Observatories

On Beyond: Calit2's 285 Megapixel 35kW HiPerSpace OptIPortal



- Display Characteristics
  - 70 Tiles (14 x 5 layout)
  - 286 Mega Pixel Resolution
  - 19 Quad-core Nodes
  - 37 nVIDIA FX5600 GPUs
  - 9 Terabytes of Storage
- Network
  - Gigabit/sec (Data, Visual, Sync)
  - 10 Gbit/sec OptIPuter Connectivity
  - Triple-homed head node
- ROCKS-based Linux Distribution

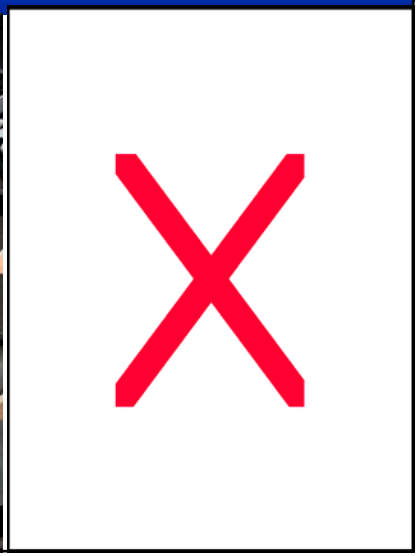
Calit2's StarCAVE
Stereo 34 Megapixel per eye 50kW OptIPortal



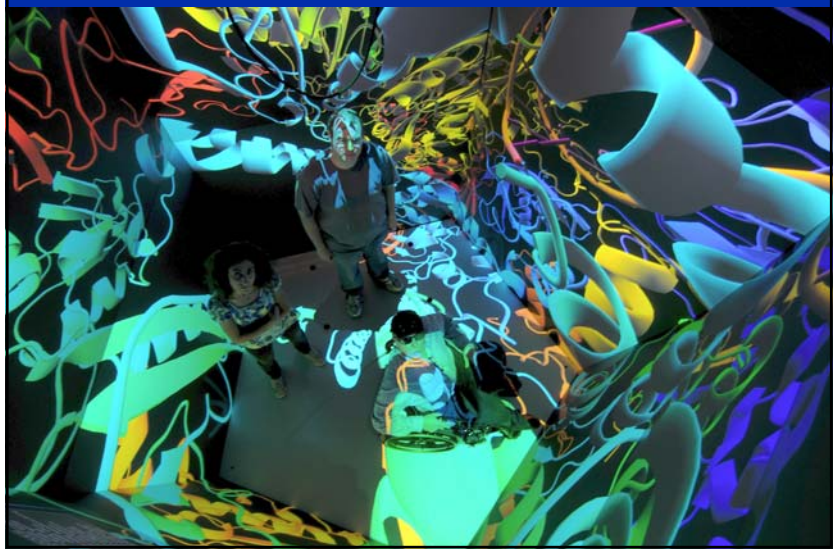
Source: Tom DeFanti, Greg Dawe, Calit2

Cluster with 34 Nvidia 5600 cards--51 GB GPU Memory
(50kW is $5/hr, $120/day, about the same as an Oz Hertz car w/petrol)

