"Toward a Global Interactive Earth Observing Cyberinfrastructure"

Invited Talk to the
21st International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology
Held at the 85th AMS Annual Meeting
San Diego, CA
January 12, 2005

Dr. Larry Smarr

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Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

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Abstract

As the earth sciences move toward an interactive global observation capability, a new generation of cyberinfrastructure is required. Realtime control of remote instruments, remote visualization or large data objects, metadata searching of federated data repositories, and collaborative analysis of complex simulations and observations must be possible using software agents interacting with web and Grid services. Several prototyping projects are underway, funded by NSF, NASA, and NIH, which are building national to global scale examples of such systems. These are driven by remote observation and simulation of the solid earth, oceans, and atmosphere with a specific focus on the coastal zone and environmental hydrology. I will review several of these projects and describe the cyber-architecture which is emerging.

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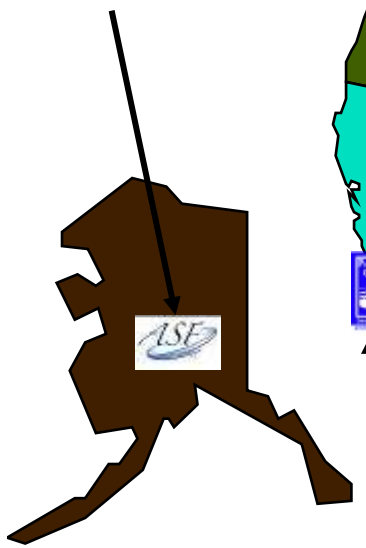
Evolutionary Stages of an Interactive Earth Sciences Architecture

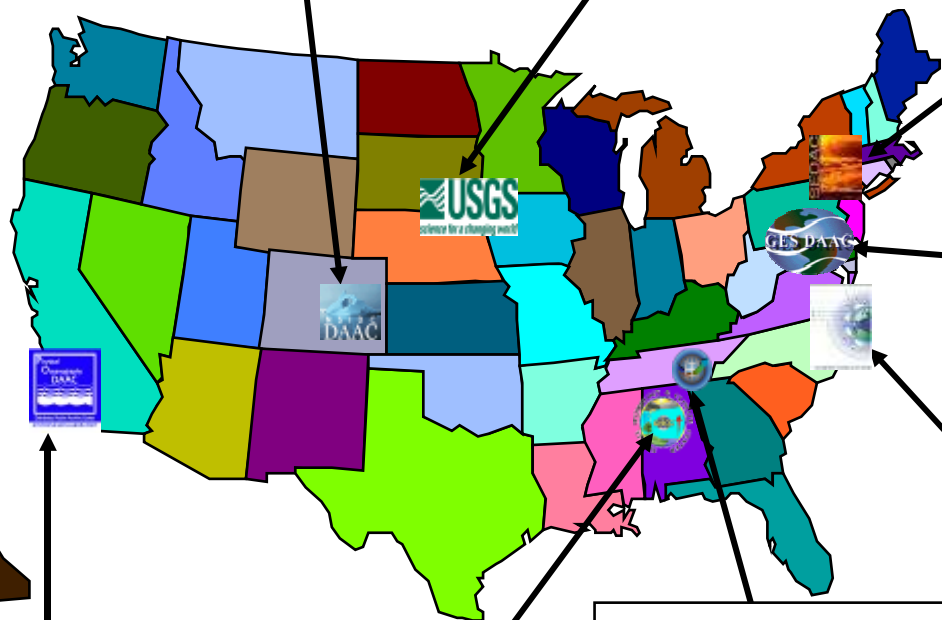
- **Library**
  - Asynchronous Access to Instrumental Data
- **Web**
  - Synchronous Access to Instrumental Data
- **Telescience**
  - Synchronous Access to Instruments and Data

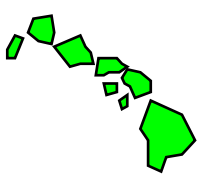
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Earth System Enterprise-Data Lives in Distributed Active Archive Centers (DAAC)







