High Performance Cyberinfrastructure Required for Data Intensive Scientific Research

Invited Presentation

National Science Foundation Advisory Committee on Cyberinfrastructure

Arlington, VA

June 8, 2011

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

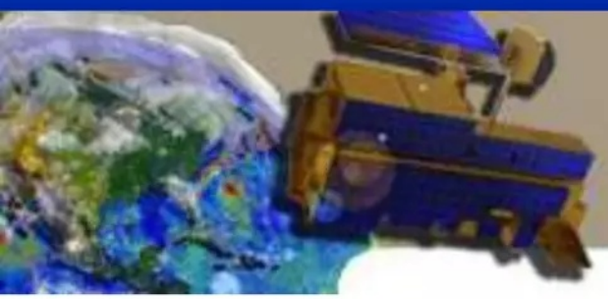
Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

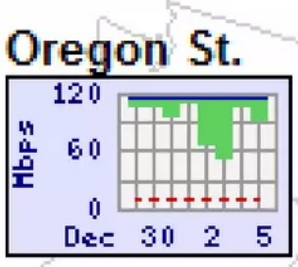
Follow me on Twitter: lsmarr

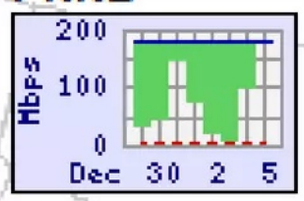
Large Data Challenge: Average Throughput to End User on Shared Internet is 10-100 Mbps

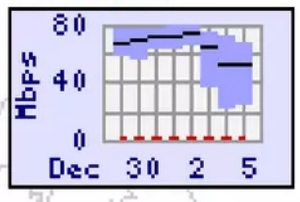


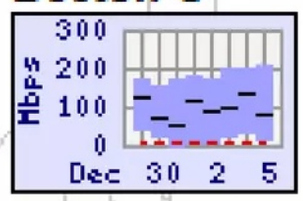
ENSIGHT Active Testing TERRA Destinations

