“The Emerging Cyberinfrastructure for Earth and Ocean Sciences"

Invited Talk to the
SIO Council
La Jolla, CA
March 5, 2005

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

Chair, NASA Earth System Science and Applications Advisory Committee

OptIPuter

it²

Calit2 -- Research and Living Laboratories on the Future of the Internet

University of California San Diego & Irvine Campuses
Faculty & Staff
Working in Multidisciplinary Teams
With Students, Industry, and the Community



One Focus Area is
Net-Centric Optical Architectures

OptIPuter

www.calit2.net

Two New Calit2 Buildings Will Provide Persistent Collaboration Environment



- Will Create New Laboratory Facilities
- International Conferences and Testbeds
- Over 1000 Researchers in Two Buildings
- Environmental Sciences a Major Application



OptIPuter

Calit2@UCSD Building Is Connected To Outside With 140 Optical Fibers

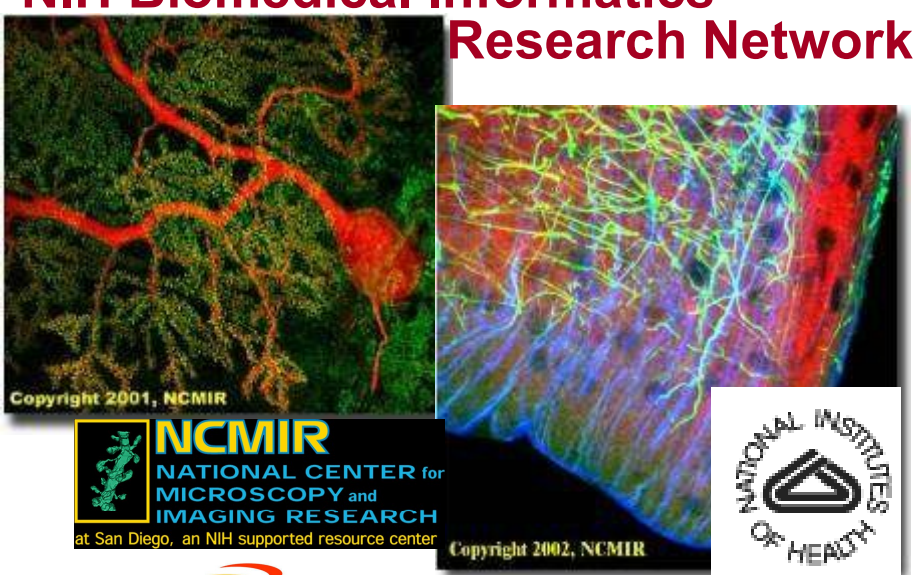
it2

The OptIPuter Project –

Creating a LambdaGrid "Web" for Gigabyte Data Objects

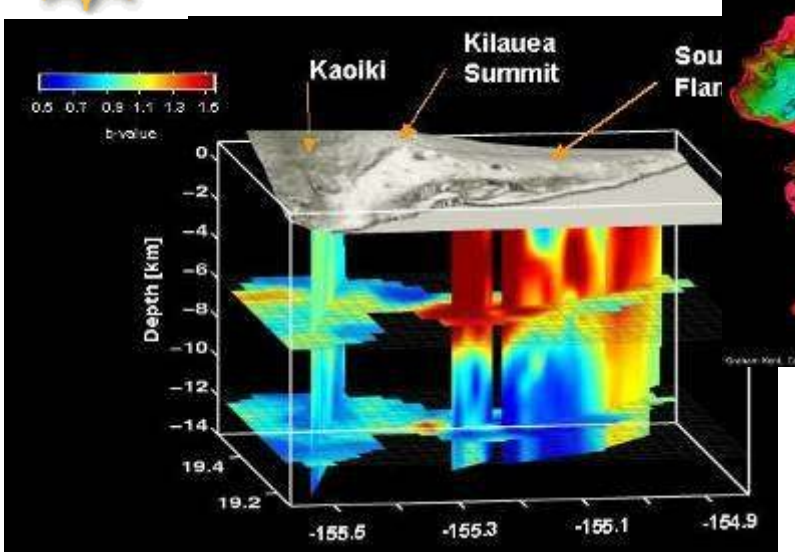
- **NSF Large Information Technology Research Proposal**
  - Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
  - Partnering Campuses: USC, SDSU, NW, TA&M, UvA, SARA, NASA
- **Industrial Partners**
  - IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent
- **$13.5 Million Over Five Years**
- **Linking Global Scale Science Projects to User's Linux Clusters**

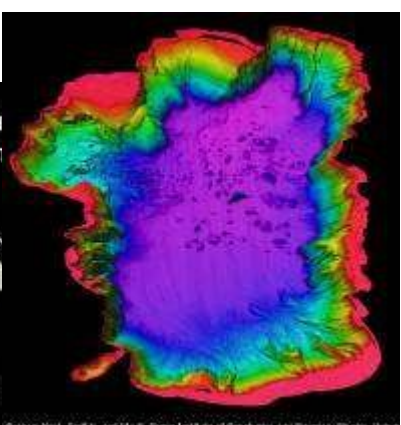
NIH Biomedical Informatics Research Network



http://ncmir.ucsd.edu/gallery.html

NSF EarthScope and ORION





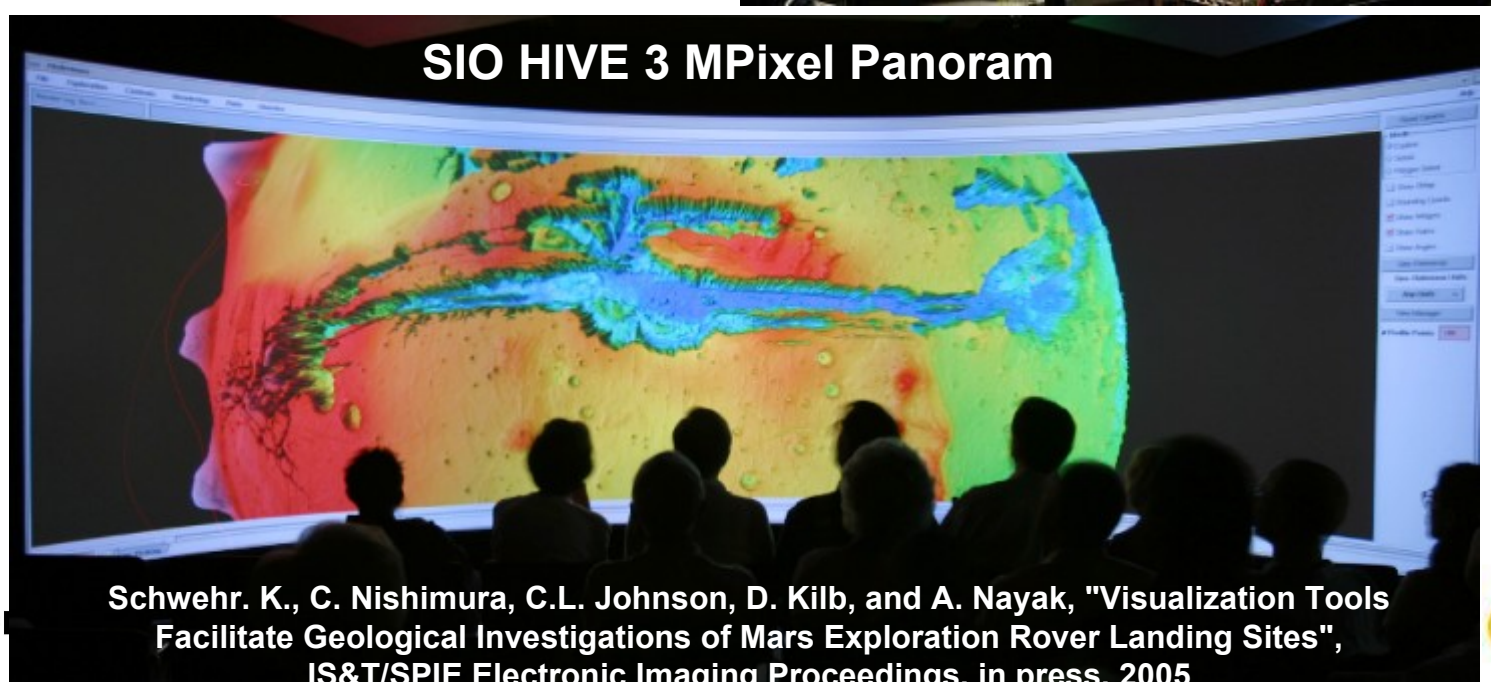
siovizcenter.ucsd.edu/library/gallery/shoot1/index.shtml

OptIPuter SDSC

Earth and Planetary Sciences are an OptIPuter Large Data Object Visualization Driver



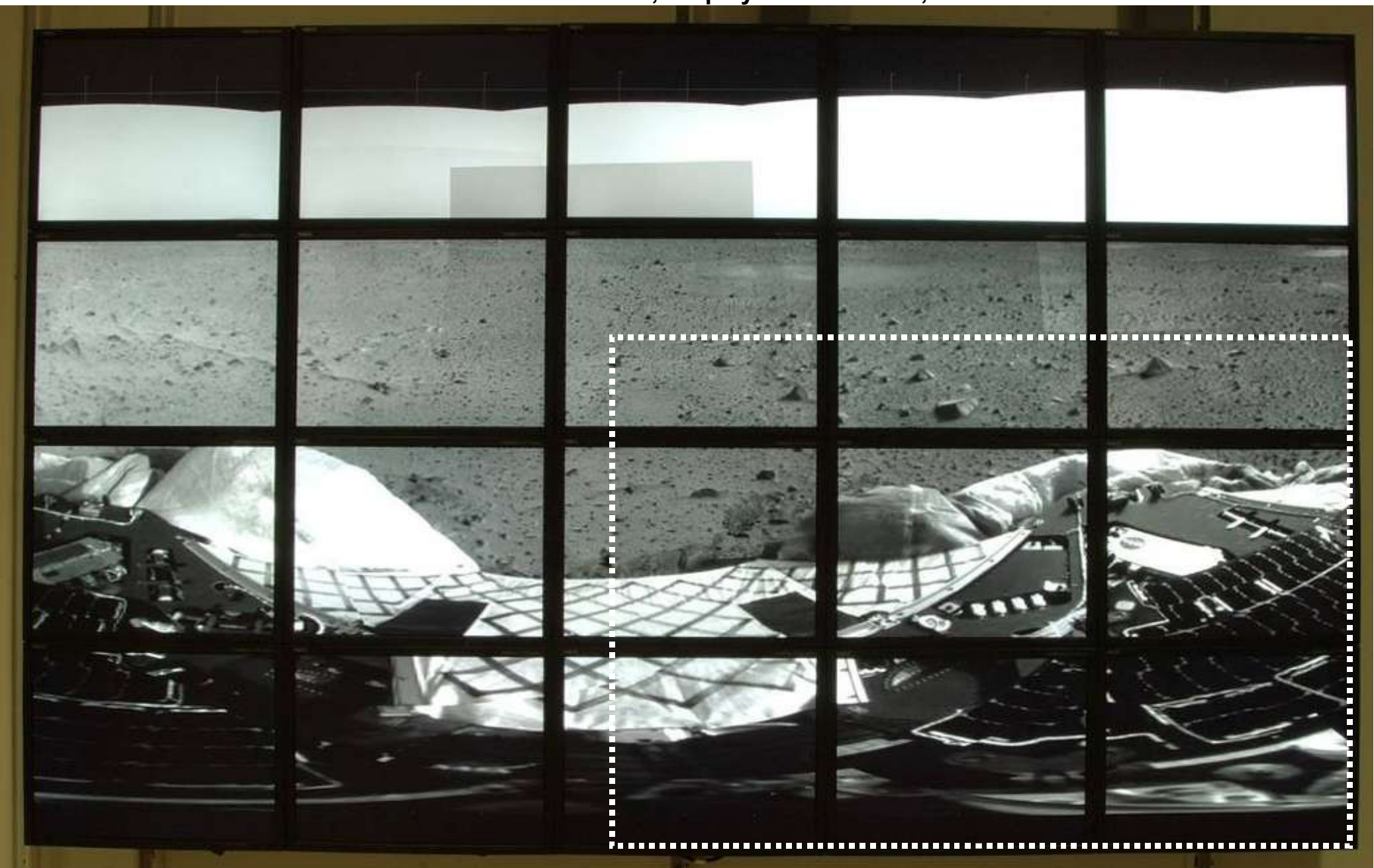




Schwehr. K., C. Nishimura, C.L. Johnson, D. Kilb, and A. Nayak, "Visualization Tools Facilitate Geological Investigations of Mars Exploration Rover Landing Sites", IS&T/SPIE Electronic Imaging Proceedings, in press, 2005