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

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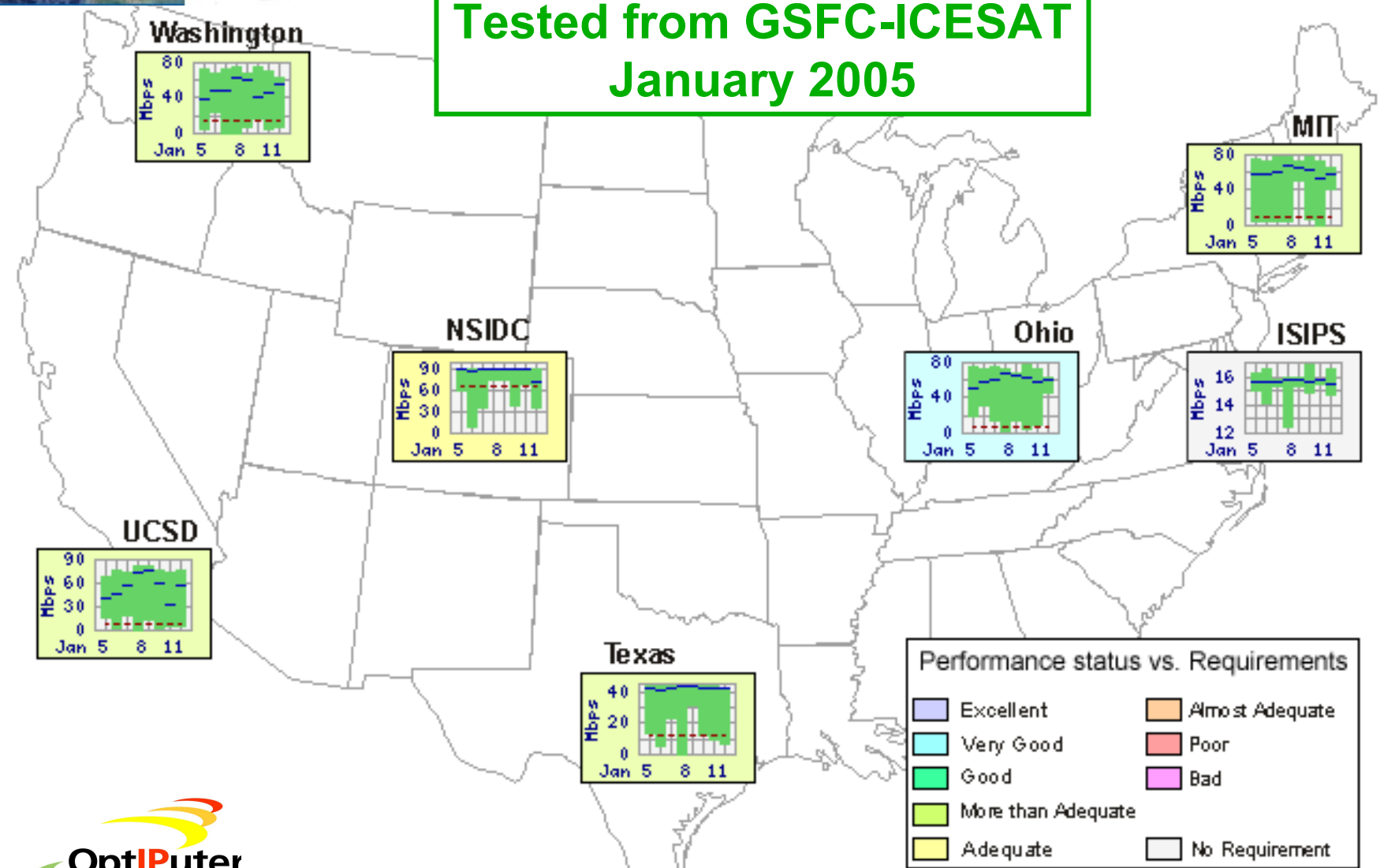
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Challenge: Average Throughput of NASA Data Products to End User is Only < 50 Megabits/s