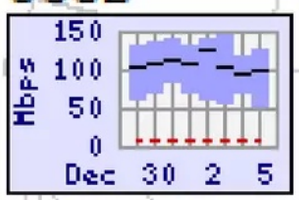
Tested January 2011

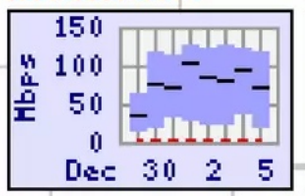


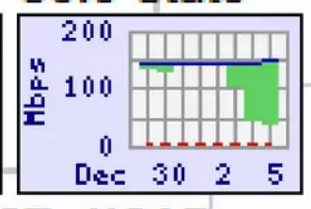


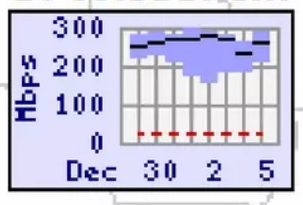


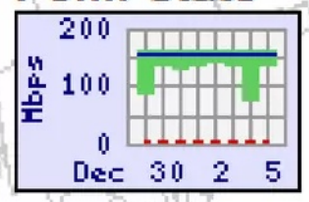


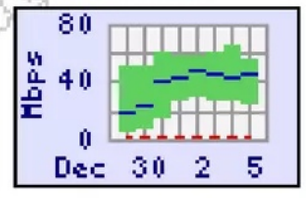


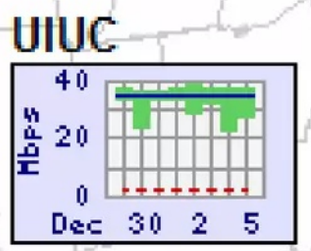


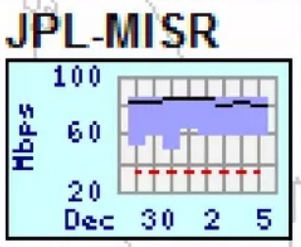


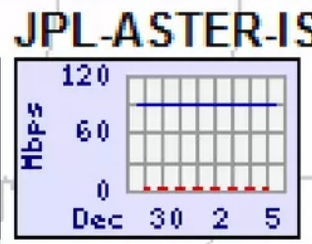


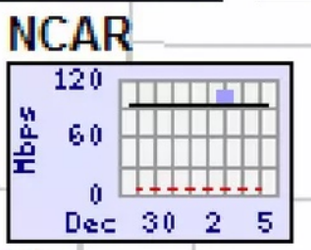


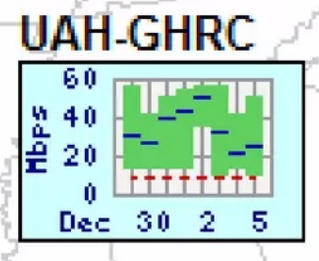


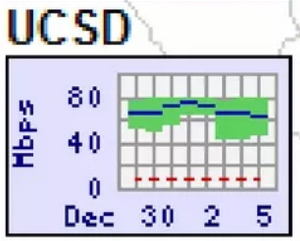


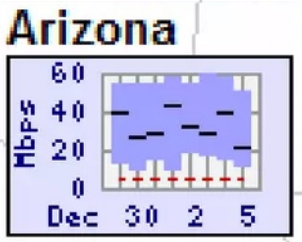


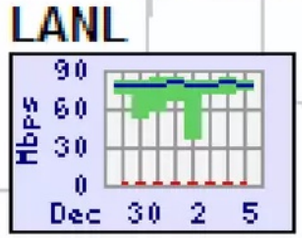








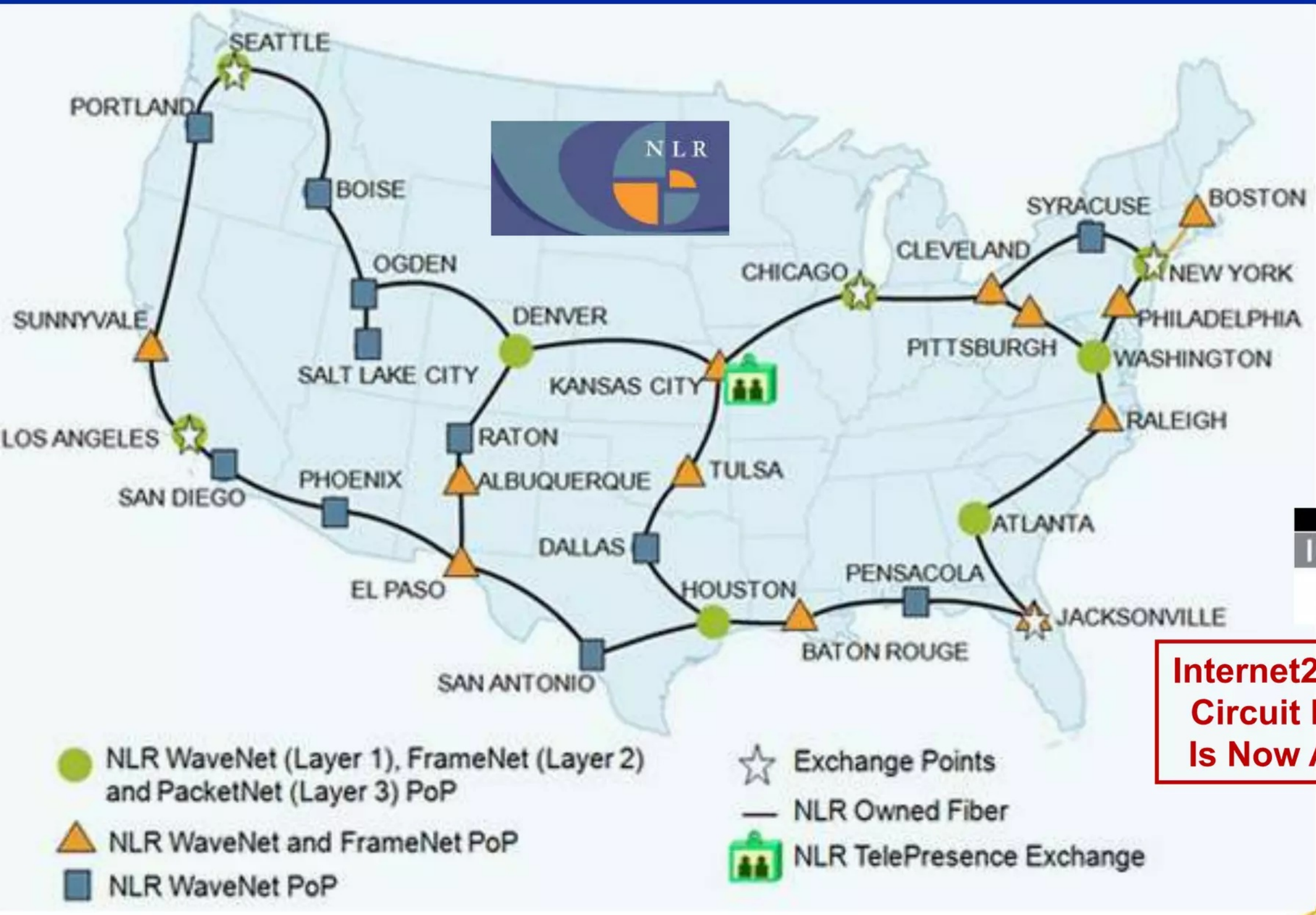




Transferring 1 TB:
--50 Mbps = 2 Days
--10 Gbps = 15 Minutes

http://ensight.eos.nasa.gov/Missions/terra/index.shtml

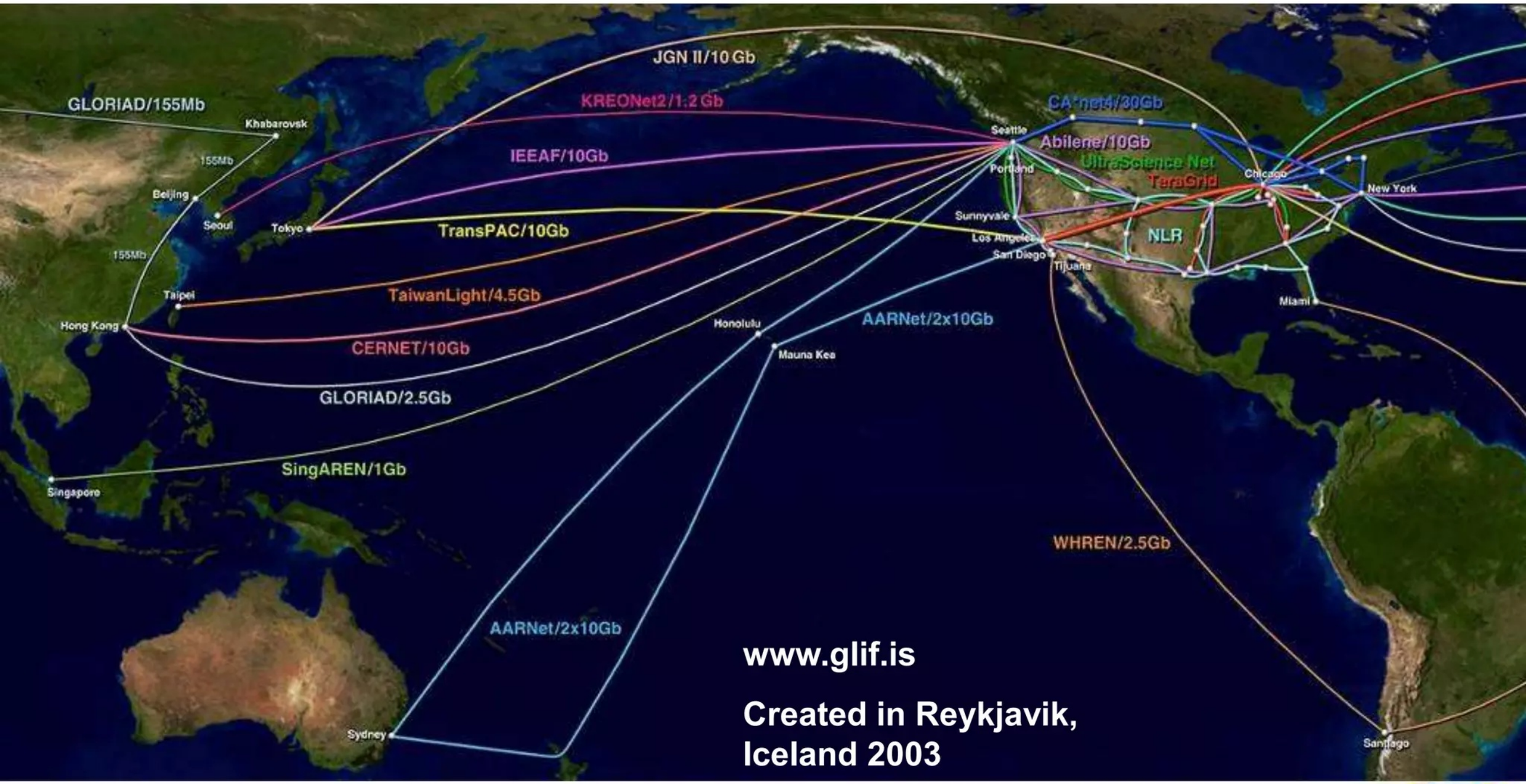
WAN Solution-Dedicated 10Gbps Lightpaths: Ties Together State & Regional Optical Networks



Internet2 WaveCo Circuit Network Is Now Available

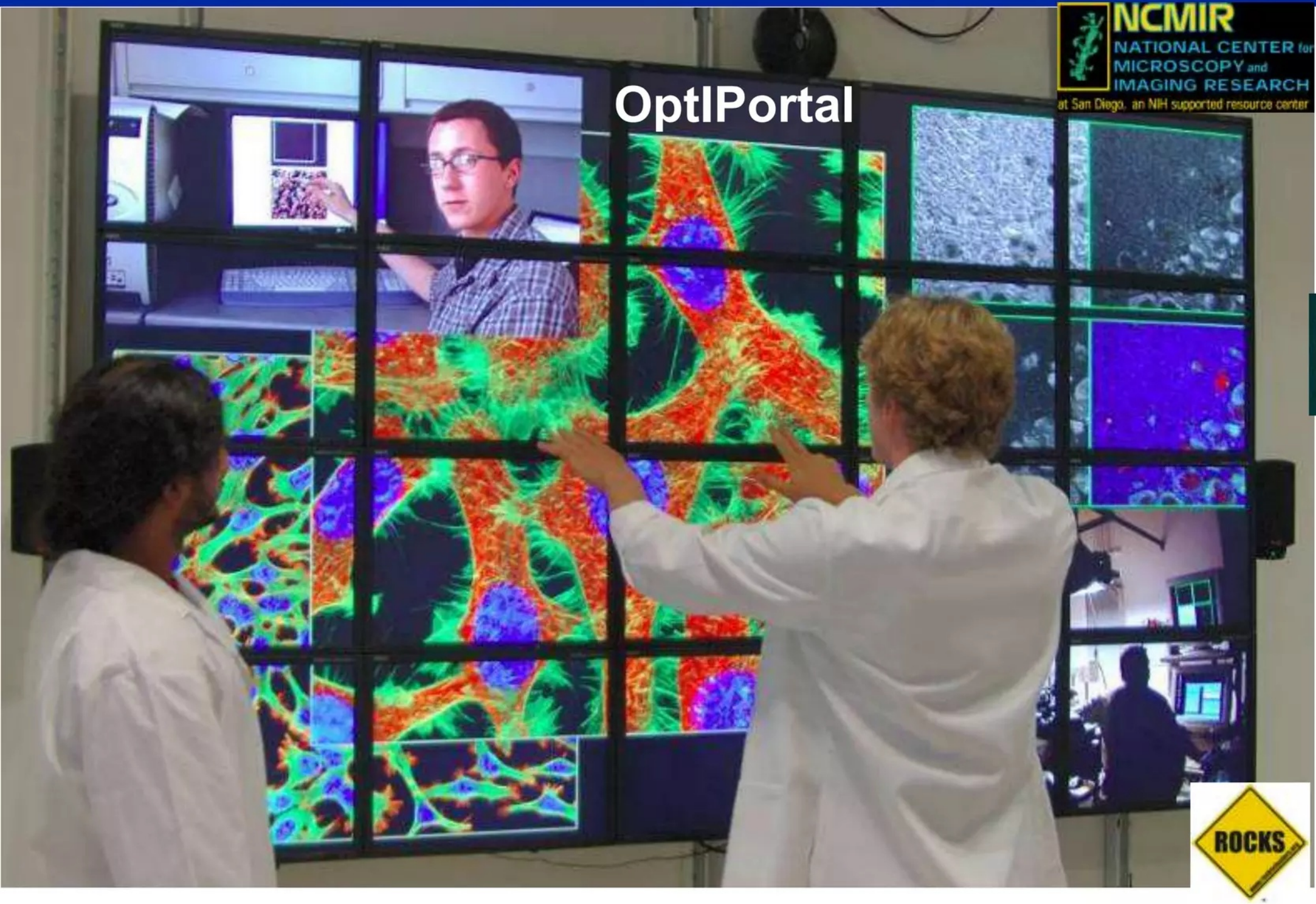
The Global Lambda Integrated Facility--
Creating a Planetary-Scale High Bandwidth Collaboratory

Research Innovation Labs Linked by 10G Dedicated Lambdas



Visualization courtesy of
Bob Patterson, NCSA.

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



NCMIR
NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH
at San Diego, an NIH supported resource center

Scalable Adaptive Graphics Environment (SAGE)

SAGE

evl electronic visualization laboratory

NSF

ROCKS

Picture Source: Mark Ellisman, David Lee, Jason Leigh

OptIPuter

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

it²

OptIPuter Software Architecture--a Service-Oriented Architecture Integrating Lambdas Into the Grid

Distributed Applications/ Web Services

Telescience

Data Services

LambdaRAM

Visualization

SAGE

JuxtaView

Vol-a-Tile

Distributed Virtual Computer (DVC) API

DVC Configuration

DVC Runtime Library

DVC Services

DVC Job Scheduling

DVC Communication

DVC Core Services

Resource Identify/Acquire

Namespace Management

Security Management

High Speed Communication

Storage Services

Globus

PIN/PDC

GRAM

GSI

XIO

RobuStore

Discovery and Control

Lambdas

IP

GTP

XCP

UDT

CEP

LambdaStream

RBUDP

OptIPuter

OptIPortals Scale to 1/3 Billion Pixels Enabling Viewing of Very Large Images or Many Simultaneous Images



Spitzer Space Telescope (Infrared)