Tiled Displays Allow for Both Global Context and High Levels of Detail—150 MPixel Rover Image on 40 MPixel OptIPuter Visualization Node Display

"Source: Data from JPL/Mica; Display UCSD NCMIR, David Lee"



Interactively Zooming In Using UIC's Electronic Visualization Lab's JuxtaView Software

"Source: Data from JPL/Mica; Display UCSD NCMIR, David Lee"



Highest Resolution Zoom

"Source: Data from JPL/Mica; Display UCSD NCMIR, David Lee"



High Resolution Aerial Photography Generates Images With 10,000 Times More Data than Landsat7

Landsat7 Imagery
100 Foot Resolution
Draped on elevation data





New USGS Aerial Imagery
At 1-Foot Resolution

~10x10 square miles of 350 US Cities
2.5 Billion Pixel Images Per City!

OptIPuter

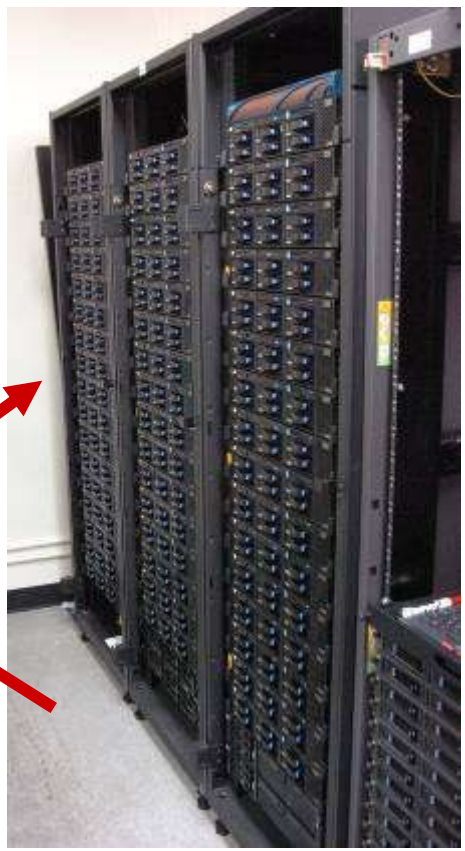
it2

Enabling Scientists to Analyze Large Data Objects: UCSD Campus LambdaStore Architecture

SIO Ocean Supercomputer

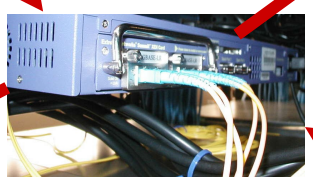


IBM Storage Cluster



Streaming Microscope









Extreme Switch with 2 Ten Gbps Uplinks





Source: Phil Papadopoulos, SDSC, Calit2

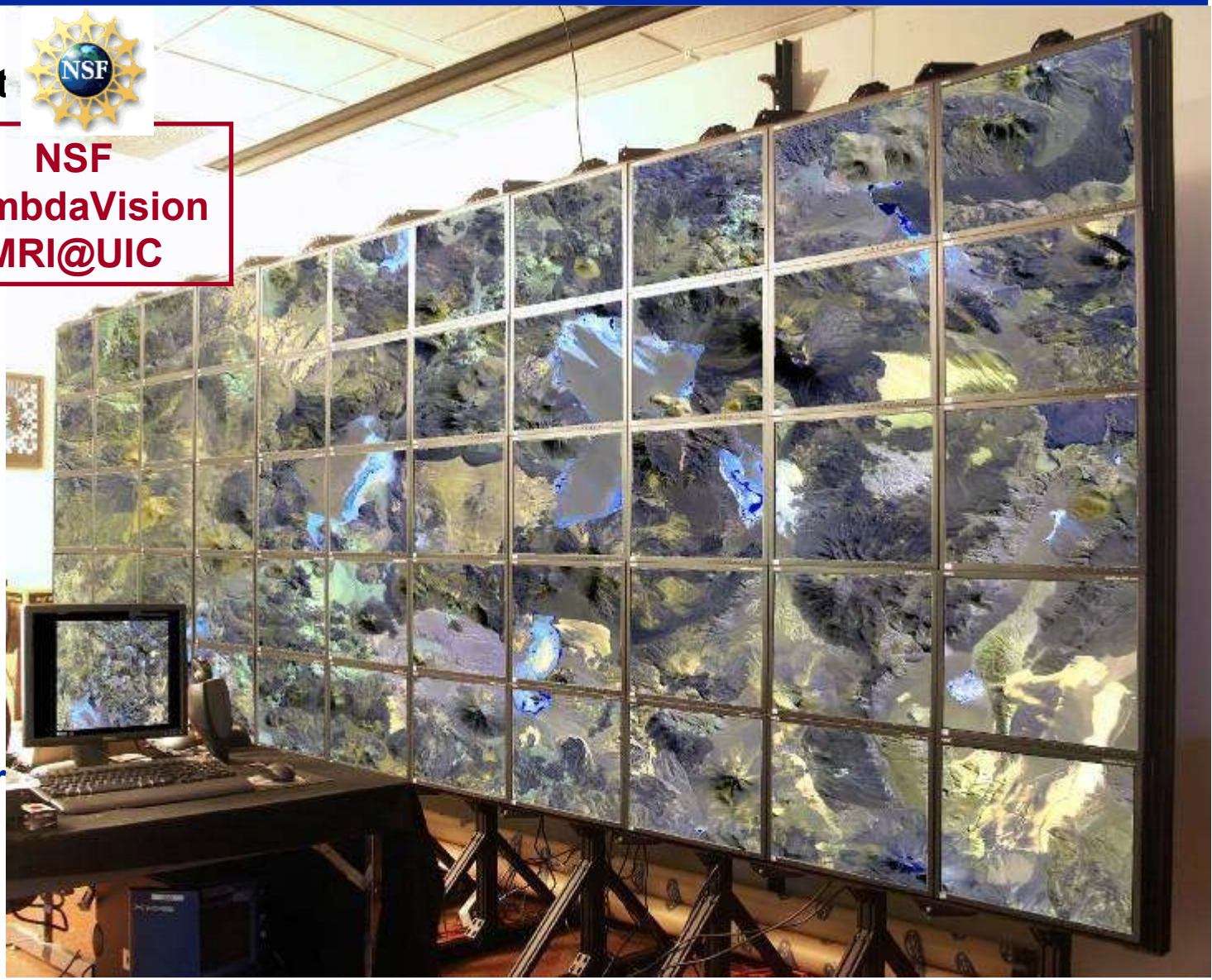
OptIPuter

it²

We Will Build a 100 MPixel OptIPuter Display in Both Calit2 Buildings

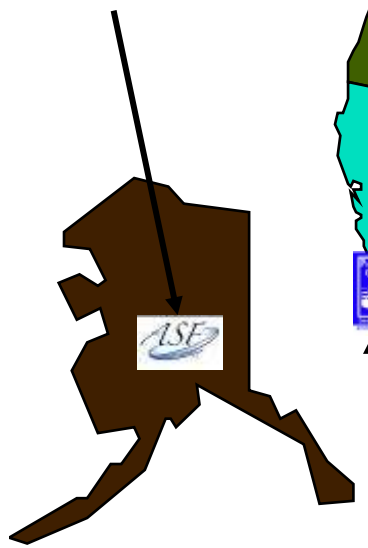
- Scalable Adaptive Graphics Environment (SAGE) Controls:
- 100 Megapixels Display
  - 55-Panel
- 1/4 TeraFLOP
  - Driven by 30 Node Cluster of 64 bit Dual Opterons
- 1/3 Terabit/sec I/O
  - 30 x 10GE interfaces
  - Linked to OptIPuter
- 1/8 TB RAM
- 60 TB Disk

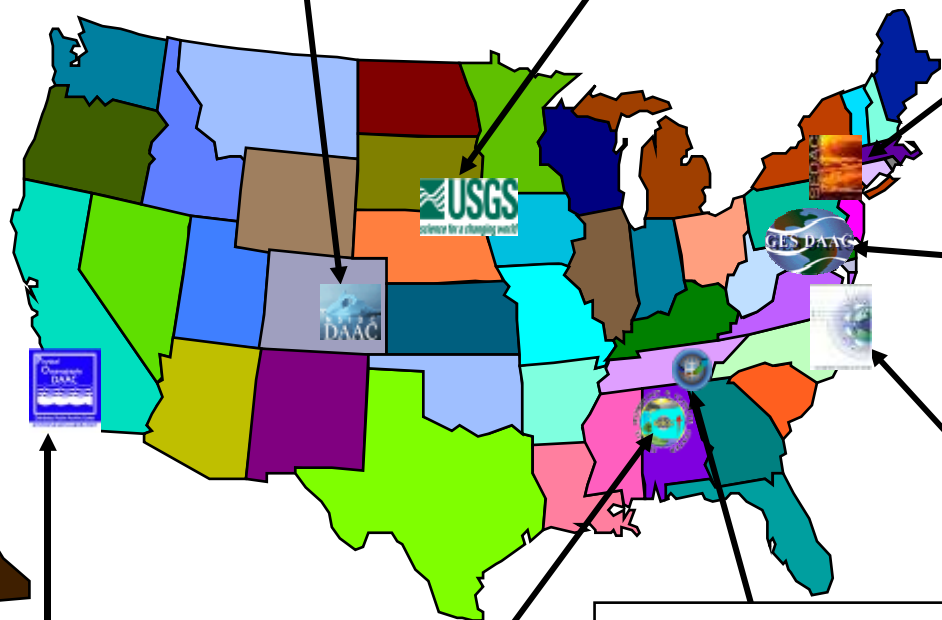
NSF LambdaVision MRI@UIC

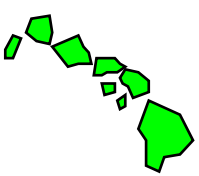


Source: Jason Leigh, Tom DeFanti, EVL@UIC
OptIPuter Co-PIs

Earth System Enterprise-Data Lives in Distributed Active Archive Centers (DAAC)







NSIDC (67 TB)
Cryosphere
Polar Processes

LPDAAC-EDC (1143 TB)
Land Processes
& Features

ASF (256 TB)
SAR Products
Sea Ice
Polar Processes

SEDAC (0.1 TB)
Human Interactions in
Global Change

GES DAAC-GSFC (1334 TB)
Upper Atmosphere
Atmospheric Dynamics, Ocean Color, Global Biosphere, Hydrology, Radiance Data