ENSIGHT Active Testing ICESat Destinations

Tested from GSFC-ICESAT January 2005

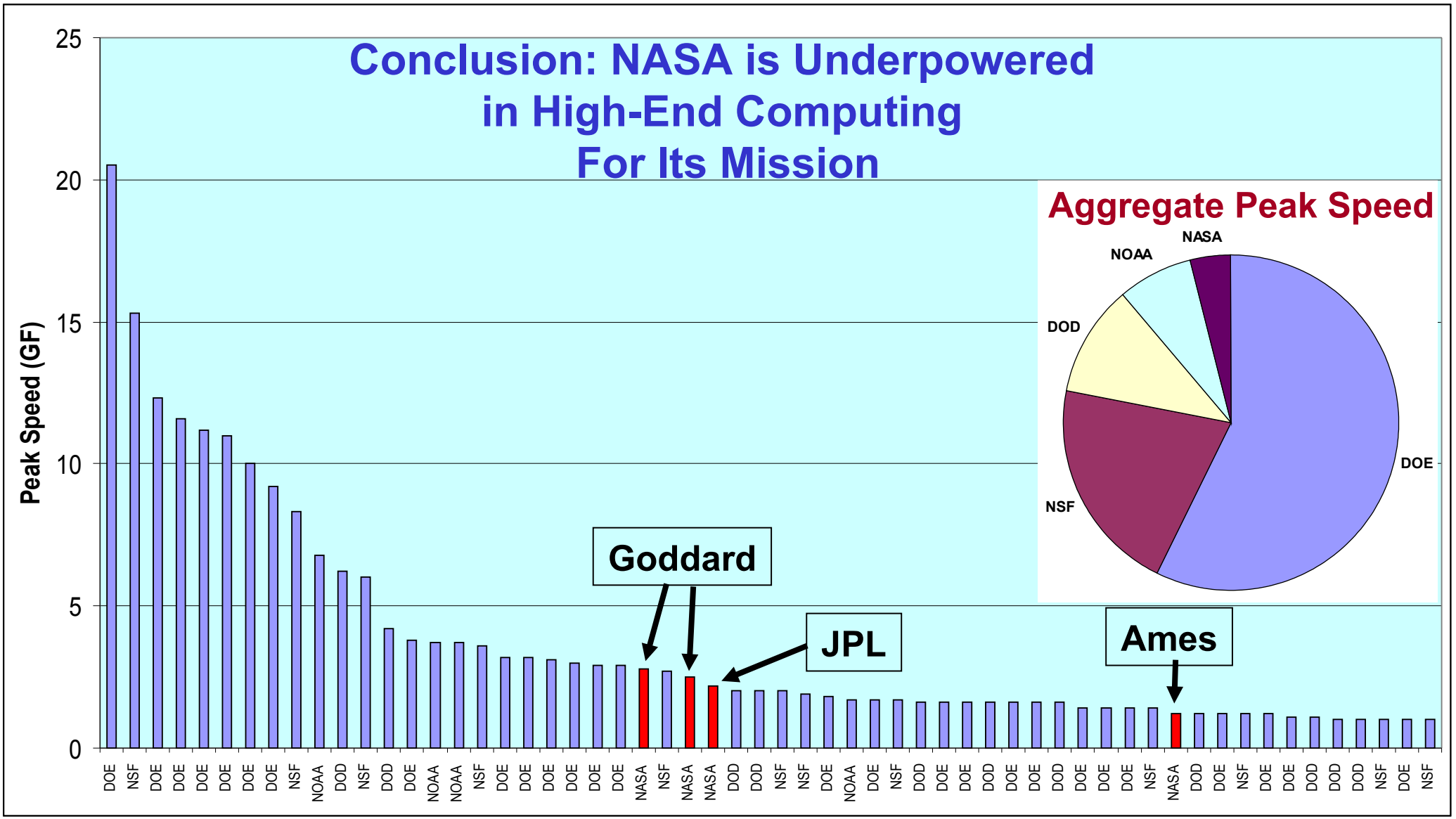


http://ensight.eos.nasa.gov/Missions/icesat/index.shtml

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Federal Agency Supercomputers Faster Than 1TeraFLOP Nov 2003



From Smarr March 2004 NAC Talk

Data From Top500 List (November 2003) Excluding No-name Agencies

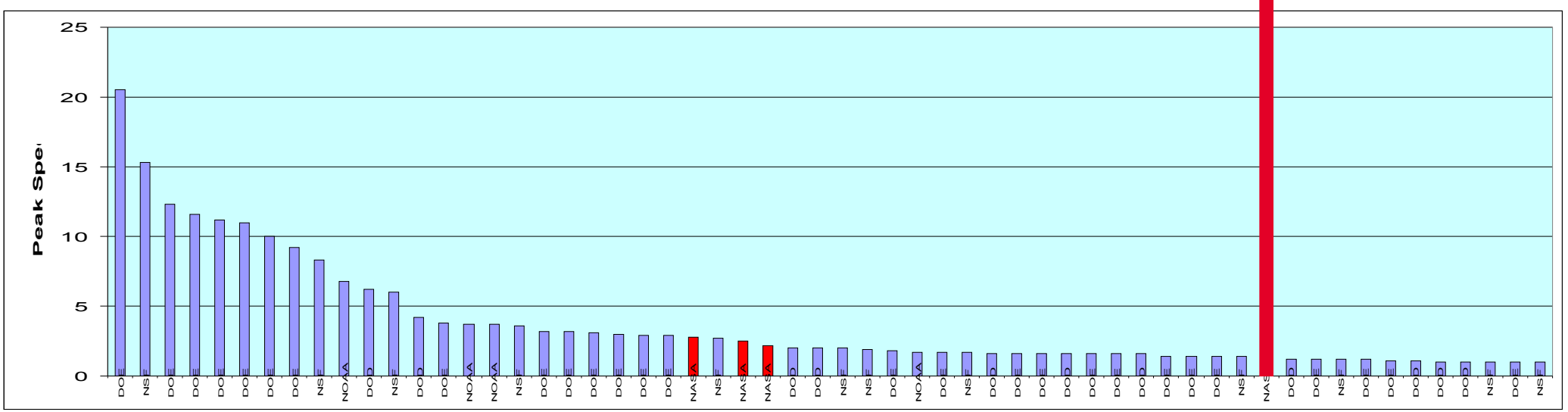
NASA Ames Brings Leadership to High-End Computing