NASA Earth Satellite Images Bushfires October 2007 San Diego

Source: Falko Kuester, Calit2@UCSD

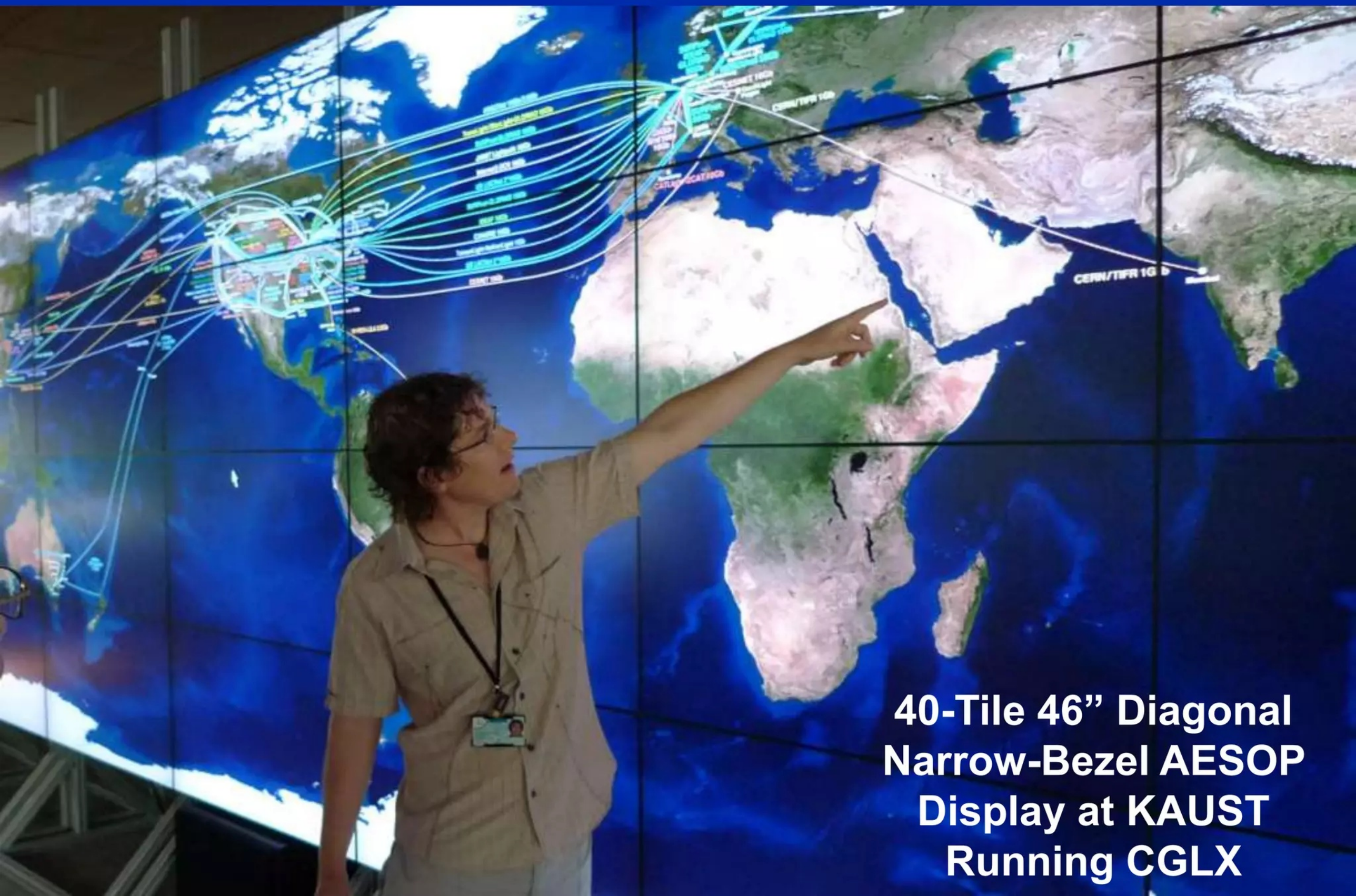
MIT's Ed DeLong and Darwin Project Team Using OptIPortal to Analyze 10km Ocean Microbial Simulation



GORDON AND BETTY MOORE FOUNDATION

Cross-Disciplinary Research at MIT, Connecting Systems Biology, Microbial Ecology, Global Biogeochemical Cycles and Climate

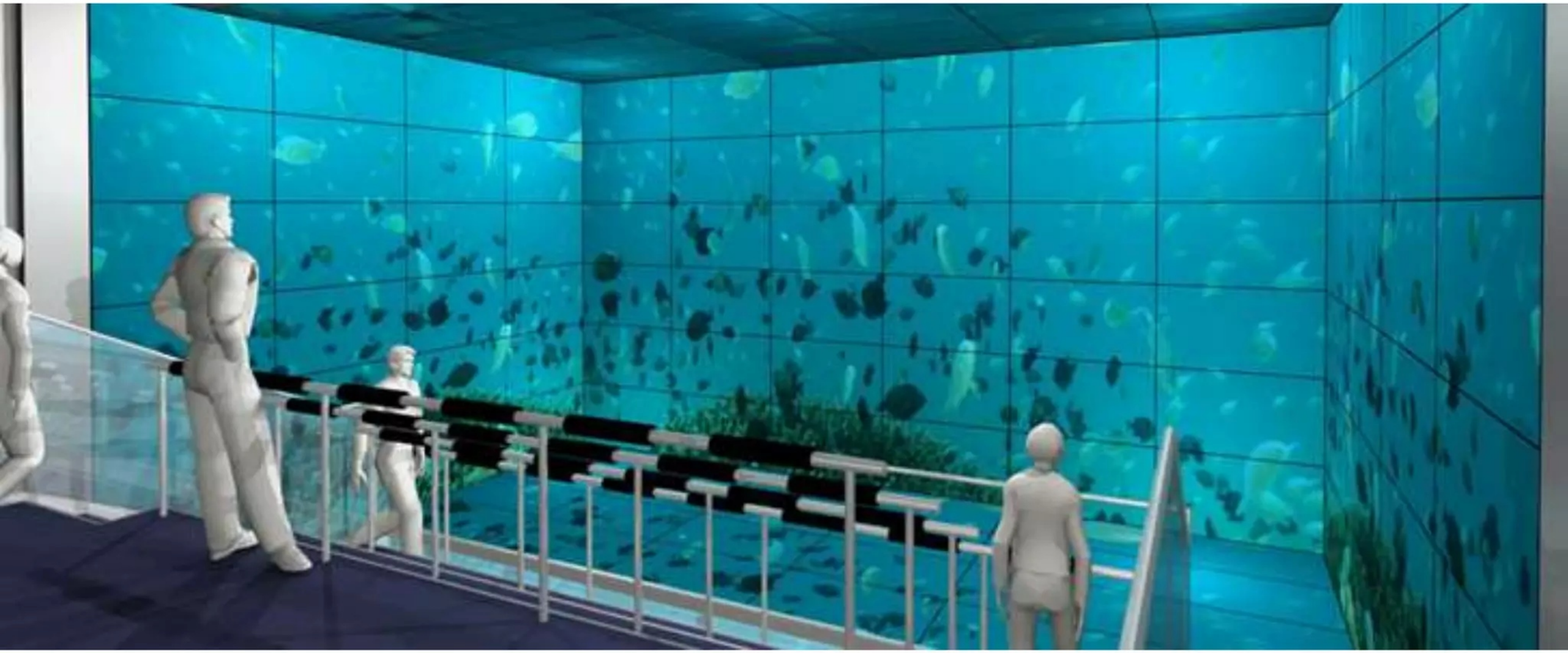
AESOP Display built by Calit2 for KAUST--
King Abdullah University of Science & Technology



40-Tile 46” Diagonal Narrow-Bezel AESOP Display at KAUST Running CGLX

Sharp Corp. Has Built an Immersive Room With Nearly Seamless LCDs

156 60”LCDs for the 5D Miracle Tour at the Hui Ten Bosch Theme Park in Nagasaki Opened April 29, 2011



http://sharp-world.com/corporate/news/110426.html

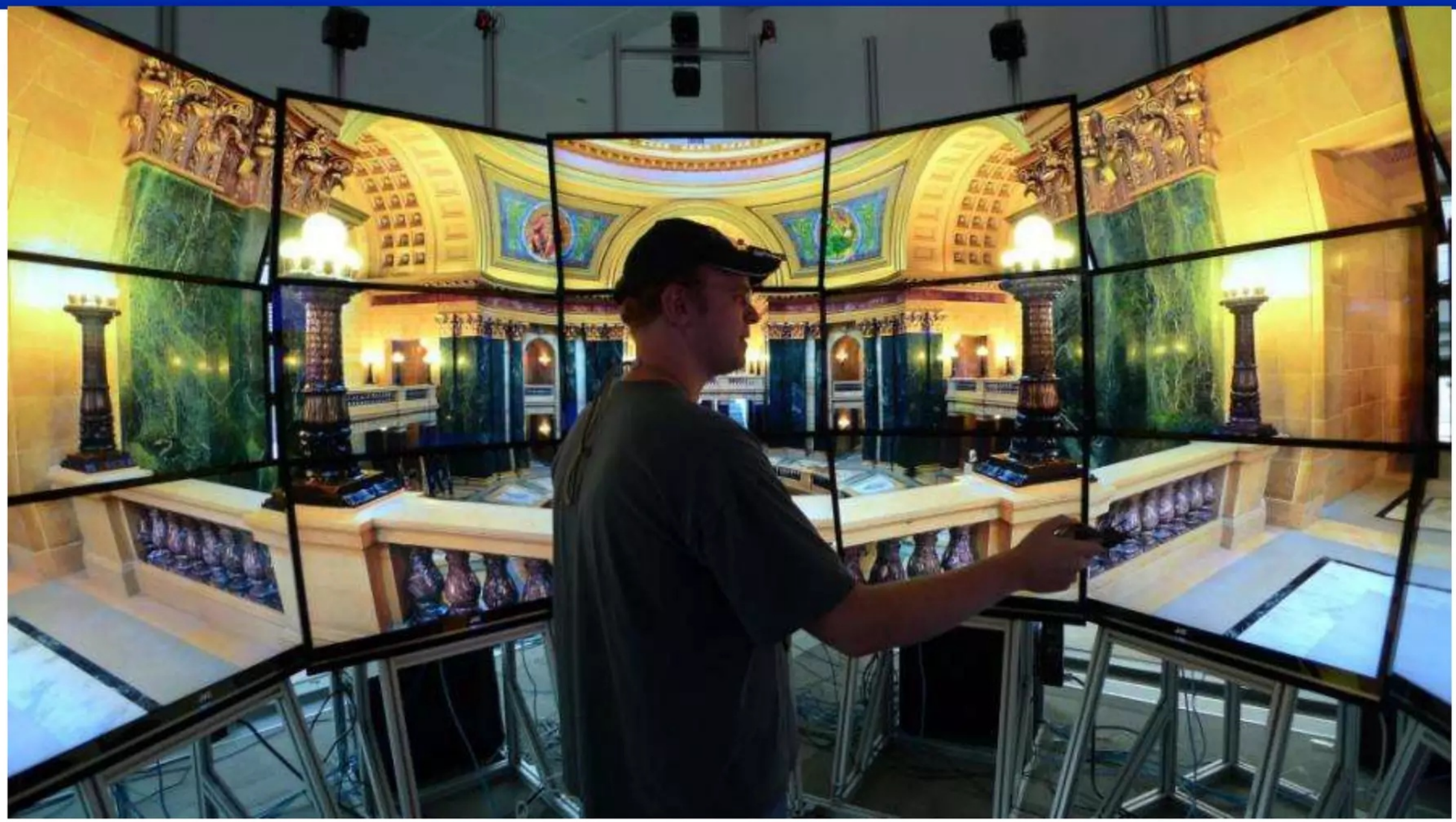
The Latest OptIPuter Innovation: Quickly Deployable Nearly Seamless OptIPortables