ASDC-LaRC (340 TB)
Radiation Budget,Clouds
Aerosols, Tropospheric
Chemistry

ORNL (1 TB)
Biogeochemical
Dynamics
EOS Land Validation

GHRC (4TB)
Global
Hydrology

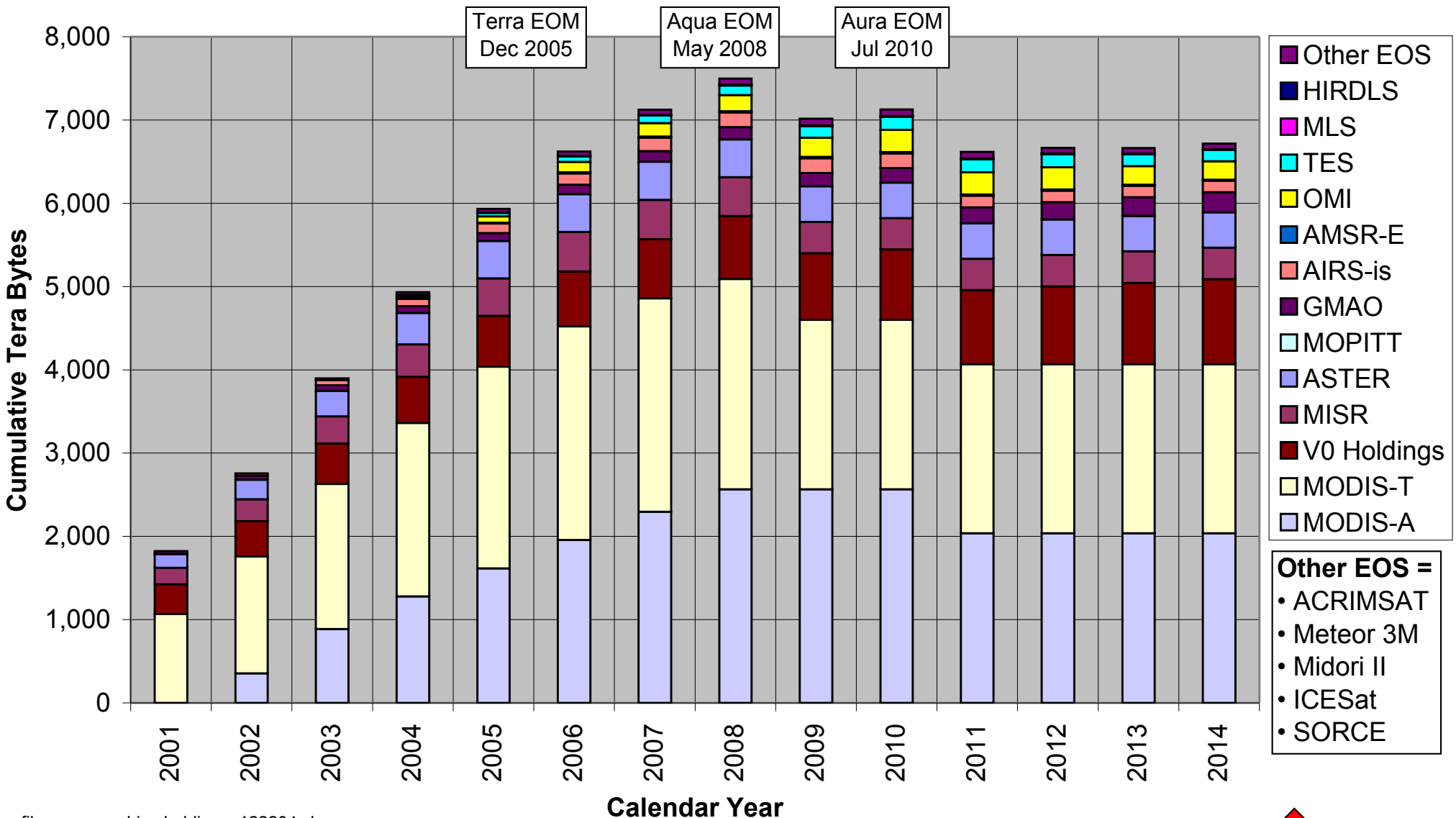
PODAAC-JPL (6 TB)
Ocean Circulation
Air-Sea Interactions

EOS Aura Satellite Has Been Launched
Challenge is How to Evolve to New Technologies

OptIPuter

it2

Cumulative EOSDIS Archive Holdings--Adding Several TBs per Day



file name: archive holdings_122204.xls
tab: all instr bar

NOTE: Data remains in the archive pending transition to LTA

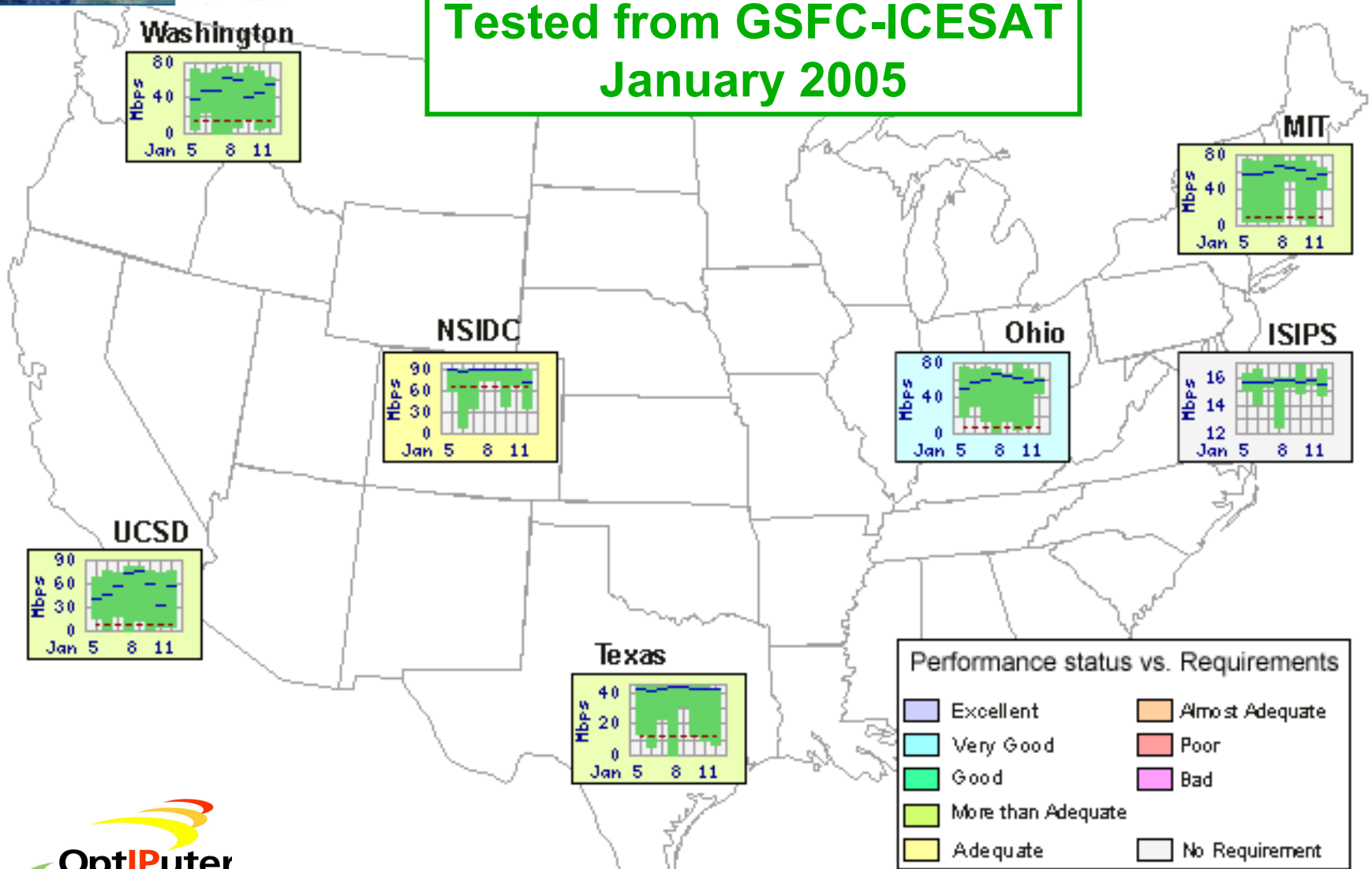
Source: Glenn Iona, EOSDIS Element Evolution Technical Working Group January 6-7, 2005

Challenge: Average Throughput of NASA Data Products to End User is Only < 50 Megabits/s



ENSIGHT Active Testing ICESat Destinations

Tested from GSFC-ICESAT January 2005



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

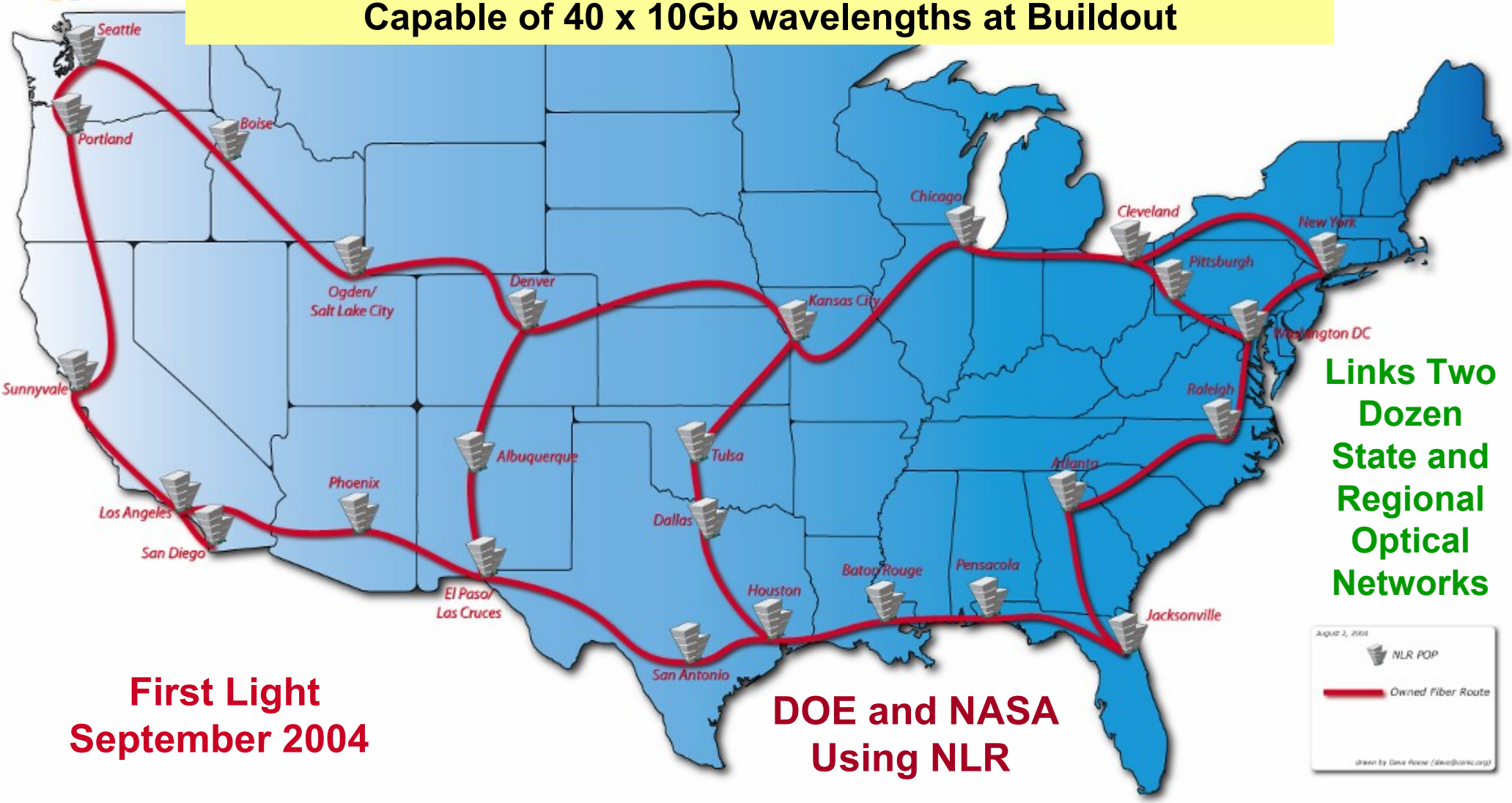
NLR Will Provide an Experimental Network Infrastructure for U.S. Scientists & Researchers