Estimated #1 or 2
Top500 (Nov. 2004)

Project Columbia!

60TF

20 x 512-Processor
SGI Altix Single-System Image
Supercomputers
= 10,240 Intel IA-64 Processors

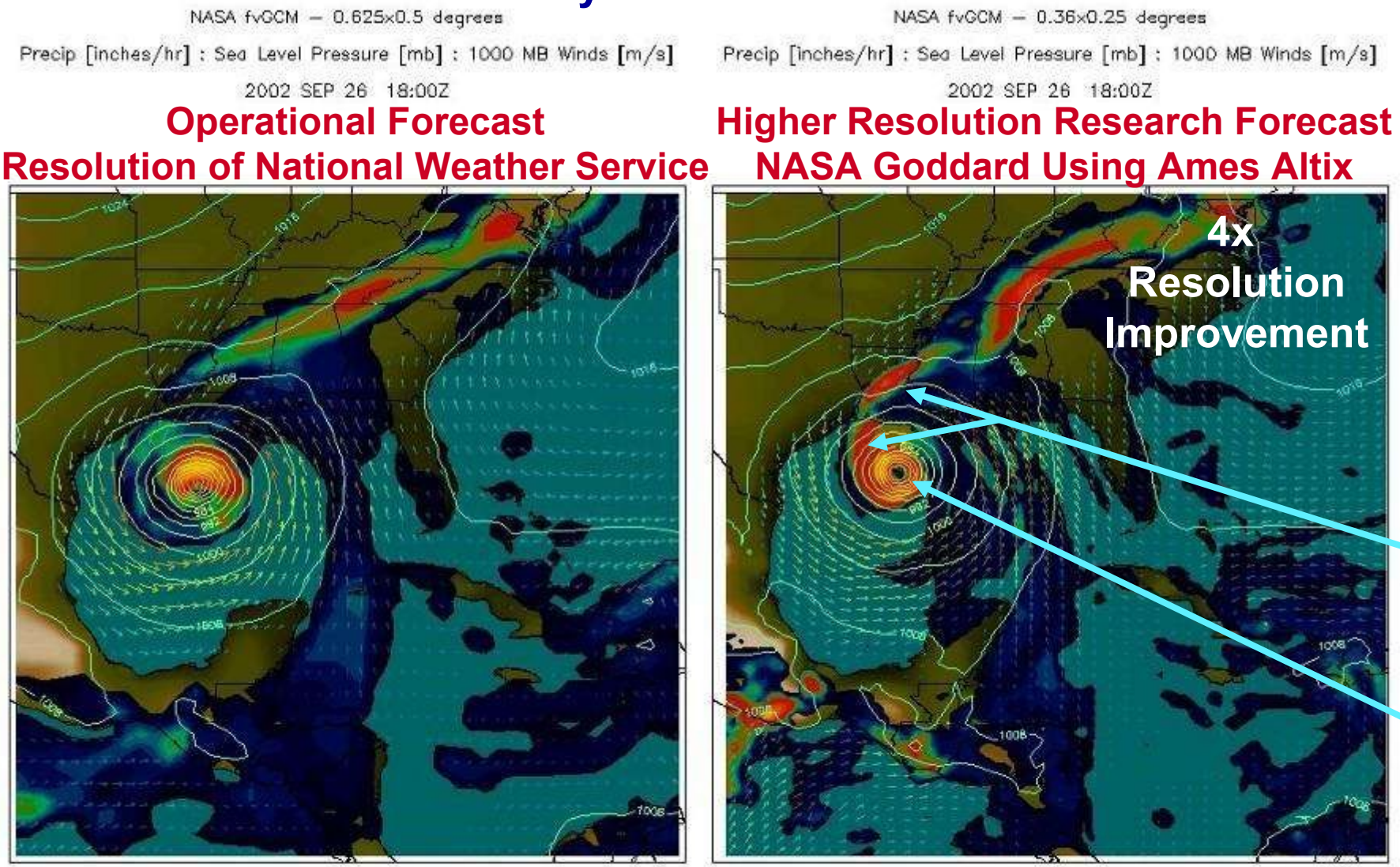


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Increasing Accuracy in Hurricane Forecasts Ensemble Runs With Increased Resolution