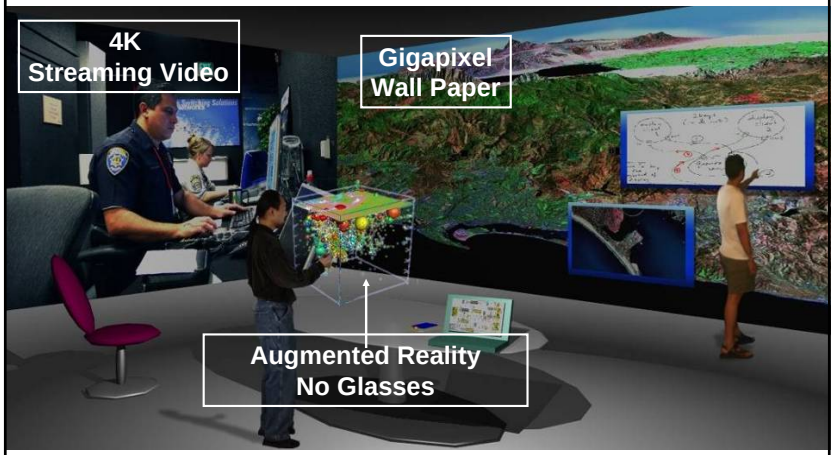
Building the StarCAVE July/August 2007



StarCAVE with Floor from Above

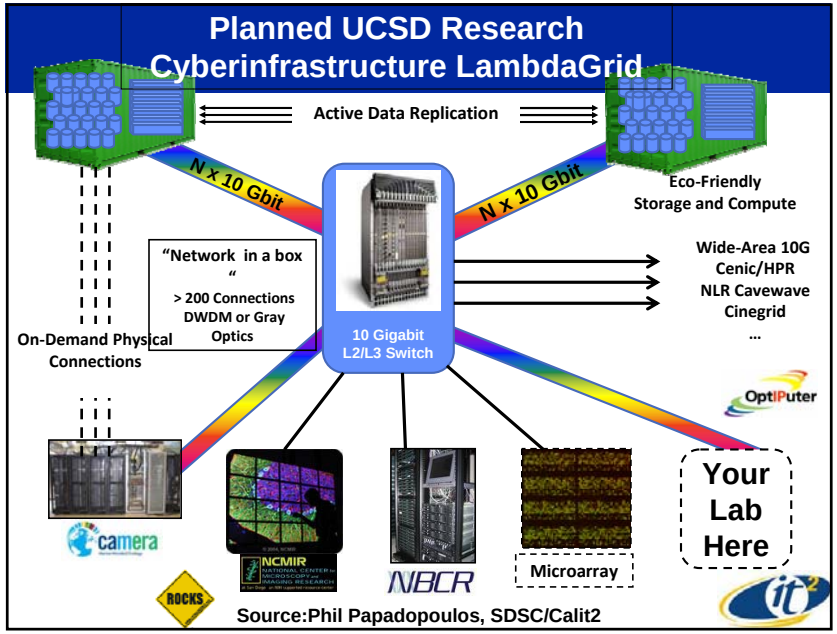


2004 OptIPuter Vision for the Next Decade
Gigapixels @ Terabits/sec



1 GigaPixel x 3 bytes/pixel @ 30fps = 1 Terabit/sec
~120kW display + 20kW per router hop

Source: Jason Leigh, EVL

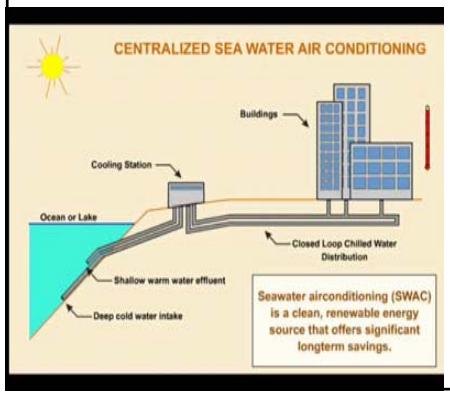


Going Green at UCSD

- UCSD now deploying first component of green cyber-infrastructure to consolidate vitrualized computer clusters and servers in energy-efficient mobile facilities.
- Expanding cogeneration capacity by 50% (15 MW) will yield $2.4M annually in savings and reduce emissions.
- UCSD plans to become the leading university site in the world for photovoltaic energy (2 MW of solar cells).

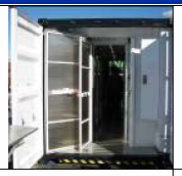
UCSD is Studying a Global Demonstration Project for Sea Water Cooling

- **UCSD is uniquely located to use cold seawater from one of only 40 deep shoreline sites in the world. It can supply cold water essential for air conditioning laboratories and computer rooms**
- **Initial study of La Jolla underwater trench suggests a seawater cooling system could produce savings of $4M/yr and 100 million gallons of fresh water per year.**



Optically Connected "Green" Modular Datacenters UCSD Installing Two Sun Microsystems Boxes

Sun Black Box Container



7 Racks plus Network

Takes up 2 Parking Spaces

Data Power Cooling

UCSD Jacobs School of Engineering

UCSD Structural Engineering Dept. Conducted Tests May 2007

The GreenLight Project

- Every dollar spent on IT equipment will cost $2 more in power (and overhead!)
- No good data connecting rack scale hardware and components
- GreenLight uses 10 Gbps over dedicated optical fiber links so end users move their clusters out of their faculty "closets" and into much "greener" configurations like data containers
- We will deploy sensors at each point of energy use, for power or cooling, and allow computer scientists to explore a wide range of tactics for allowing end users to perform the same applications, but with savings in energy: more work per watt
- Our conceptual image is of a cupcake in a calorimeter, but in this case, the GreenLight Instrument is the calorimeter and the cupcake is cyberinfrastructure at campus, regional, national, and global scale.