45 minute setup, 15 minute tear-down with two people (possible with one)



Image From the Calit2 KAUST Lab

3D Stereo Head Tracked OptIPortal: NexCAVE

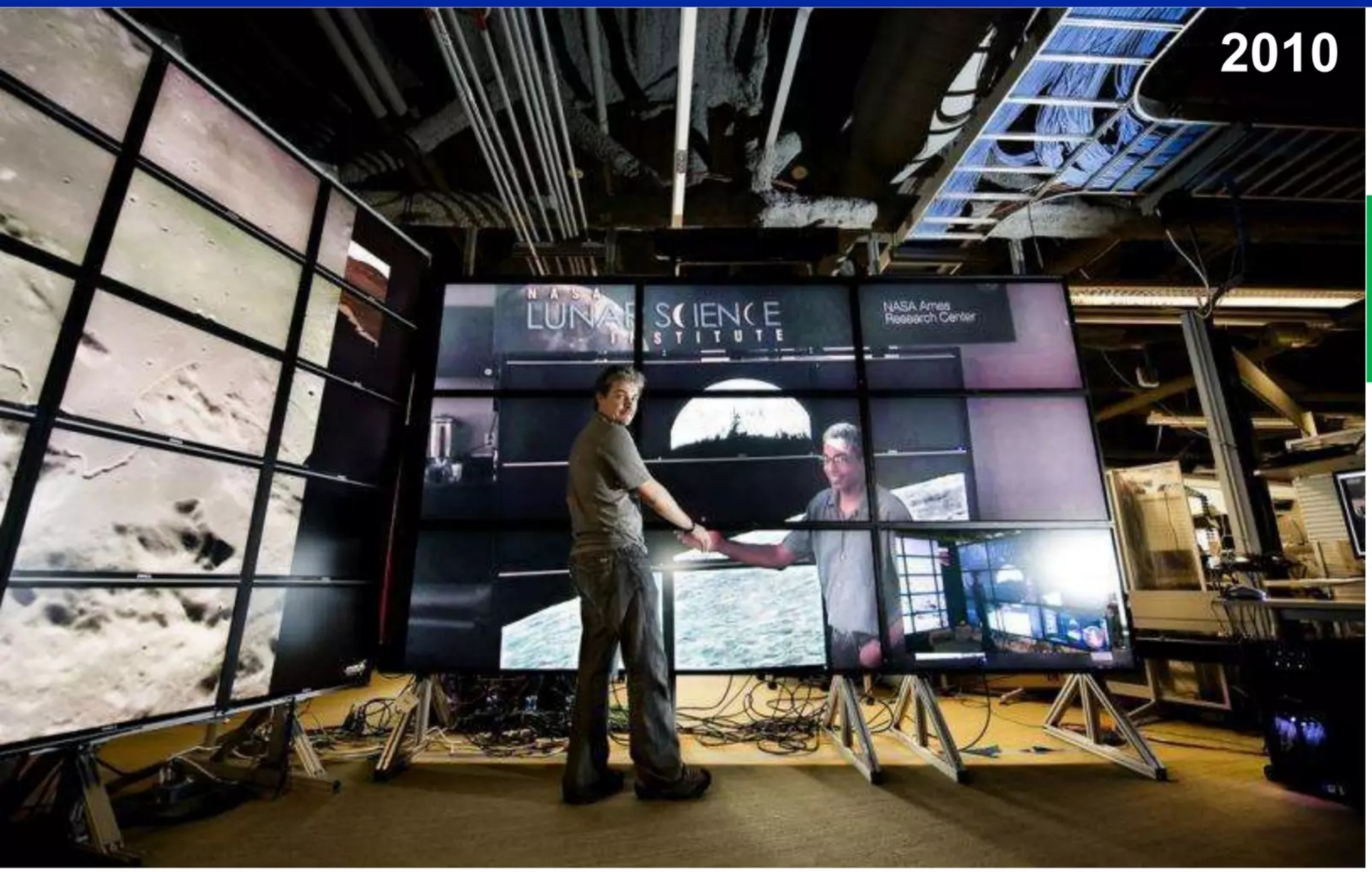


Array of JVC HDTV 3D LCD Screens
KAUST NexCAVE = 22.5MPixels

www.calit2.net/newsroom/article.php?id=1584

Source: Tom DeFanti, Calit2@UCSD

High Definition Video Connected OptIPortals: Virtual Working Spaces for Data Intensive Research



NASA Supports Two Virtual Institutes

LifeSize HD

Calit2@UCSD 10Gbps Link to NASA Ames Lunar Science Institute, Mountain View, CA

Source: Falko Kuester, Kai Doerr Calit2; Michael Sims, Larry Edwards, Estelle Dodson NASA

OptIPuter Persistent Infrastructure Enables Calit2 and U Washington CAMERA Collaboratory



OptIPuter

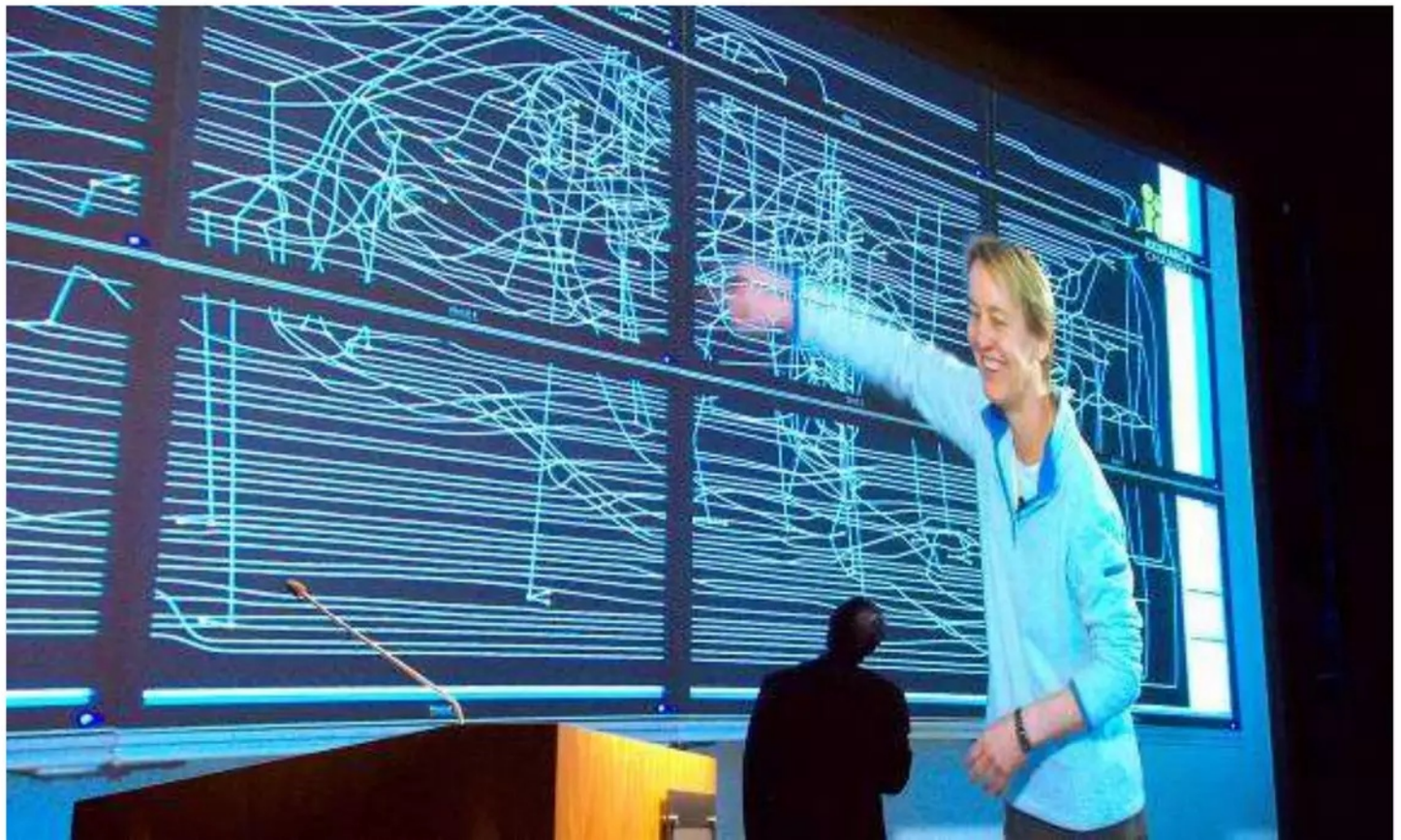
Ginger Armbrust's Diatoms: Micrographs, Chromosomes, Genetic Assembly