5.75 Day Forecast of Hurricane Isidore



Operational Forecast Resolution of National Weather Service

Higher Resolution Research Forecast NASA Goddard Using Ames Altix

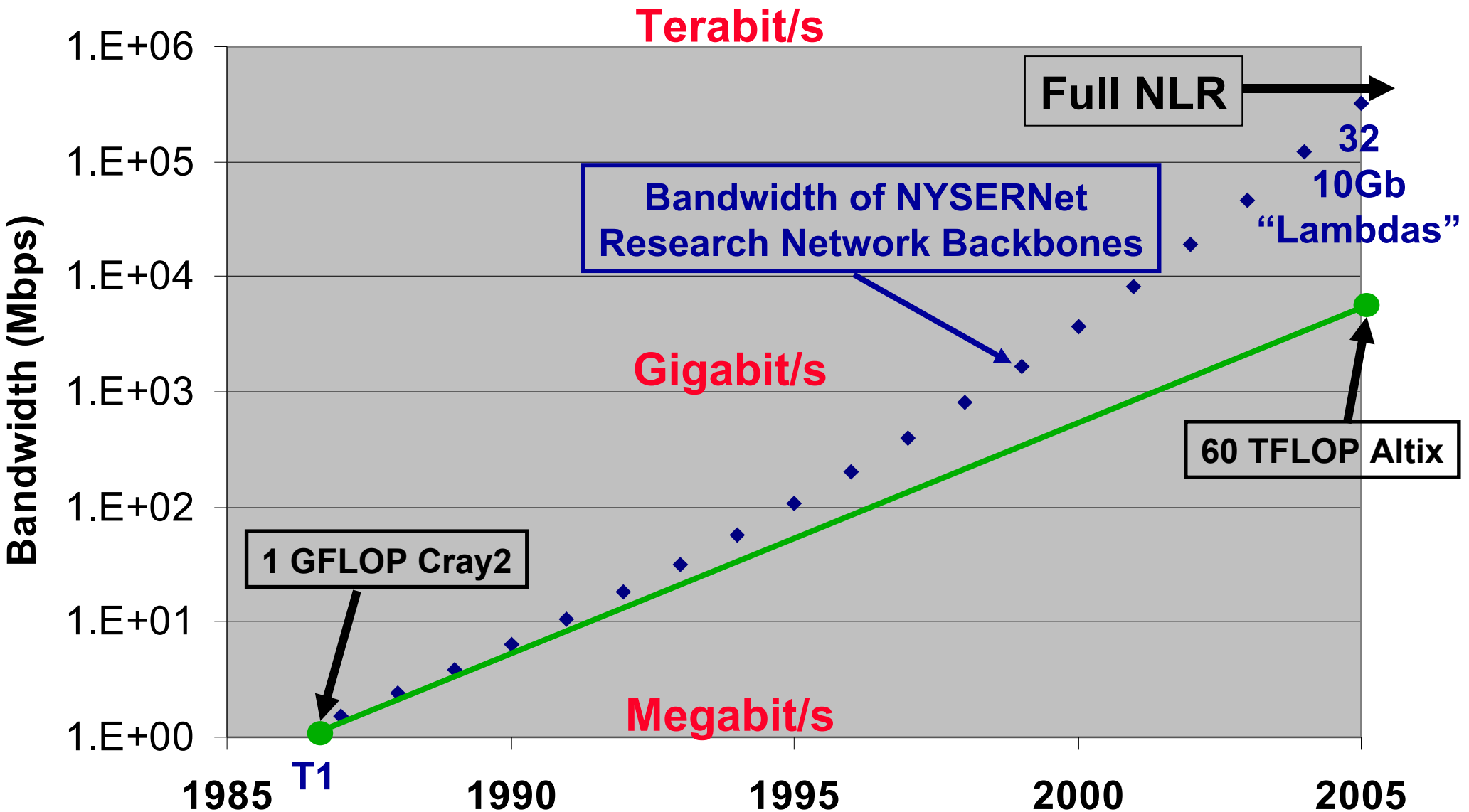
InterCenter Networking is Bottleneck

Intense Rain-Bands

Resolved Eye Wall

Source: Bill Putman, Bob Atlas, GFSC

Optical WAN Research Bandwidth Has Grown Much Faster than Supercomputer Speed!