"National LambdaRail" Partnership

Serves Very High-End Experimental and Research Applications

4 x 10Gb Wavelengths Initially

Capable of 40 x 10Gb wavelengths at Buildout



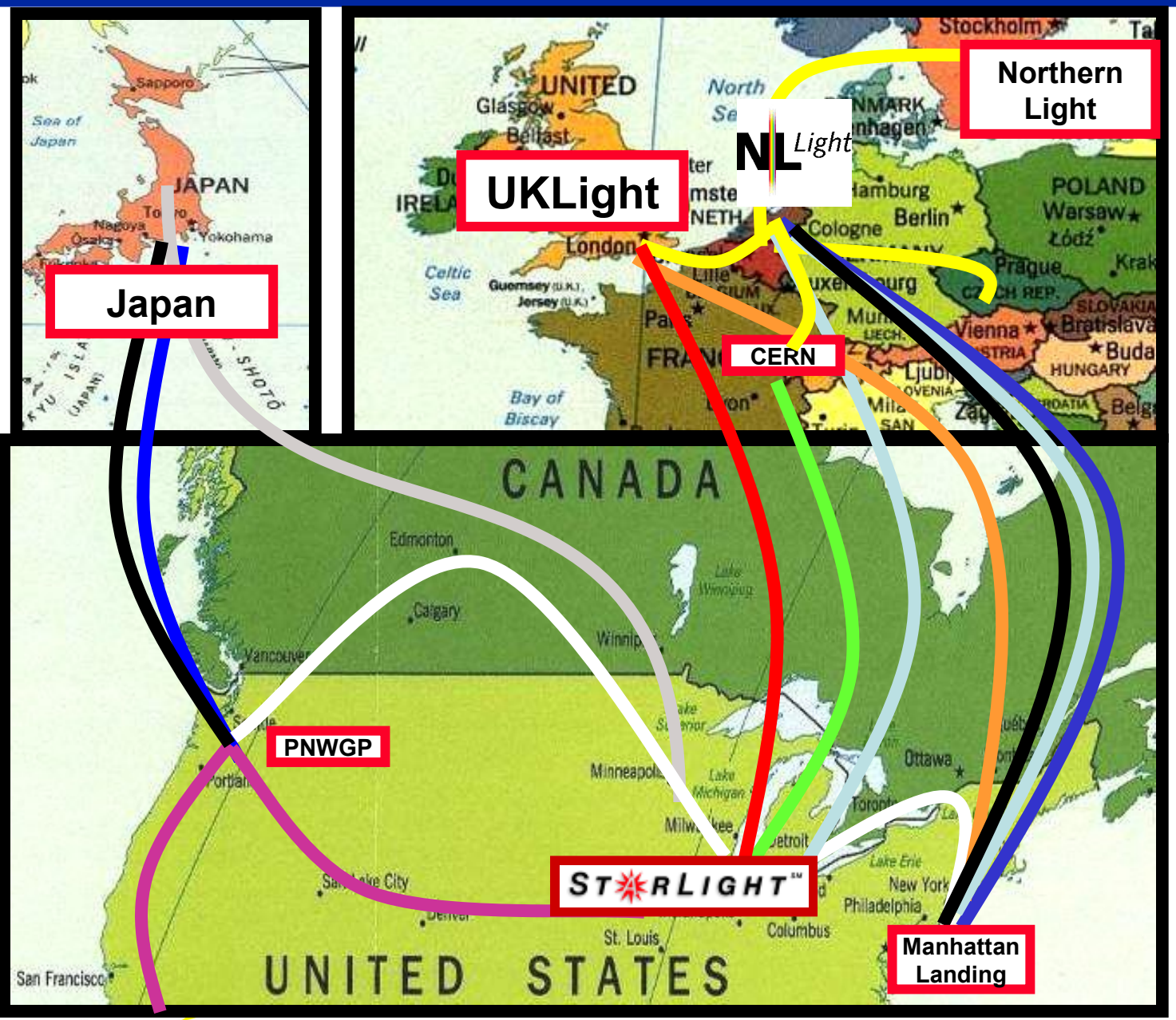
Links Two Dozen State and Regional Optical Networks

First Light September 2004

DOE and NASA Using NLR

For more information regarding NLR see http://www.nlr.net or contact info@nlr.net

Dedicated Research 10Gb Optical Circuits in 2005
North America, Europe and Japan

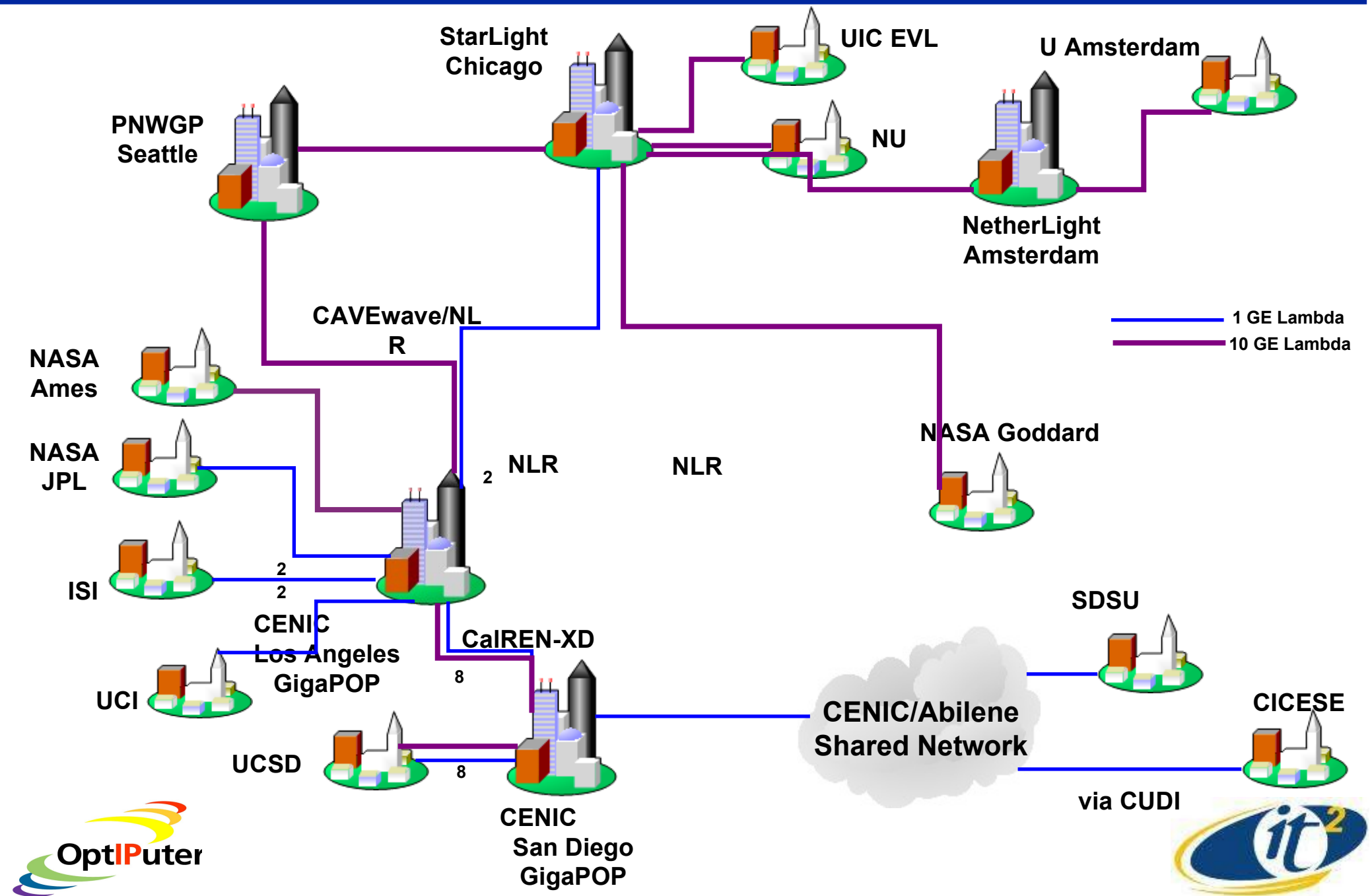


US IRNC (black)
–20Gb NYC—Amsterdam
–10Gb LA—Tokyo
GEANT/I2 (orange)
–30Gb London, etc.—NYC
UK to US (red)
–10Gb London—Chicago
SURFnet to US (light blue)
–10Gb Amsterdam—NYC
–10Gb Amsterdam—Chicago
Canadian CA*net4 to US (white)
–30Gb Chicago-Canada-NYC
–30Gb Chicago-Canada-Seattle
Japan JGN II to US (grey)
–10Gb Chicago—Tokyo
European (not GEANT) (yellow)
–10Gb Amsterdam—CERN
–10Gb Prague—Amsterdam
–2.5Gb Stockholm—Amsterdam
–10Gb London—Amsterdam
IEEAF lambdas (dark blue)
–10Gb NYC—Amsterdam
–10Gb Seattle—Tokyo
CAVEwave/PacificWave (purple)
–10Gb Chicago—Seattle—SD
–10Gb Seattle—LA—SD

OptIPuter

it2

Expanding the OptIPuter LambdaGrid Providing 1-10 Gbps Bandwidth



GSFC IRAD Proposal "Preparing Goddard for Large Scale Team Science in the 21st Century: Enabling an All Optical Goddard Network Cyberinfrastructure"

Funded February 2004

Objectives Summary

- "…establish a 10 Gbps Lambda Network from GSFC's Earth Science Greenbelt facility in MD to the Scripps Institute of Oceanography (SIO) over the National Lambda Rail (NLR)"
- "…make data residing on Goddard's high speed computer disks available to SIO with access speeds as if the data were on their own desktop servers or PC's."
- "…enable scientists at both institutions to share and use compute intensive community models, complex data base mining and multi-dimensional streaming visualization over this highly distributed, virtual working environment."