Gordon and Betty MOORE FOUNDATION

camera
Marine Microbial Ecology



NSF

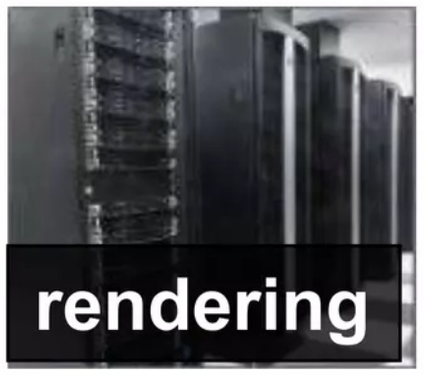
it²

Using Supernetworks to Couple End User's OptIPortal to Remote Supercomputers and Visualization Servers

Source: Mike Norman, Rick Wagner, SDSC

Argonne NL

DOE Eureka
100 Dual Quad Core Xeon Servers
200 NVIDIA Quadro FX GPUs in 50 Quadro Plex S4 1U enclosures
3.2 TB RAM



Real-Time Interactive Volume Rendering Streamed from ANL to SDSC

ESnet
10 Gb/s fiber optic network

SDSC



Calit2/SDSC OptIPortal1
20 30" (2560 x 1600 pixel) LCD panels
10 NVIDIA Quadro FX 4600 graphics cards > 80 megapixels
10 Gb/s network throughout