Source: Timothy Lance, President, NYSERNet

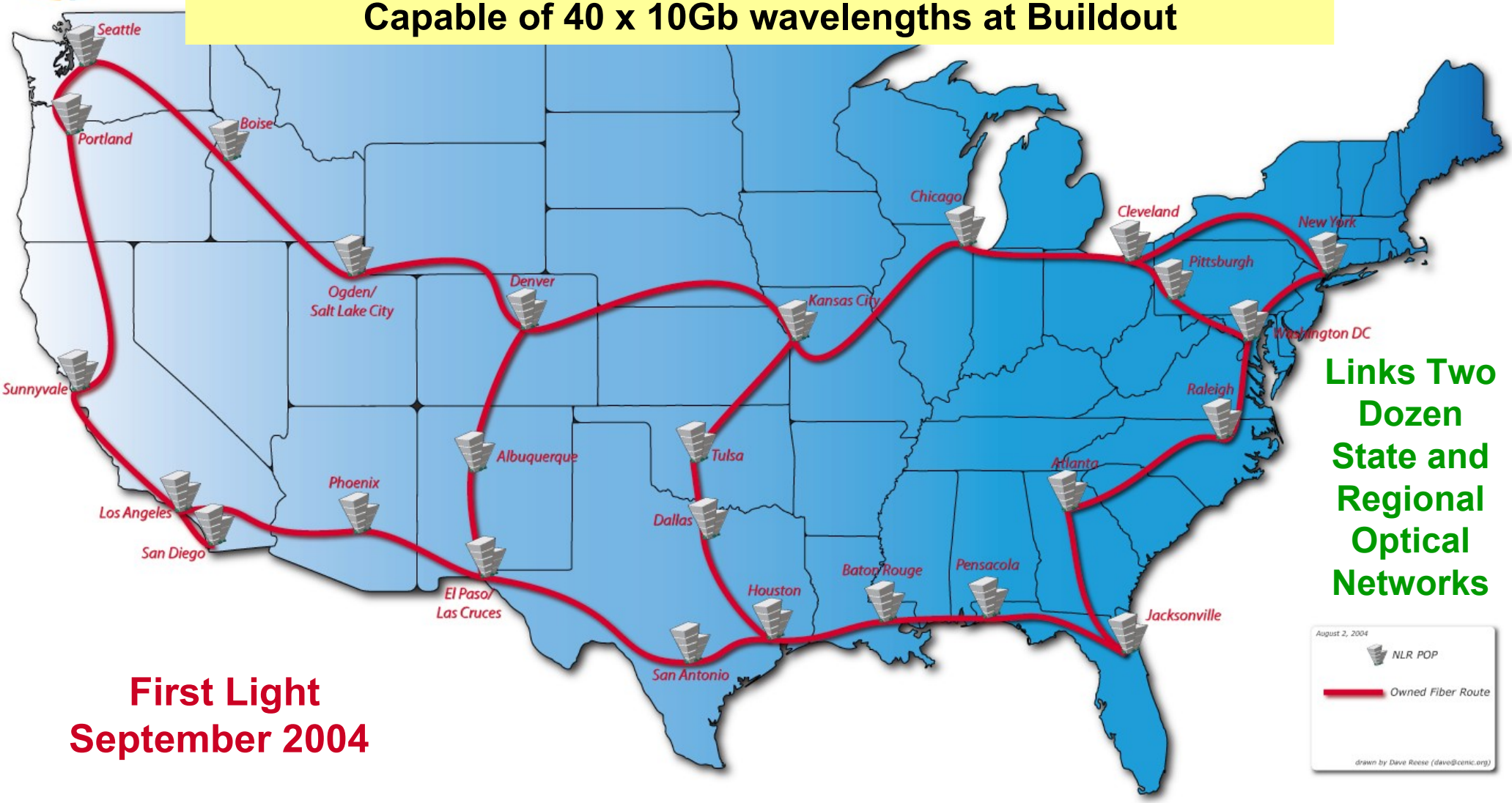
NLR Will Provide an Experimental Network Infrastructure for U.S. Scientists & Researchers