5 levels of Green Optimization in the GreenLight Instrument:

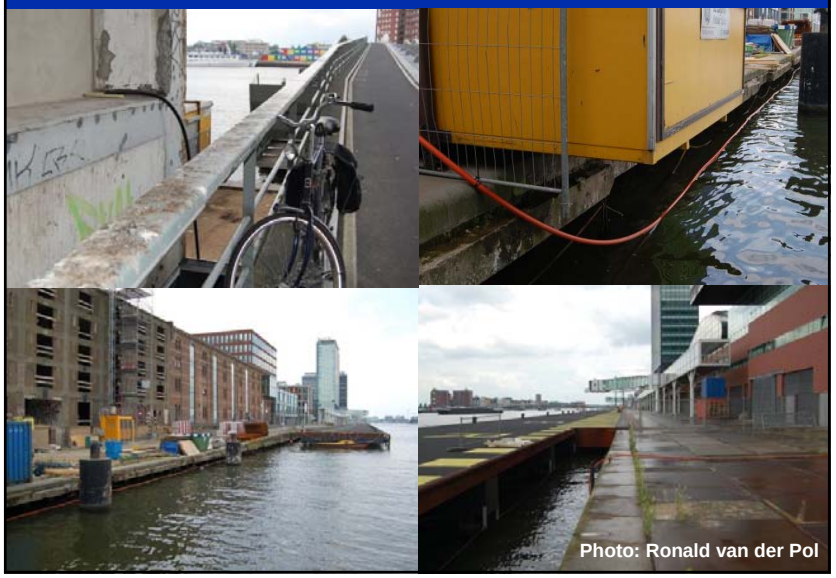
1. *The container as the controlled environment:*
   1. measure temperature at 40 points in the air stream (5 spots on 8 racks), internal humidity and temperature at the sensor module, external temperature and humidity, incoming and exiting water temperature and power utilization in each of the 8 racks;
2. *The open instrument accessible via web services infrastructure:* many sensor types will be provided and data fed to the outside world and internally back into virtualization software through SOAs
3. *Rack/clusters to provide architectural instrumentation for power/temperature:* each Black Box will have 7 rack spaces devoted to 1 type of cluster each, plus one rack for switches
4. *Hardware platform and software tools for hosting alternative architectures:*
   - clusters with multi-core processors,
   - processor/arithmetical logic unit (ALU) arrays,
   - specialized processing units such as graphics processing units (GPGPUs),
   - reconfigurable co-processing units using field-programmable gate arrays (FPGAs),
   - and hybrid processing options tbd
5. *Instrumented processing units, memory, disk drives and network interfaces.*

We will see and hear what is being measured by developing 3D VR/surround audio walk-through displays of the GreenLight Instrument

CineGrid @ Holland Festival 2007
As Seen In the Calit2@UCSD Auditorium

Era la Notte, June 20-21, 2007 (Live!)

Swimming Fiber the Last 500m to the Muziekgebouw



What Makes It All so Hard?

- Going into a new place
  - Lots of proud 1990's networking
  - Power and lighting issues
  - Permission for fiber in often historic venues
- Not enough setup time (conflict with other events)
- Not enough people (a DITF or bad cold takes out a site)
- OptIPuter version of NTSC (never twice the same config)
- Staying up all night after 12-hour flights
- Once it works (1/9), expectation zooms to 5 demos a day (99%)
- So, we need persistence…to support 5 demos a day
  - Redundant equipment
  - Permanent vlans on the networks until dynamic networks come up
  - More trained engineers
  - 24-hour NOCs

Some Additional Issues & Worries

- Contiguous lightpaths not always available
- L1/L2 transitions along path
- Terminating equipment might not support GFP/VCAT/LCAS
- Some apps want > 1 GE (therefore 10 GE)
- Interdomain communication & configuration
- Resources shared at end sites
- Multiple sites collaborating on one app
- Many apps use bandwidth only sporadically
- Policing/admission control
- Global vlan id coordination
- Debugging considerations and back channels
- Path resiliency
- Shipping and receiving(!)

Source: Alan Verlo

Toward Koala-Class Computing

Don't be Afraid to Lead in Style

Size Your Brain Power, Storage, and Sleep Cycles to Your Problem

Thank You Very Much!

- Our planning, research, and education efforts are made possible, in major part, by funding from:
  - US National Science Foundation (NSF) awards ANI-0225642, EIA-0115809, and SCI-0441094
  - State of California, Calit2 UCSD Division
  - State of Illinois I-WIRE Program, and major UIC cost sharing
- Argonne National Laboratory, UIC, and Northwestern University for StarLight networking and management
- National Lambda Rail, Pacific Wave, and CENIC
- NTT Network Innovations Lab
- Cisco Systems, Inc.
- Pacific Interface, Inc.