Currently Adding in ARC and JPL

Source: Milt Halem, GSFC

Interactive Retrieval and Hyperwall Display of Earth Sciences Images Using NLR

Enables Scientists To Perform Coordinated Studies Of Multiple Remote-Sensing Datasets

Source: Milt Halem & Randall Jones, NASA GSFC
& Maxine Brown, UIC EVL





Earth science data sets created by GSFC's Scientific Visualization Studio were retrieved across the NLR in real time from OptIPuter servers in Chicago and San Diego and from GSFC servers in McLean, VA, and displayed at the SC2004 in Pittsburgh

OptIPuter

http://esdcd.gsfc.nasa.gov/LNetphoto3.html

it2

Calit2 is Partnering with the new SIO Center for Earth Observations and Applications

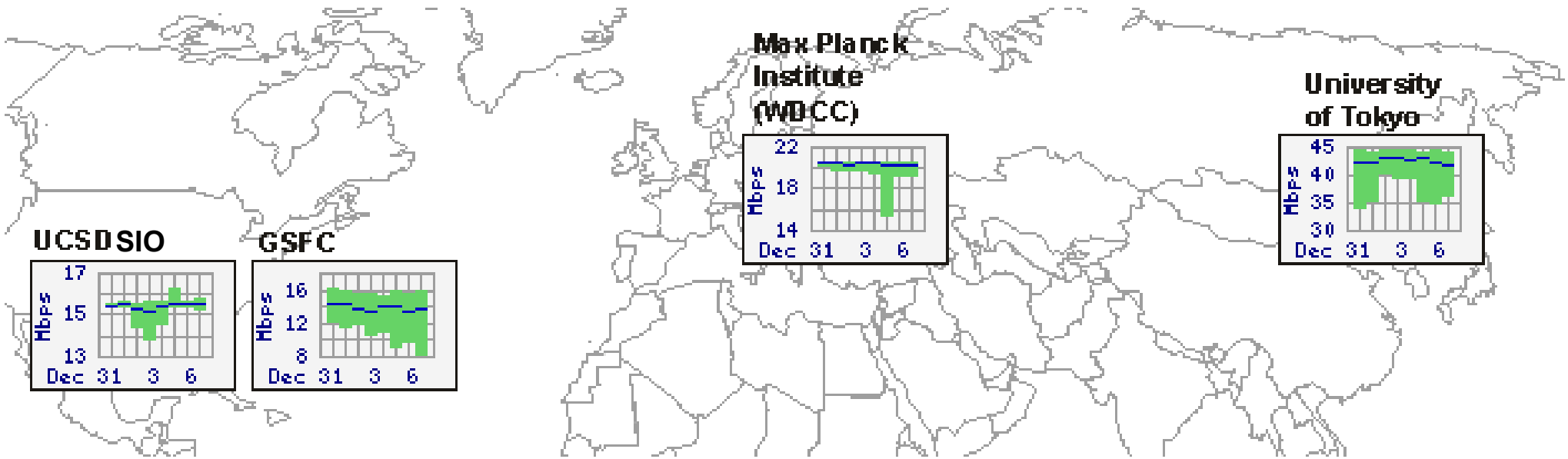
- Viewing and Analyzing Earth Satellite Data Sets
- Earth Topography
- Project Atmospheric Brown Clouds
- Climate Modeling
- Coastal Zone Data Assimilation
- Ocean Observatories



OptIPuter, NLR, and Starlight Enabling Coordinated Earth Observing Program (CEOP)

Source: Milt Halem, NASA GSFC

Accessing 300TB's of Observational Data in Tokyo and 100TB's of Model Assimilation Data in MPI in Hamburg -- Analyzing Remote Data Using GRaD-DODS at These Sites Using OptIPuter Technology Over the NLR and Starlight



Note Current Throughput 15-45 Mbps:
OptIPuter 2005 Goal is ~1-10 Gbps!

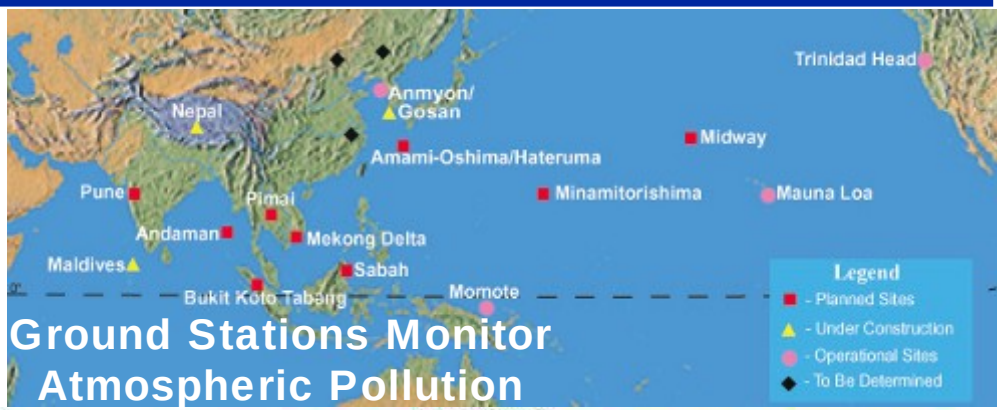
OptIPuter

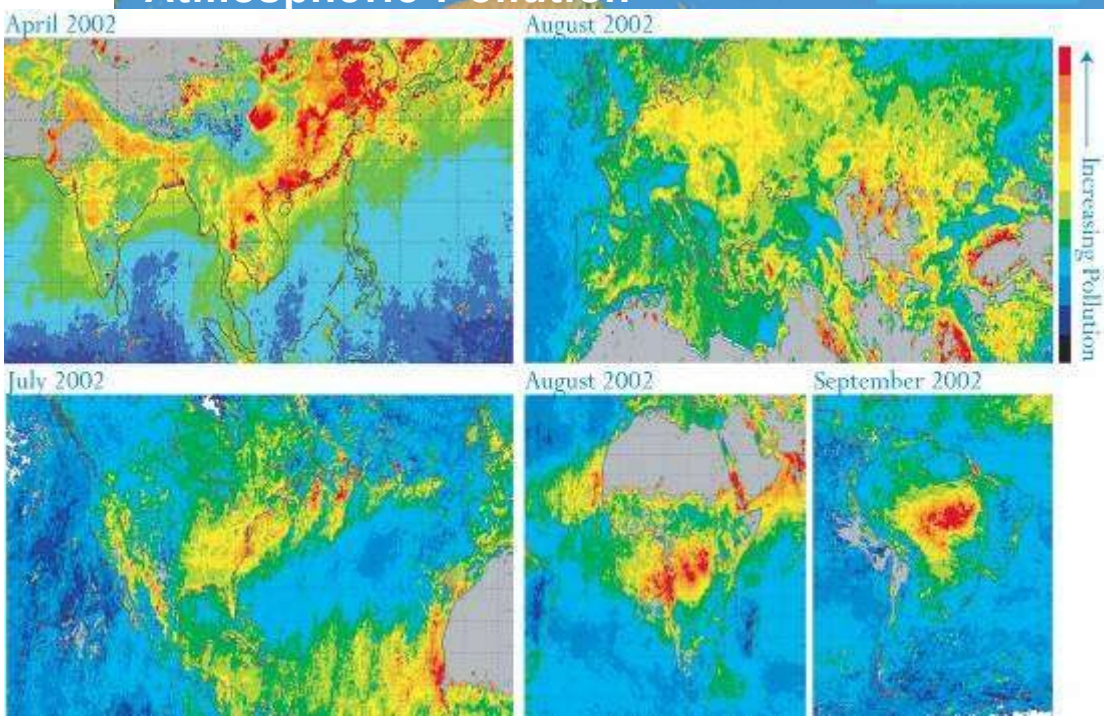
http://ensight.eos.nasa.gov/Organizations/ceop/index.shtml

it2

Project Atmospheric Brown Clouds (ABC) -- NLR Linking GSFC and UCSD/SIO

- A Collaboration to Predict the Flow of Aerosols from Asia Across the Pacific to the U.S. on Timescales of Days to a Week
- GSFC will Provide an Aerosol Chemical Tracer Model (GOCAR) Embedded in a High-Resolution Regional Model (MM5) that can Assimilate Data from Indo-Asian and Pacific Ground Stations, Satellites, and Aircraft
- Remote Computing and Analysis Tools Running over NLR will Enable Acquisition & Assimilation of the Project ABC Data
- Key Contacts: Yoram Kaufman, William Lau, GSFC; V. Ramanathan, Chul Chung, SIO



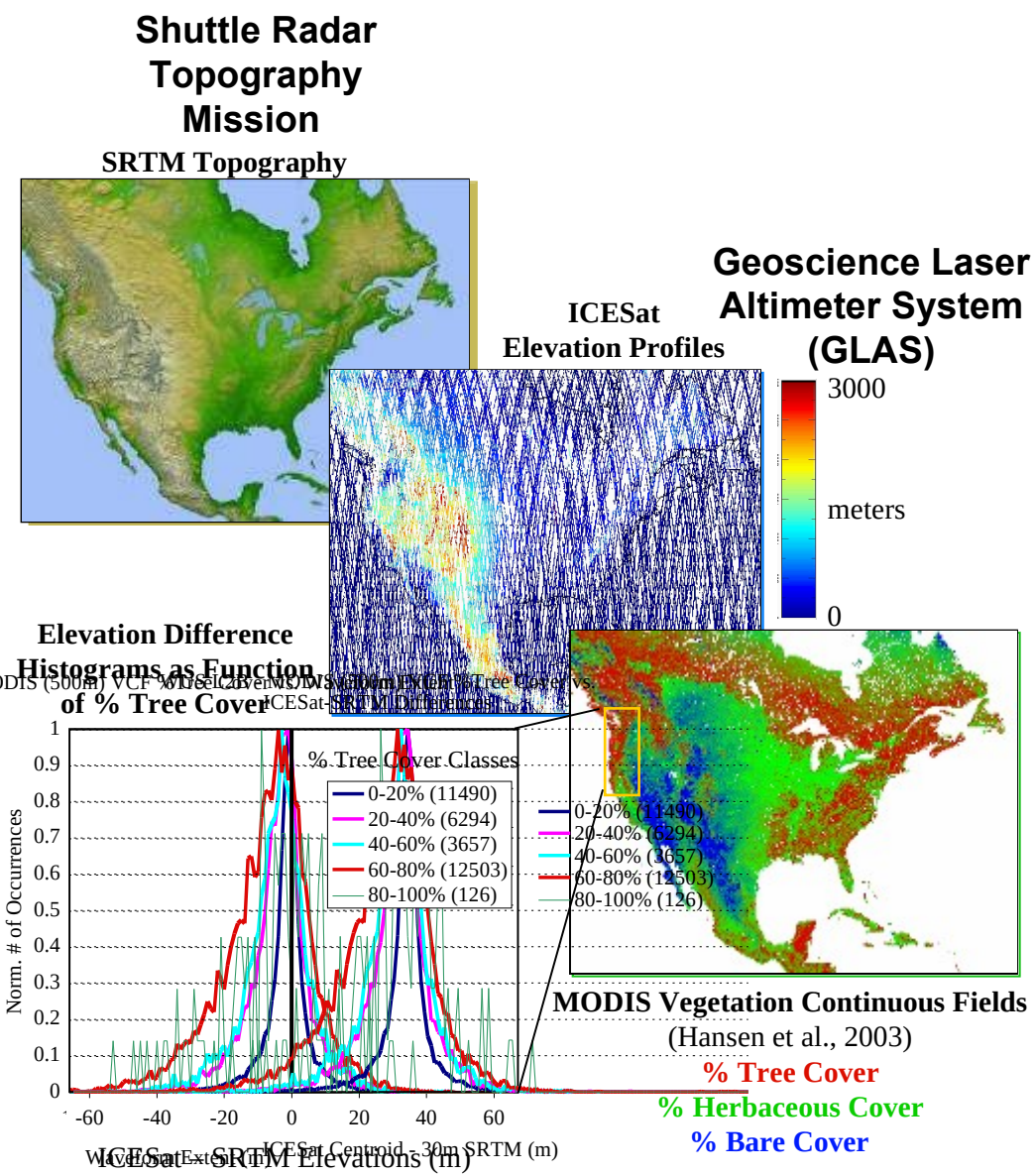


The Global Nature of Brown Clouds is Apparent in Analysis of NASA MODIS Data. Research by V. Ramanathan, C. Corrigan, and M. Ramana, SIO

http://www-abc-asia.ucsd.edu

NLR GSFC/JPL/SIO Application: Integration of Laser and Radar Topographic Data with Land Cover Data