"National LambdaRail" Partnership

Serves Very High-End Experimental and Research Applications

4 x 10Gb Wavelengths Initially

Capable of 40 x 10Gb wavelengths at Buildout



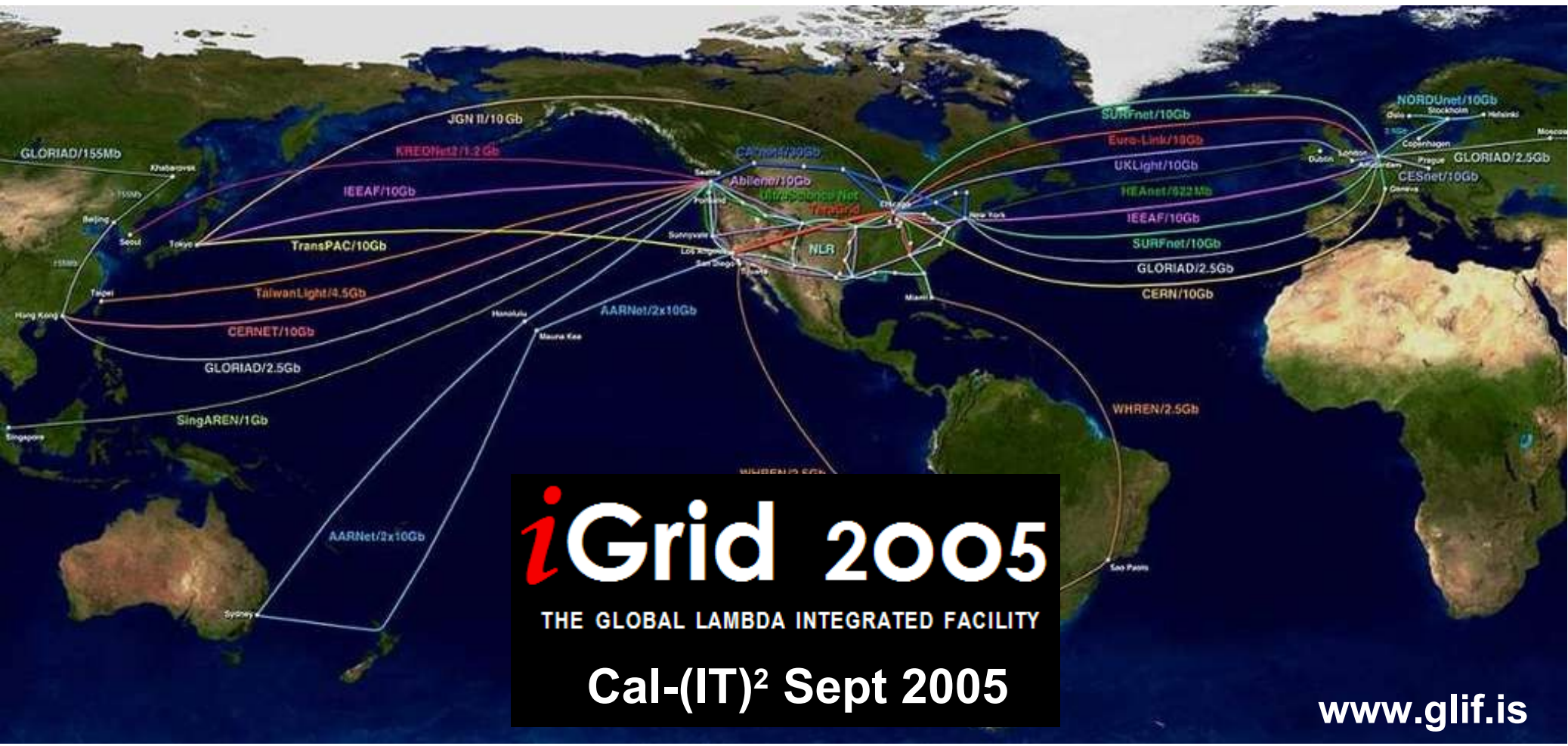
Links Two Dozen State and Regional Optical Networks

First Light September 2004

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

Global Lambda Integrated Facility: Coupled 1-10 Gb/s Research Lambdas

Predicted Bandwidth, to be Made Available for Scheduled Application and Middleware Research Experiments by December 2004