NICS ORNL

NSF TeraGrid Kraken Cray XT5
8,256 Compute Nodes
99,072 Compute Cores
129 TB RAM



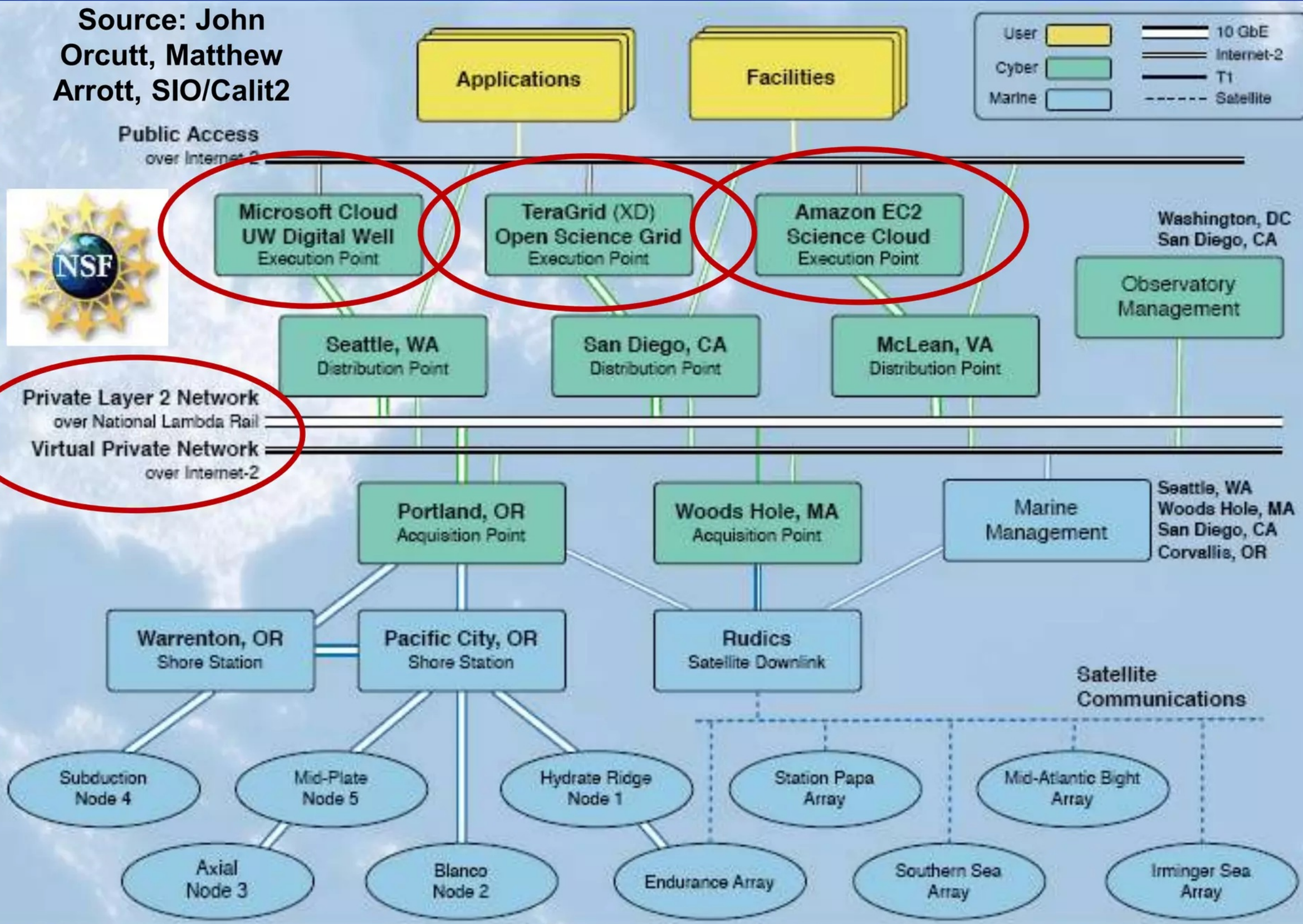
SDSC

***ANL * Calit2 * LBNL * NICS * ORNL * SDSC**

OOI CI
is Built on NLR/I2 Optical Infrastructure

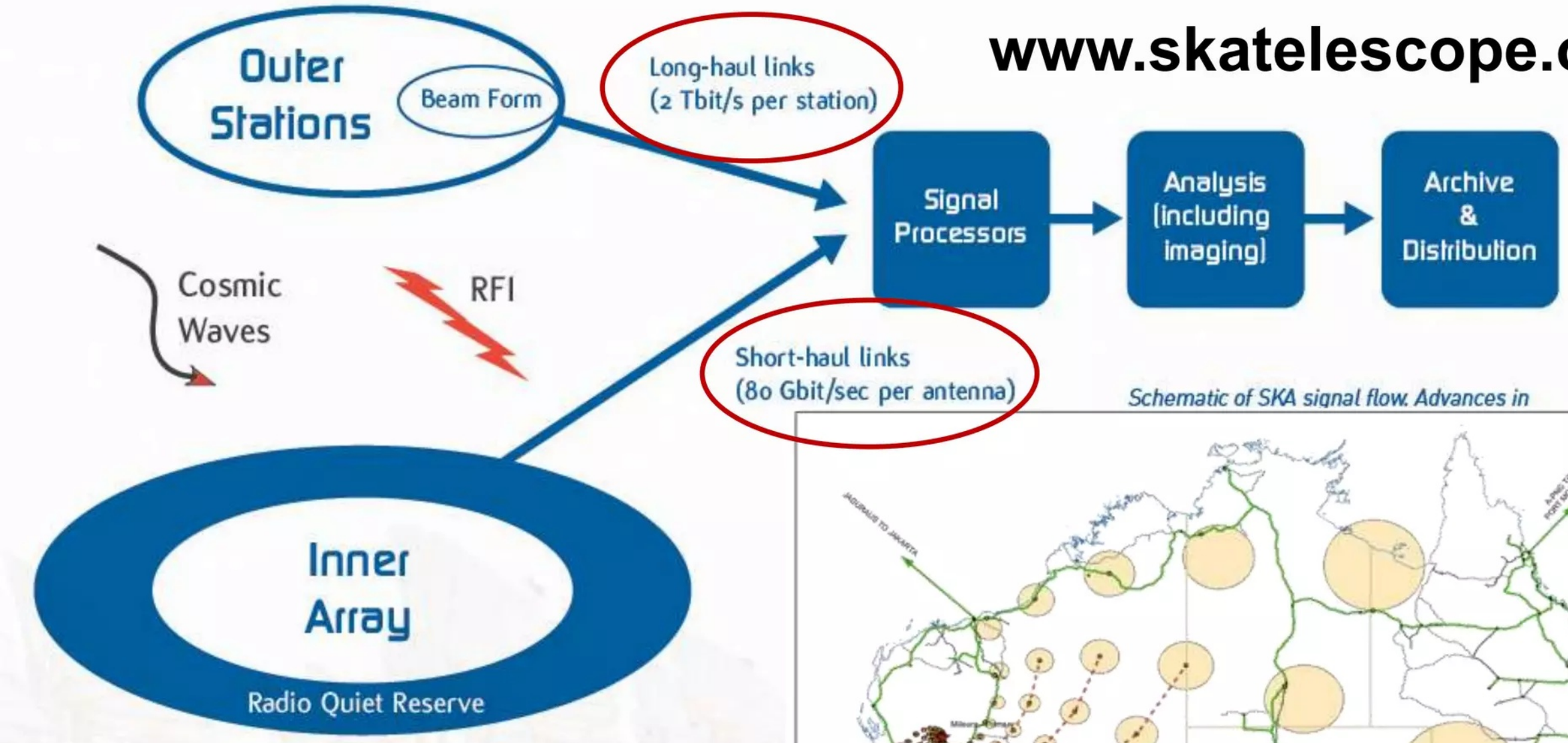
OCEAN OBSERVATORIES INITIATIVE

Source: John Orcutt, Matthew Arrott, SIO/Calit2



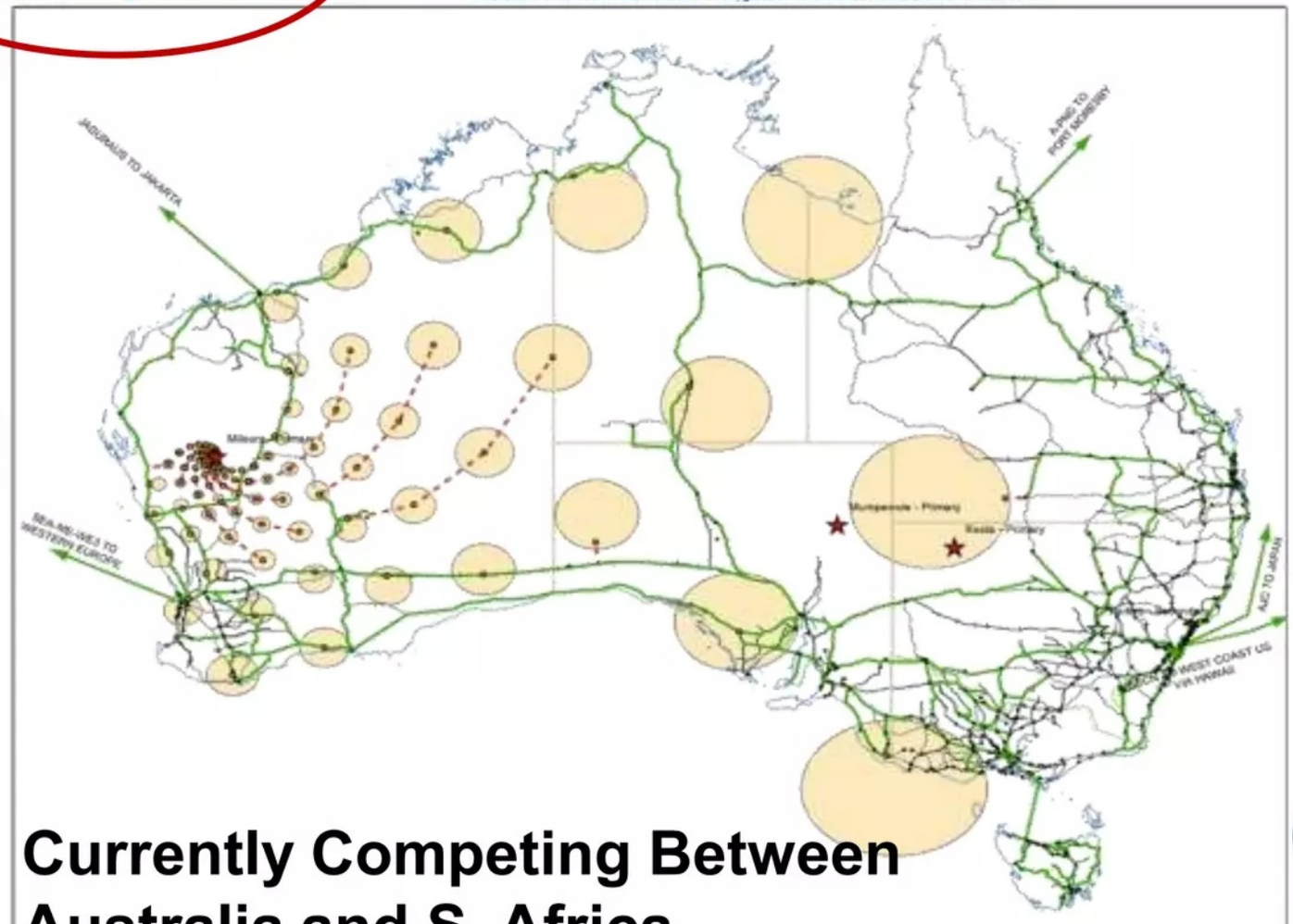
Next Great Planetary Instrument:
The Square Kilometer Array Requires Dedicated Fiber

www.skatelescope.org



Transfers Of 1 TByte Images World-wide Will Be Needed Every Minute!

Schematic of SKA signal flow. Advances in



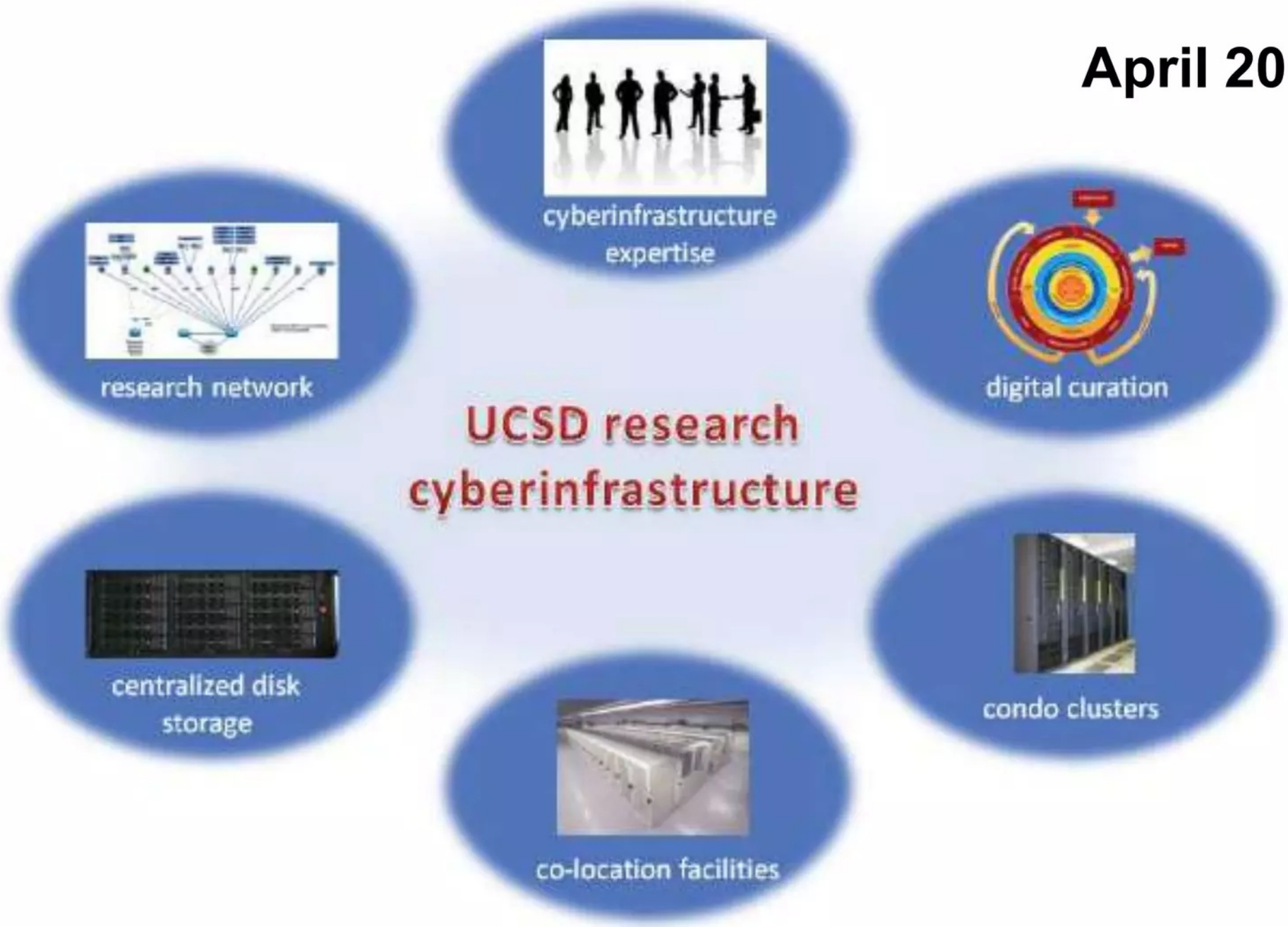
Currently Competing Between Australia and S. Africa

Campus Bridging: UCSD is Creating a Campus-Scale High Performance CI for Data-Intensive Research

- **Focus on Data-Intensive Cyberinfrastructure**

April 2009

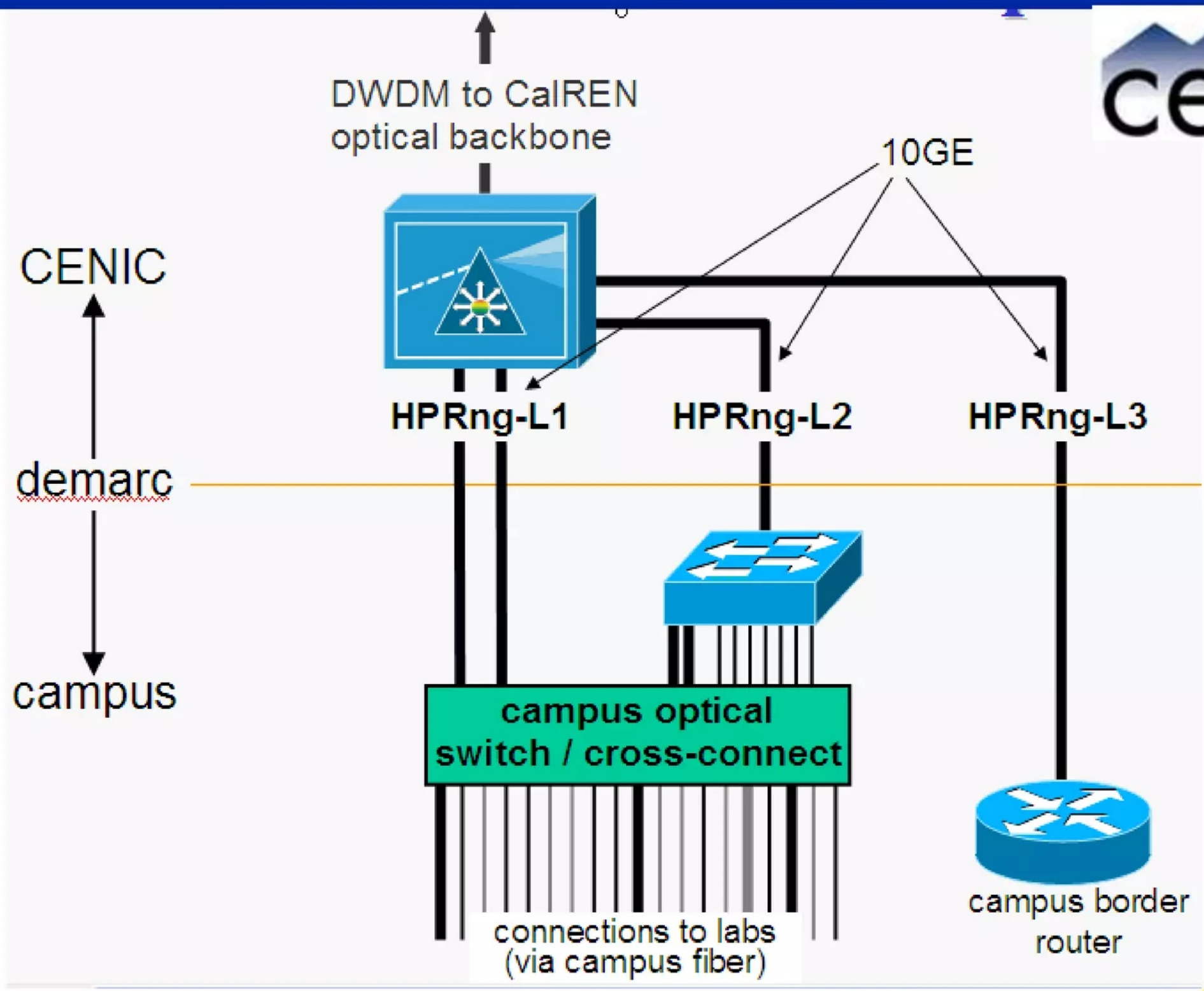
No Data Bottlenecks --Design for Gigabit/s Data Flows