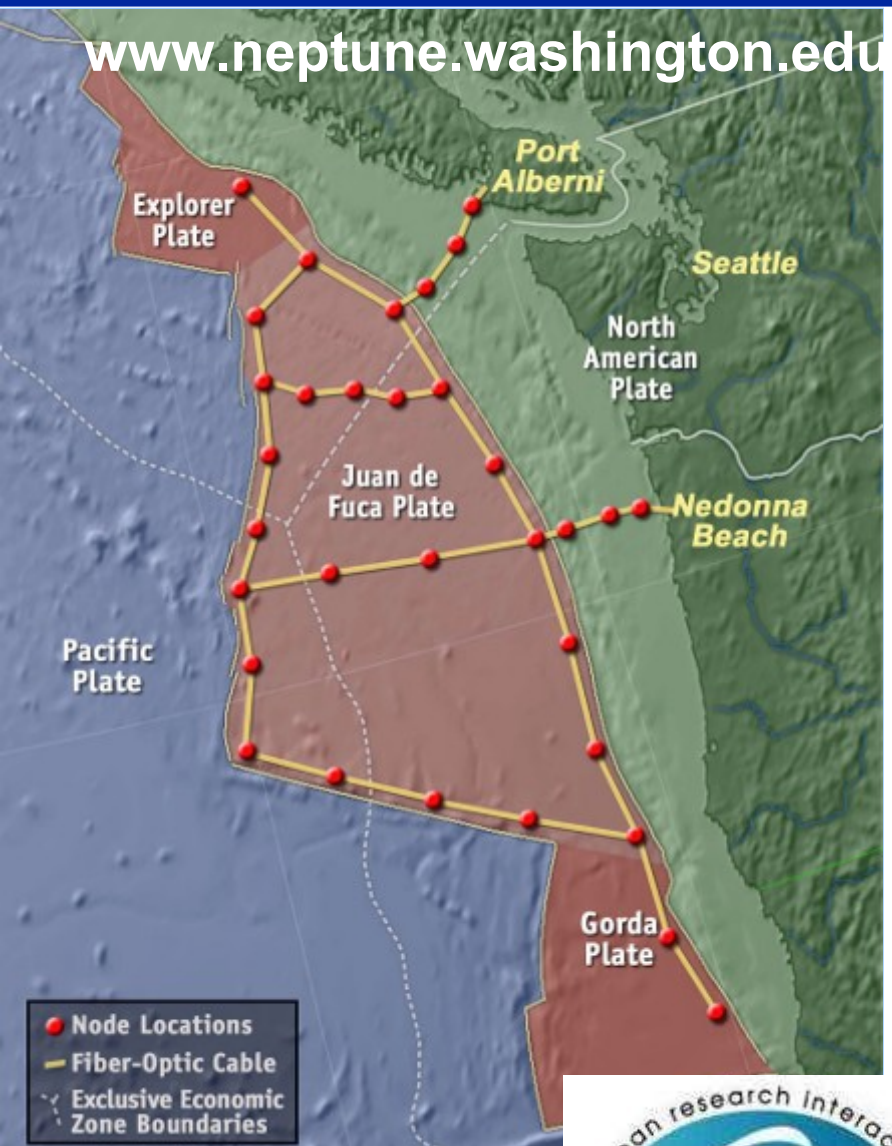
- **Merge the 2 Data Sets, Using SRTM to Achieve Good Coverage & GLAS to Generate Calibrated Profiles**
- **Interpretation Requires Extracting Land Cover Information from Landsat, MODIS, ASTER, and Other Data Archived in Multiple DAACs**
- **Use of the NLR and Local Data Mining and Sub-Setting Tools will Permit Systematic Fusion Of Global Data Sets, Which are Not Possible with Current Bandwidth**
- **Key Contacts: Bernard Minster, SIO; Tom Yunck, JPL; Dave Harding, Claudia Carabajal, GSFC**



http://icesat.gsfc.nasa.gov
http://www2.jpl.nasa.gov/srtm
http://glcf.umiacs.umd.edu/data/modis/vc

OptIPuter

New Instrument Infrastructure: Gigabit Fibers on the Ocean Floor



LOOKING:
(Laboratory for the Ocean Observatory Knowledge Integration Grid)

- **LOOKING NSF ITR with PIs:**
  - **John Orcutt & Larry Smarr - UCSD**
  - **John Delaney & Ed Lazowska –UW**
  - **Mark Abbott – OSU**
- **Collaborators at:**
  - **MBARI, WHOI, NCSA, UIC, CalPoly, UVic, CANARIE, Microsoft, NEPTUNE-Canarie**
- **Extend SCCOOS to the Ocean Floor**

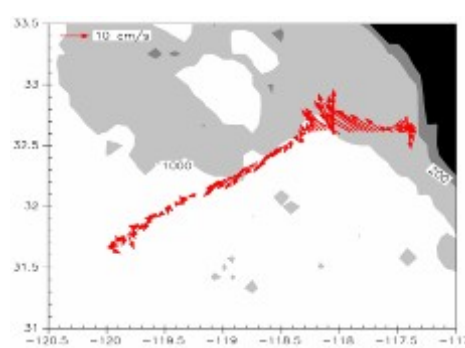
LOOKING--
Integrate Instruments & Sensors (Real Time Data Sources) Into a LambdaGrid Computing Environment With Web Services Interfaces

OptIPuter NSF ORION ocean research interactive observatory networks CENTER FOR EARTH OBSERVATIONS & APPLICATIONS it2

LOOKING Builds on the Multi- Institutional SCCOOS Program, OptIPuter, and CENIC-XD

- **SCCOOS is Integrating:**
  - Moorings
  - Ships
  - Autonomous Vehicles
  - Satellite Remote Sensing
  - Drifters
  - Long Range HF Radar
  - Near-Shore Waves/Currents (CDIP)
  - COAMPS Wind Model
  - Nested ROMS Models
  - Data Assimilation and Modeling
  - Data Systems