Report of the UCSD Research Cyberinfrastructure Design Team

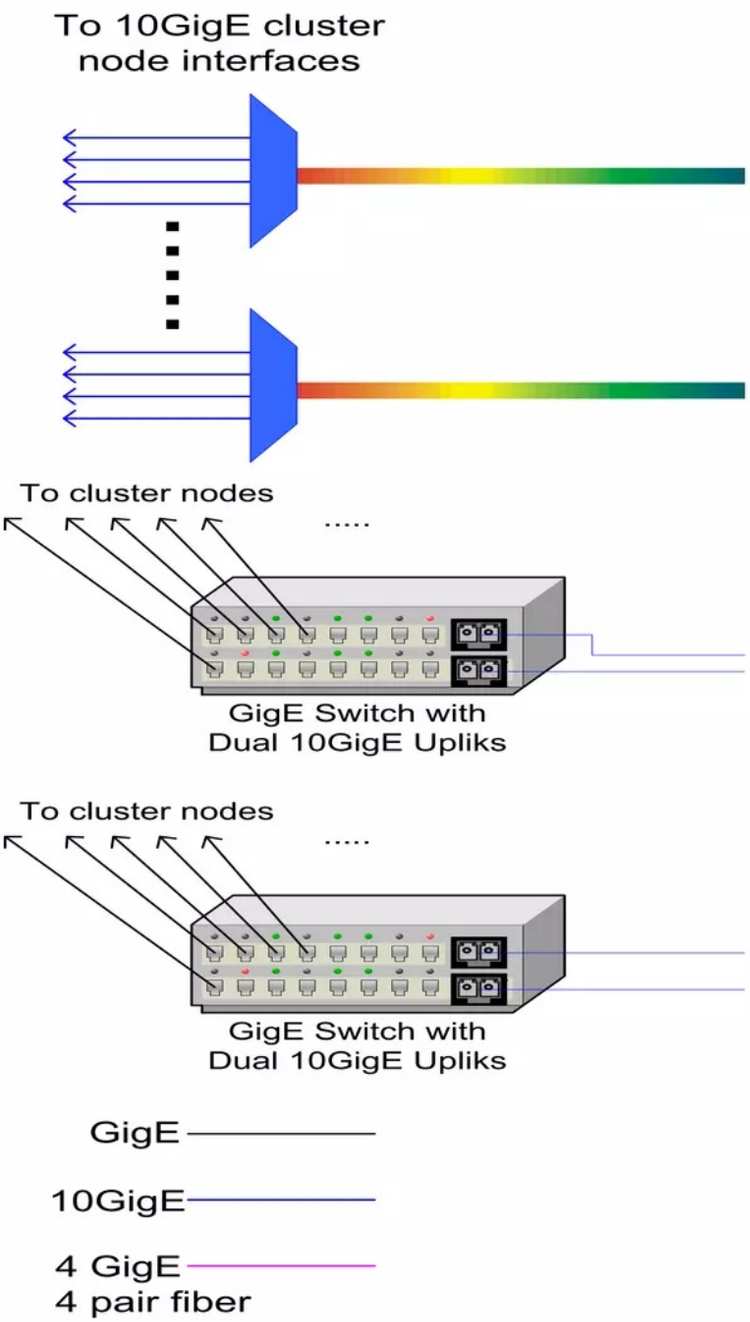
research.ucsd.edu/documents/rcidt/RCIDTReportFinal2009.pdf

Campus Preparations Needed to Accept CENIC CalREN Handoff to Campus



Source: Jim Dolgonas, CENIC

Current UCSD Prototype Optical Core: Bridging End-Users to CENIC L1, L2, L3 Services



Enpoints:

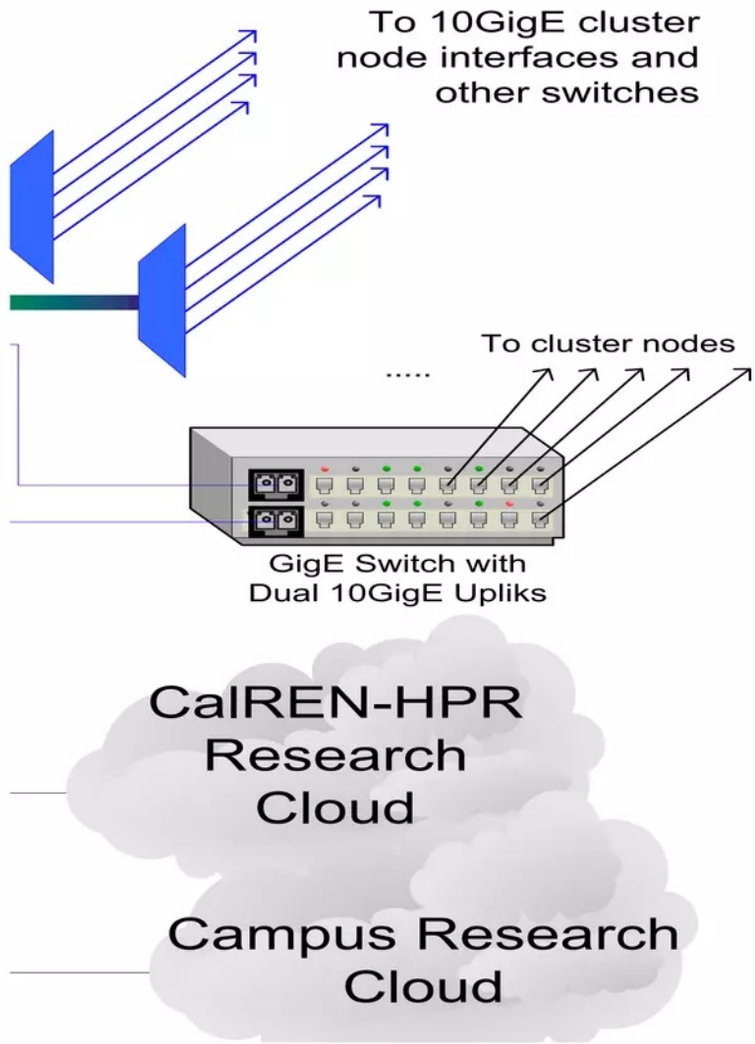
>= 60 endpoints at 10 GigE

>= 32 Packet switched

>= 32 Switched wavelengths

>= 300 Connected endpoints

Approximately 0.5 TBit/s Arrive at the "Optical" Center of Campus. Switching is a Hybrid of: Packet, Lambda, Circuit -- OOO and Packet Switches



Source: Phil Papadopoulos, SDSC/Calit2 (Quartzite PI, OptIPuter co-PI) Quartzite Network MRI #CNS-0421555; OptIPuter #ANI-0225642

SDSC

Calit2 Sunlight Optical Exchange Contains Quartzite



Maxine Brown, EVL, UIC OptIPuter Project Manager

SDSC

it²

The GreenLight Project: Instrumenting the Energy Cost of Data-Intensive Science

- **Focus on 5 Data-Intensive Communities:**
  - **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**
  - **Connected with 10Gbps Lambdas to End Users and SDSC**
- **Developing Middleware that Automates Optimal Choice of Compute/RAM Power Strategies for Desired Greenness**
- **Data Center for UCSD School of Medicine Illumina Next Gen Sequencer Storage & Processing**





SDSC

Source: Tom DeFanti, Calit2; GreenLight PI

NSF

it²

UCSD Campus Investment in Fiber Enables Consolidation of Energy Efficient Computing & Storage

N x 10Gb/s

WAN 10Gb:
CENIC, NLR, I2

Gordon – HPD System

Cluster Condo

Triton – Petascale Data Analysis

Scientific Instruments

GreenLight Data Center

Digital Data Collections

Campus Lab Cluster

DataOasis (Central) Storage

Extensible Disk Farm

Lustre | GridFTP | NFS | WebDAV | ...

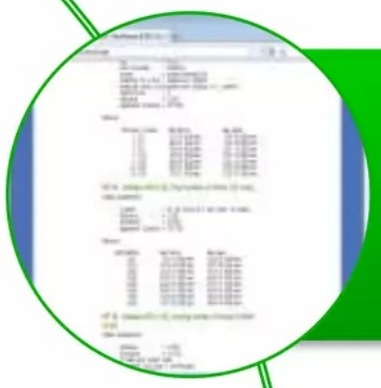
Remote Access Interfaces

OptIPortal Tiled Display Wall

SDSC

Source: Philip Papadopoulos, SDSC, UCSD

SDSC Data Oasis – 3 Different Types of Storage



HPC Storage (Lustre-Based PFS)

- Purpose: Transient Storage to Support HPC, HPD, and Visualization
- Access Mechanisms: Lustre Parallel File System Client



Project (Traditional File Server) Storage

- Purpose: Typical Project / User Storage Needs
- Access Mechanisms: NFS/CIFS “Network Drives”



Cloud Storage

- Purpose: Long-Term Storage of Data that will be Infrequently Accessed
- Access Mechanisms: S3 interfaces, DropBox-esq web interface, CommVault

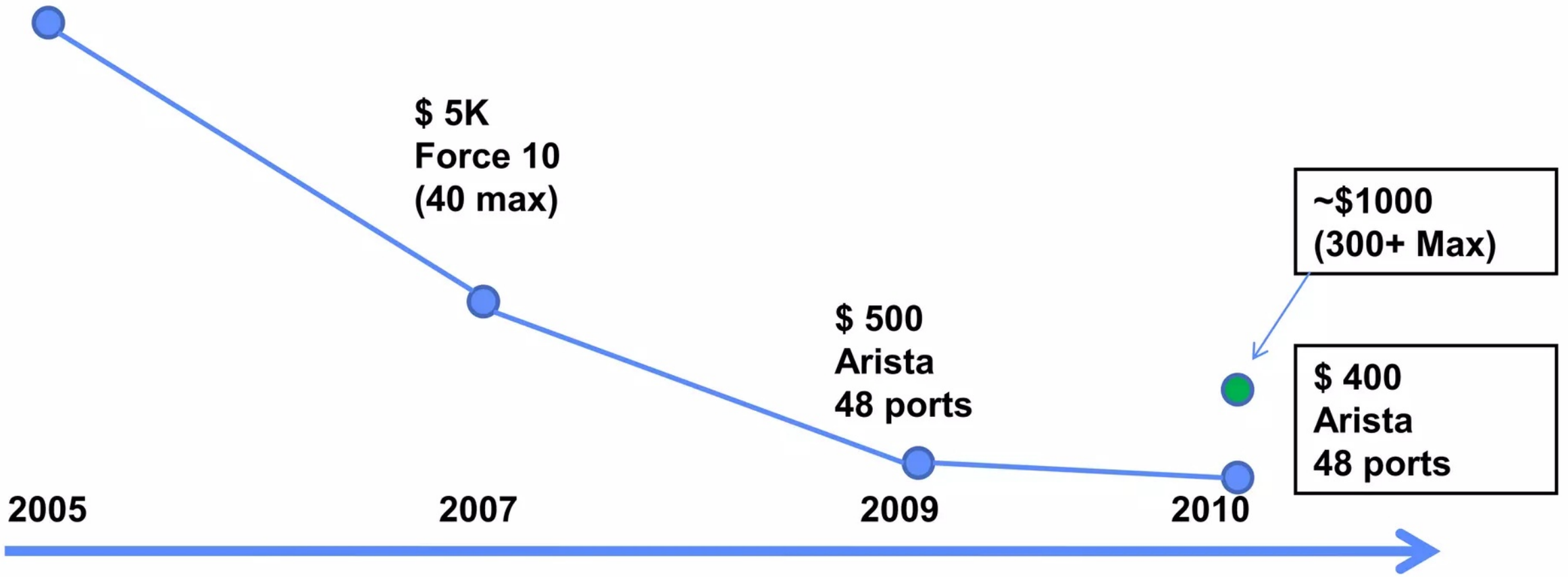
Coupled with 10G Lambda to Amazon Over CENIC

SDSC

it²

Rapid Evolution of 10GbE Port Prices Makes Campus-Scale 10Gbps CI Affordable

- **Port Pricing is Falling**
- **Density is Rising – Dramatically**
- **Cost of 10GbE Approaching Cluster HPC Interconnects**



SDSC

Source: Philip Papadopoulos, SDSC/Calit2

it²

Arista Enables SDSC's Massive Parallel 10G Switched Data Analysis Resource

10Gbps

OptIPuter

Co-Lo

UCSD RCI

CENIC/ NLR

5

8

2

4

32

12

8

128

Triton

Trestles 100 TF

Dash

Gordon

8

40→128

Radical Change Enabled by Arista 7508 10G Switch 384 10G Capable

Existing Commodity Storage 1/3 PB

Oasis Procurement (RFP)

2000 TB
> 50 GB/s

- Phase0: > 8GB/s Sustained Today
- Phase I: > 50 GB/sec for Lustre (May 2011)
- :Phase II: >100 GB/s (Feb 2012)

SDSC

Source: Philip Papadopoulos, SDSC/Calit2

it²

OptIPlanet Collaboratory:
Enabled by 10Gbps "End-to-End" Lightpaths



End User
OptIPortal





Local or Remote
Instruments



HD/4k Live Video



10G
Lightpaths



HPC

TeraGrid

amazon
web services

Campus
Optical Switch



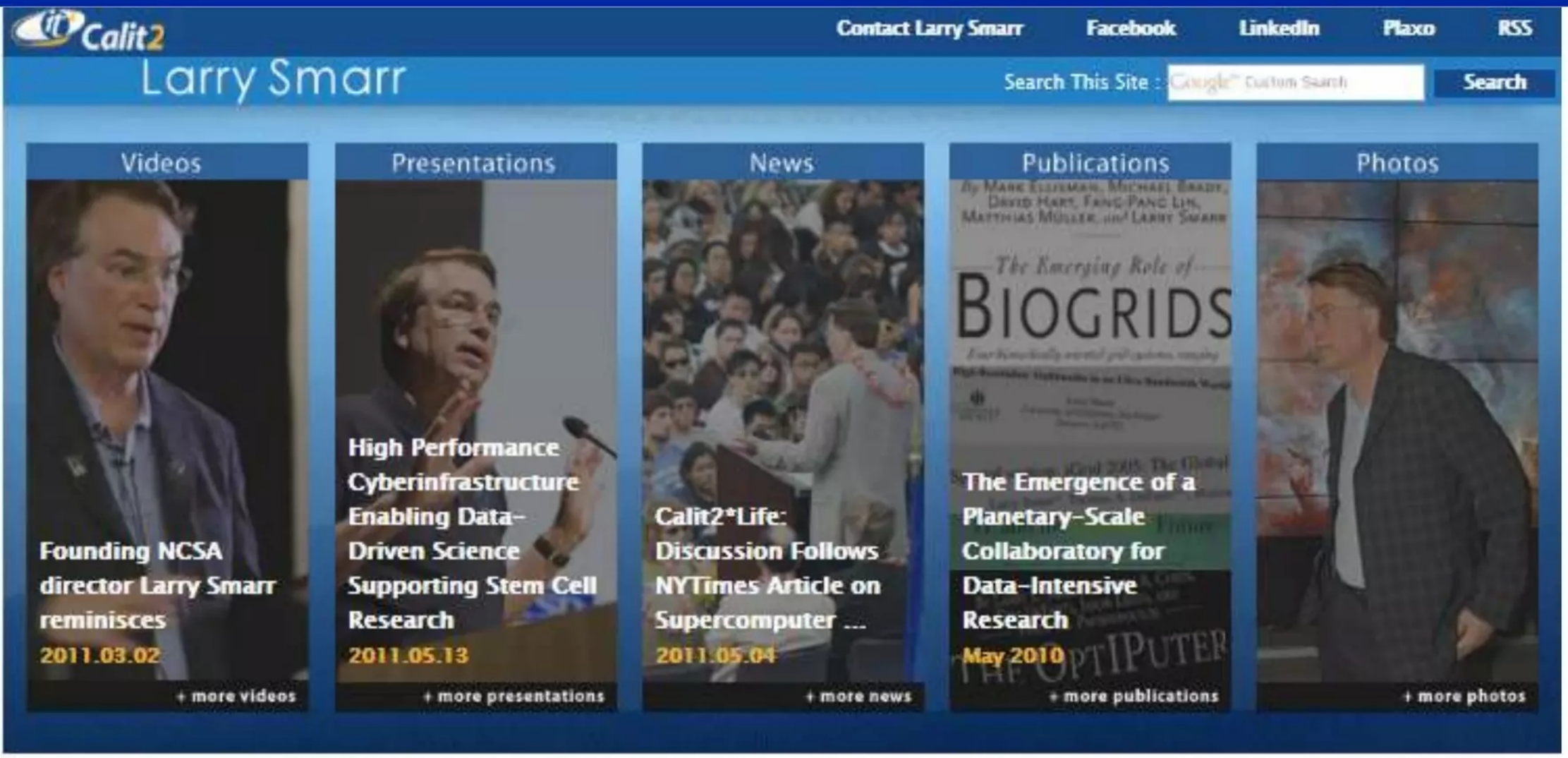
Data Repositories & Clusters



HD/4k Video Repositories

it²

You Can Download This Presentation at lsmarr.calit2.net



ABOUT LARRY SMARR

Larry Smarr is the founding Director of the California Institute for Telecommunications and Information Technology (Calit2), a UC San Diego/UC Irvine partnership, and holds the Harry E. Gruber professorship in Computer Science and Engineering (CSE) at UCSD's Jacobs School. At Calit2, Smarr has continued to drive major developments in information infrastructure-- including the Internet,

WHAT I'M READING

Complete List of Larry's Recommendations

Homo Britannicus: The Incredible Story of Human Life in Britain (2006)

American College and University Presidents' Climate Commitment

A Doctor's Vision of the Future of Medicine

RECENT TWITTER POSTS

Twitter? Click To Follow Me

lsmarr: Light going up-what an energy waste! RT @ISS_Research: Night view of US East Coast from ISS Crew Earth Observations http://1.usa.gov/INWw5d *Tue, 24 May*