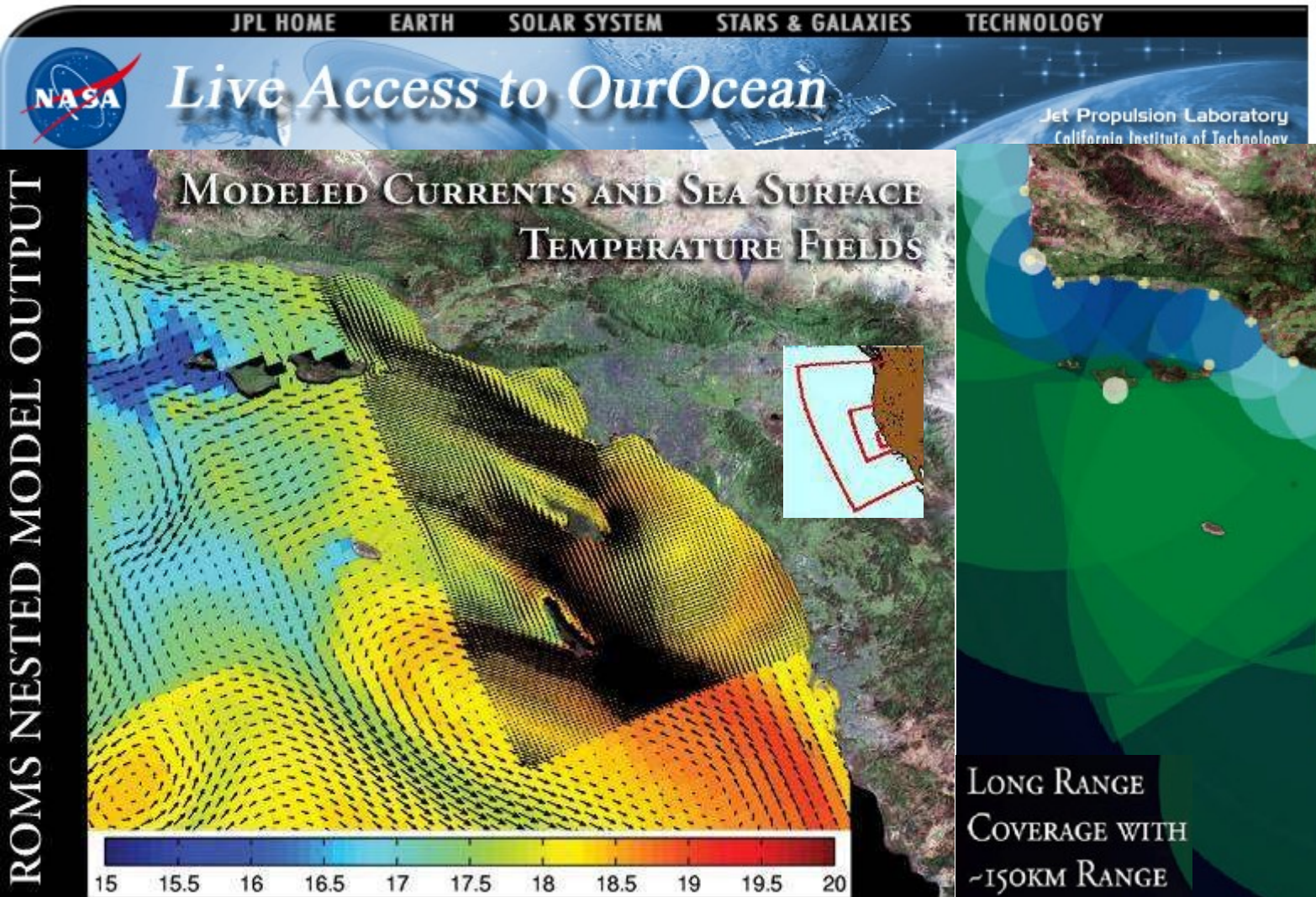




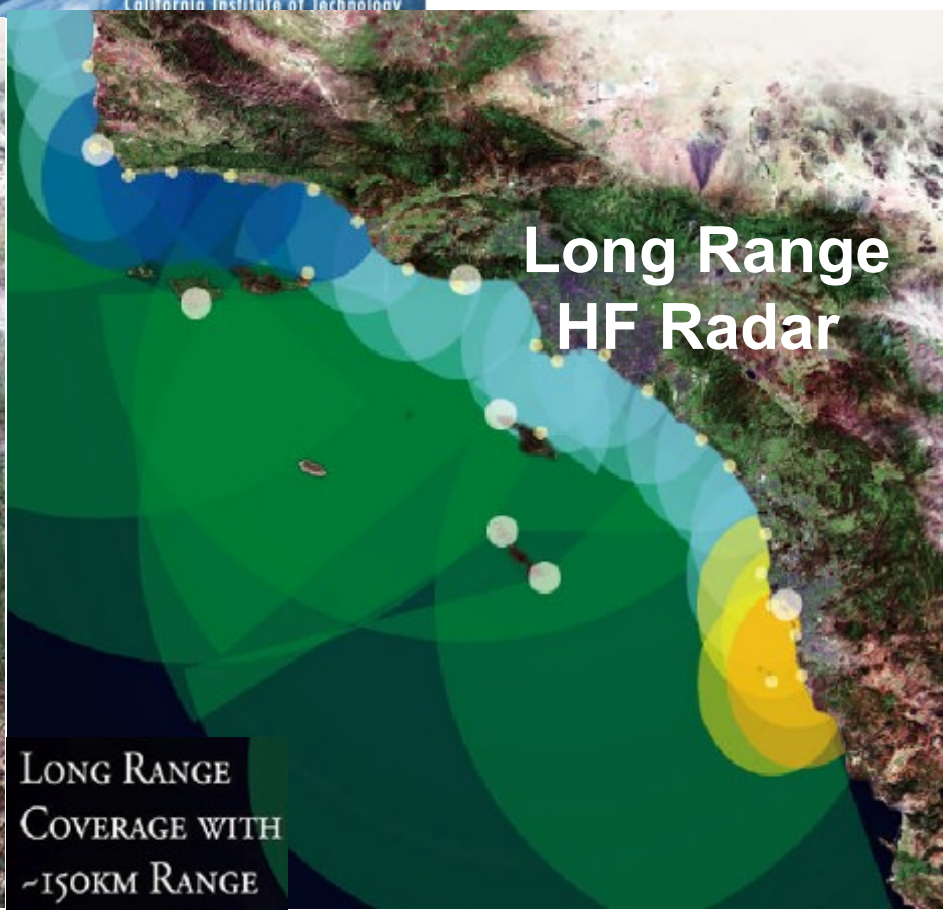


OptIPuter NSF ROADNet

Use OptIPuter to Couple Data Assimilation Models to Remote Data Sources and Analysis in Near Real Time



Goal is Real Time Local Digital Ocean Models



JPL ONR MBARI California Institute of Technology

Similar Work on SoCal Coast at SIO

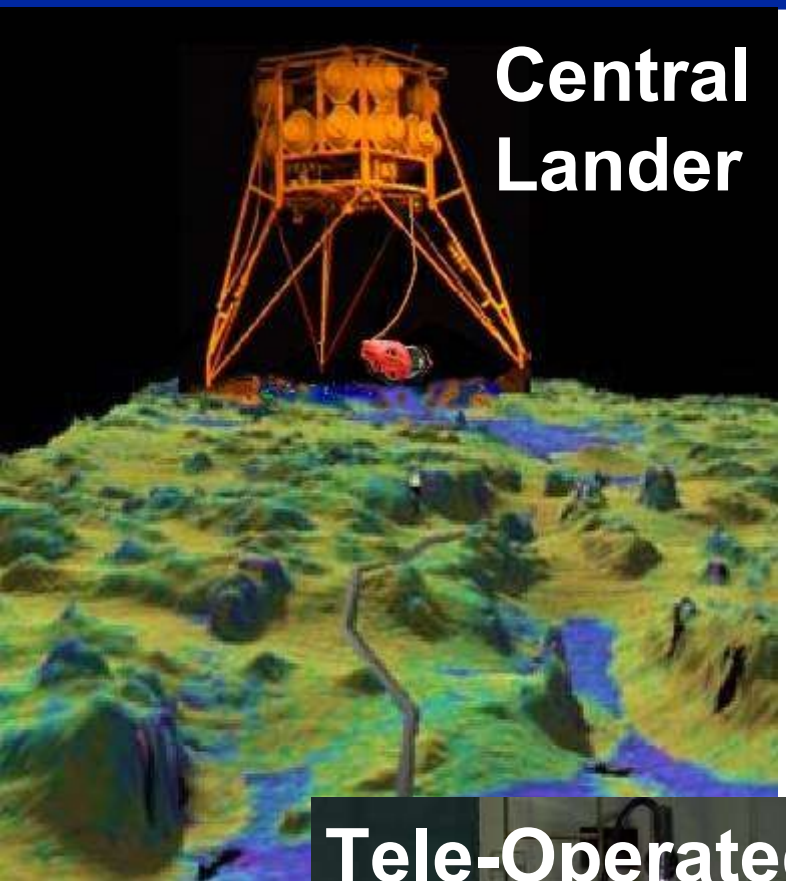
OptIPuter

Regional Ocean Modeling System (ROMS)

http://ourocean.jpl.nasa.gov/

it2

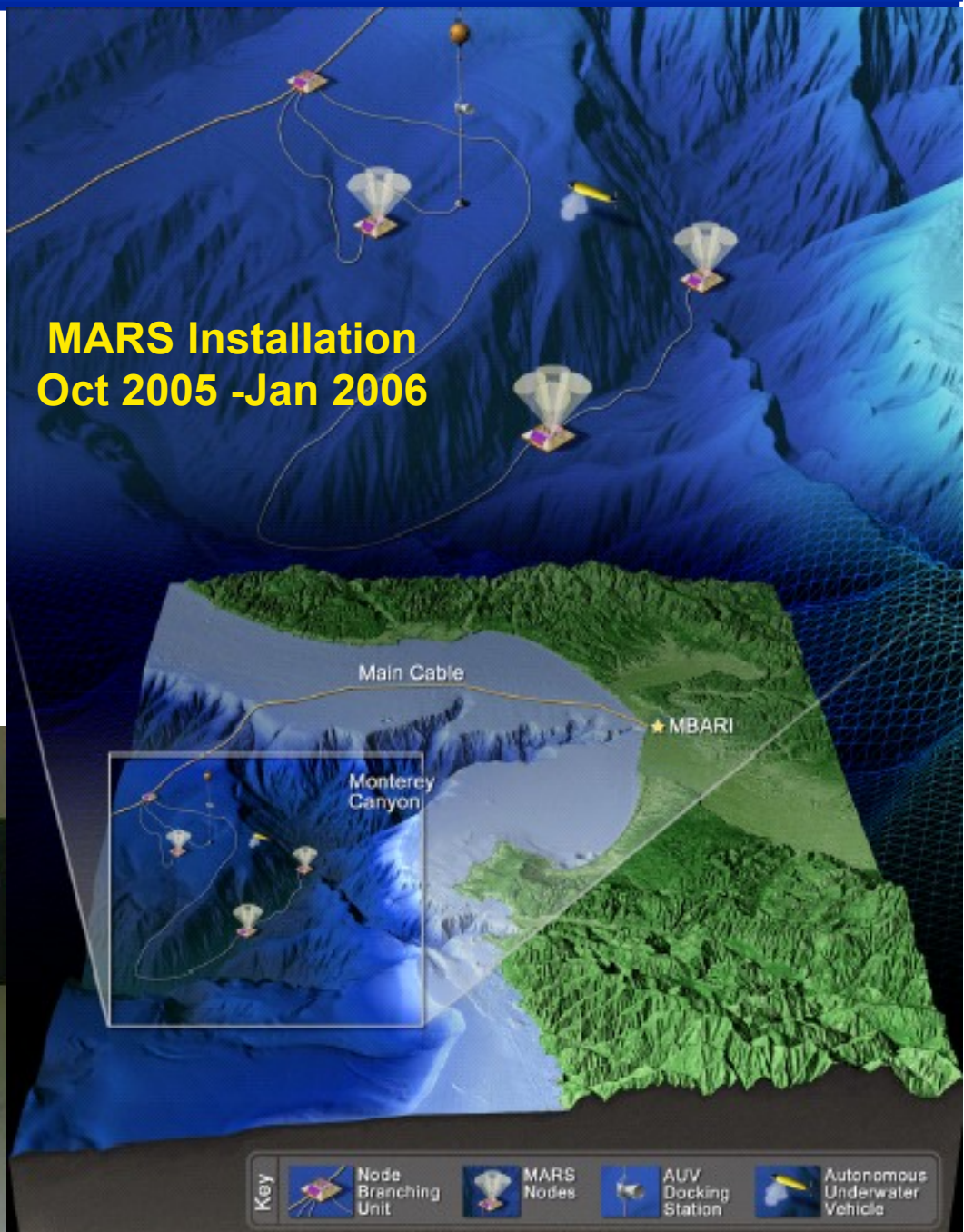
MARS Cable Observatory Testbed – LOOKING Living Laboratory



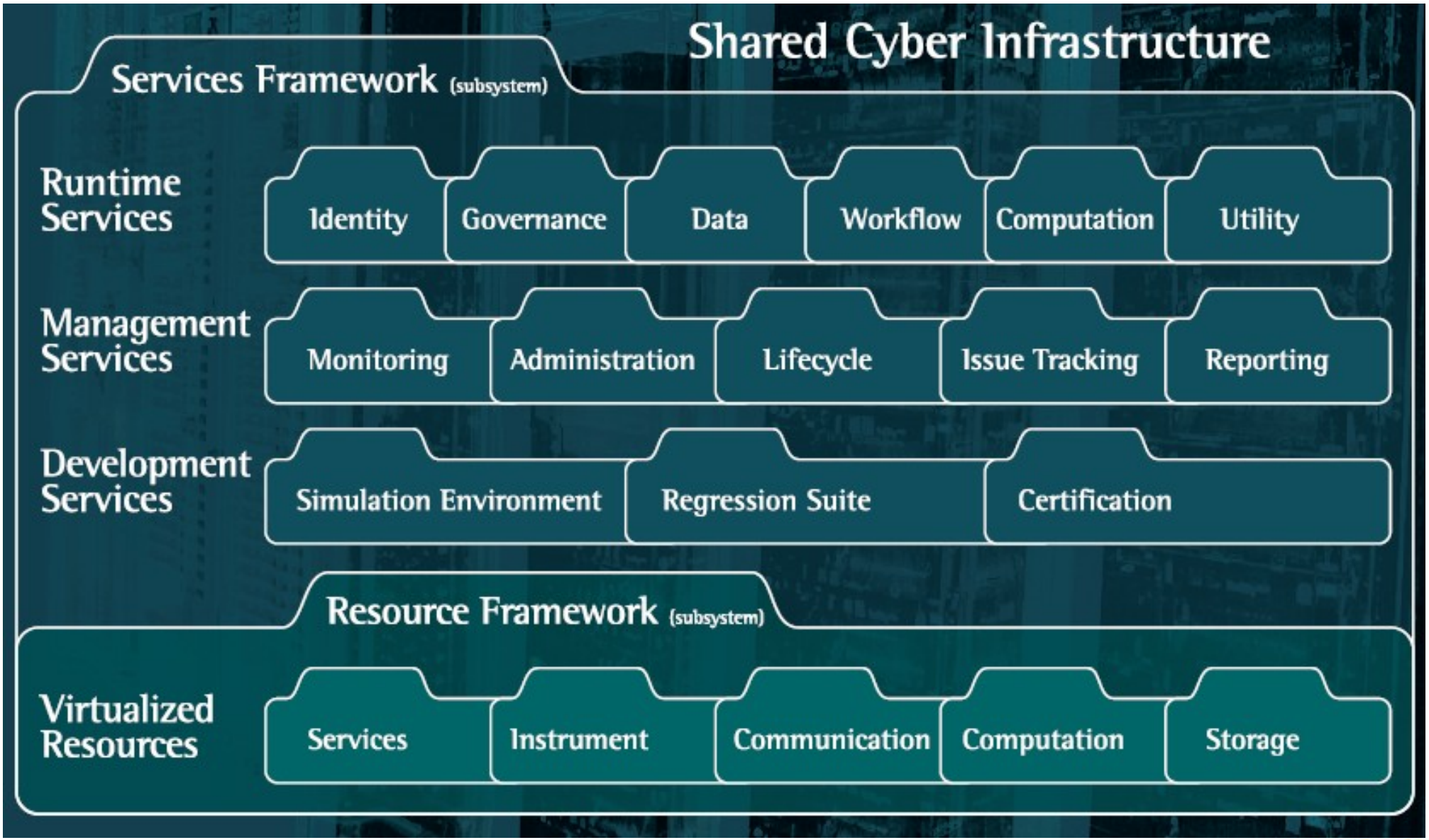


Source:
Jim
Bellingham,
MBARI

OptIPuter



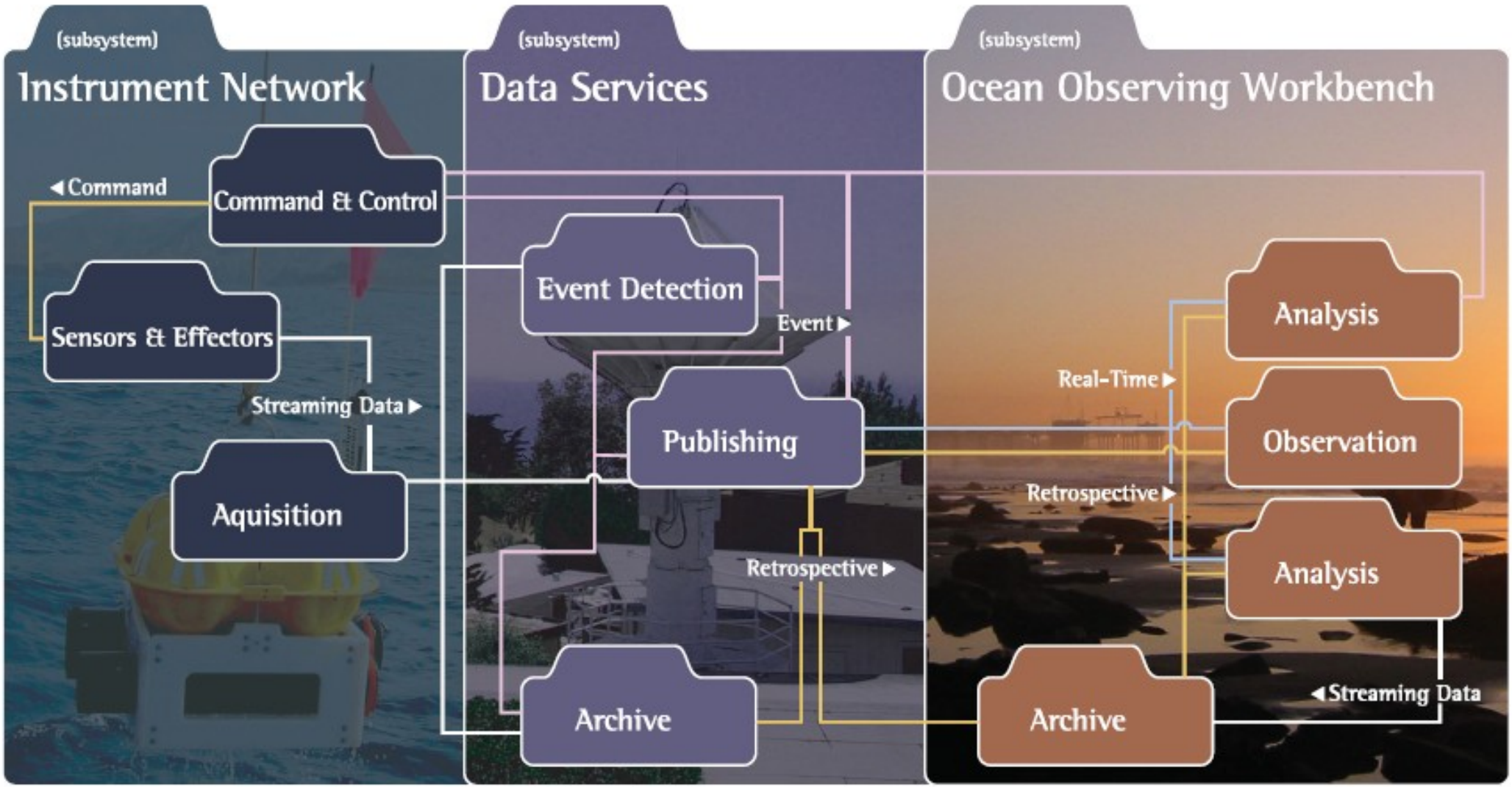
LOOKING Service Architecture



OptIPuter

it2

Looking High Level System Architecture



OptIPuter

it2

Goal – From Expedition to Cable Observatories with Streaming Stereo HDTV Robotic Cameras

http://disney.go.com/disneypictures/aliensofthedeep/alienseduguide.pdf





Scenes from The Aliens of the Deep, Directed by James Cameron & Steven Quale

OptIPuter

Multiple HD Streams Over Lambdas Will Radically Transform Campus Collaboration





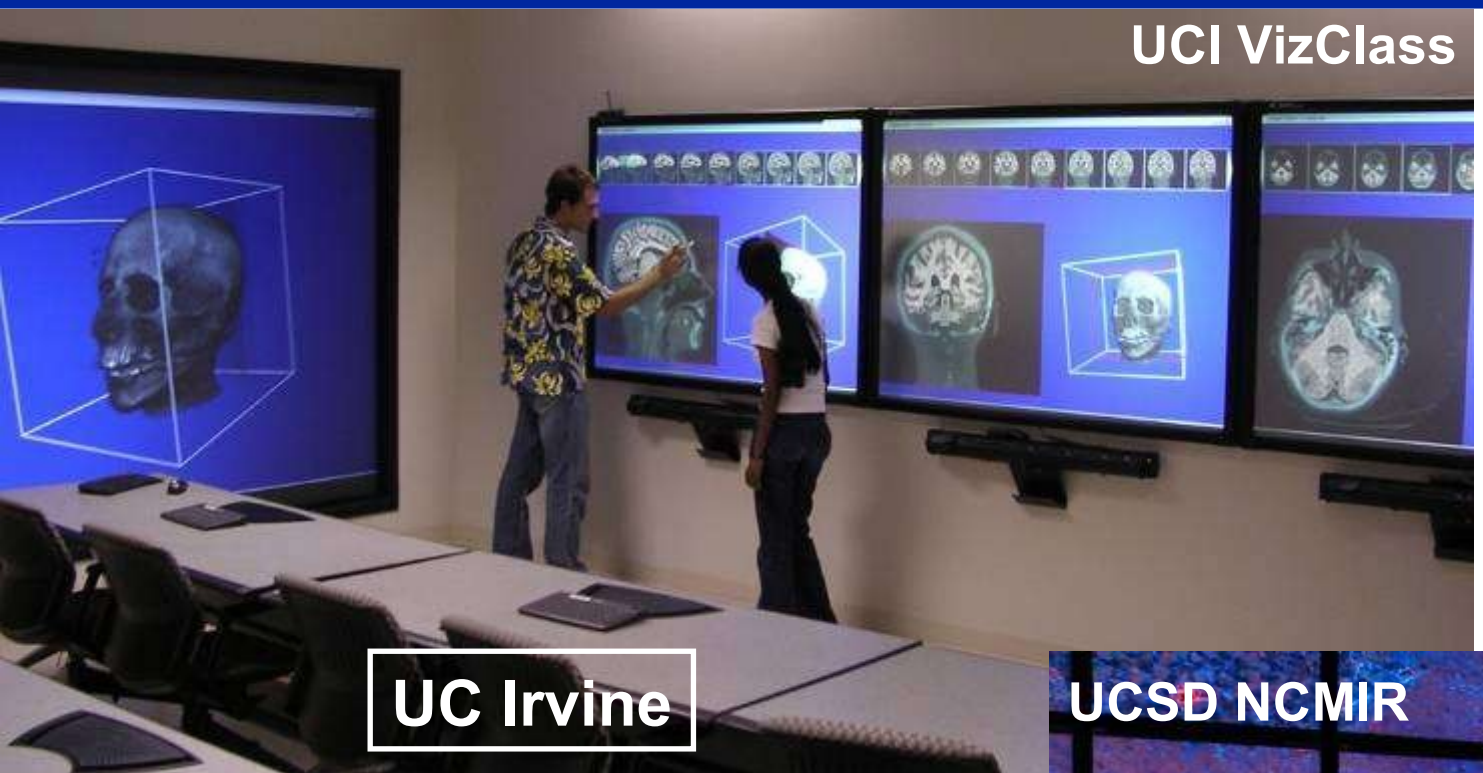


OptIPuter

Source: U Washington Research Channel

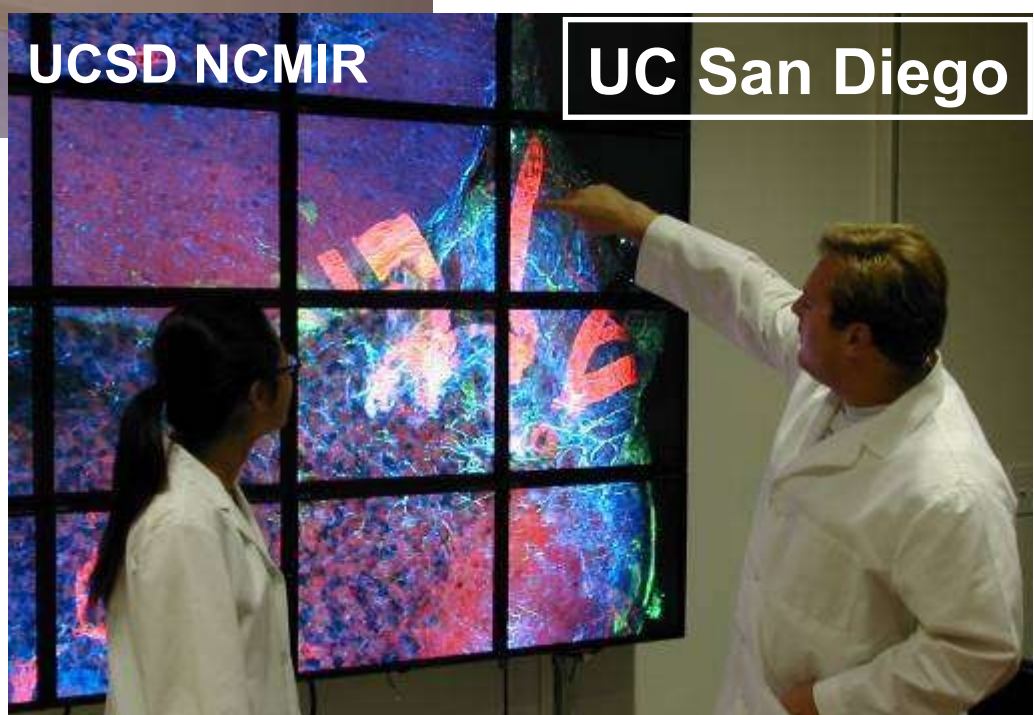
it2

Calit2 Collaboration Rooms Testbed Will Link to SIO



Source: Falko Kuester, UCI & Mark Ellisman, UCSD

OptIPuter



In 2005 Calit2 will Link Its Two Buildings via CENIC-XD Dedicated Fiber over 75 Miles Using OptIPuter Architecture to Create a Distributed Collaboration Laboratory

OptIPuter