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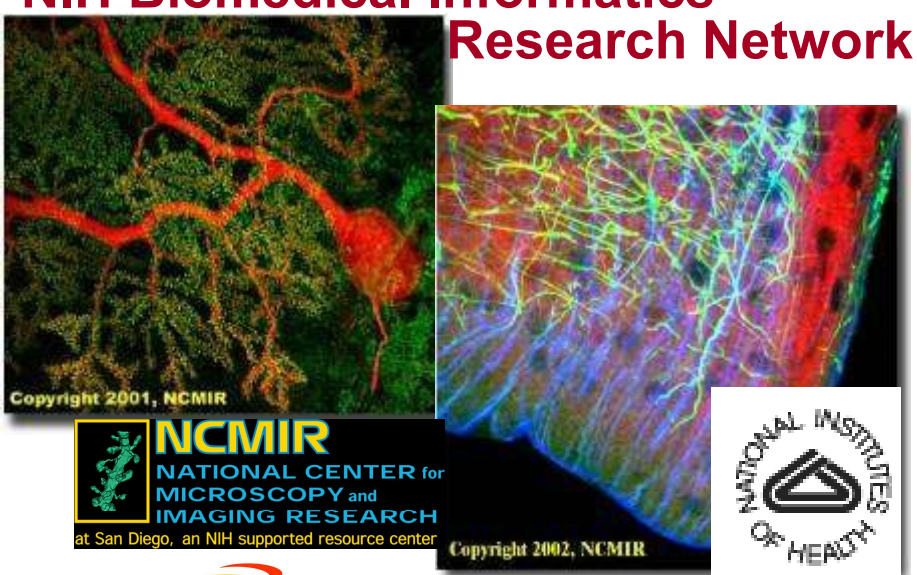
Visualization courtesy of
Bob Patterson, NCSA

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The OptIPuter Project –
Creating a LambdaGrid "Web" for Gigabyte Data Objects

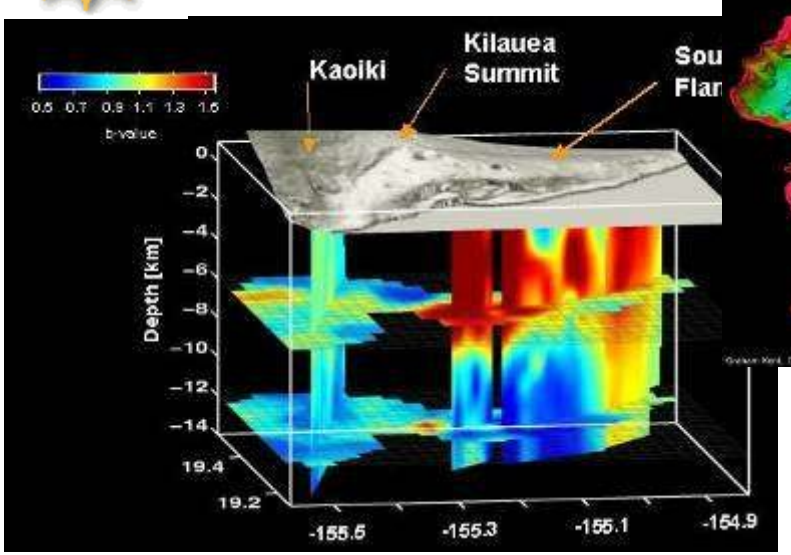
- NSF Large Information Technology Research Proposal
  - Cal-(IT)^2 and UIC Lead Campuses—Larry Smarr PI
  - USC, SDSU, NW, Texas A&M, Univ. Amsterdam Partnering Campuses
- Industrial Partners
  - IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent
- $13.5 Million Over Five Years
- Optical IP Streams From Lab Clusters to Large Data Objects

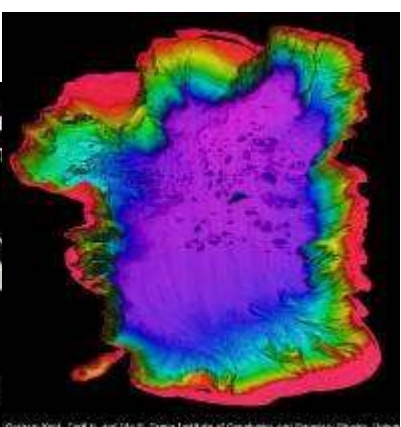
NIH Biomedical Informatics Research Network



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

NSF EarthScope and ORION





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

OptIPuter SDSC

What is the OptIPuter?

- **Optical networking, Internet Protocol, Computer Storage, Processing and Visualization Technologies**
  - **Dedicated Light-pipe (One or More 1-10 Gbps WAN Lambdas)**
  - **Links Linux Cluster End Points With 1-10 Gbps per Node**
  - **Clusters Optimized for Storage, Visualization, and Computing**
  - **Does NOT Require TCP Transport Layer Protocol**
  - **Exploring Both Intelligent Routers and Passive Switches**

- **Applications Drivers:**
  - **Interactive Collaborative Visualization of Large Remote Data Objects**
    - **Earth and Ocean Sciences**
    - **Biomedical Imaging**

- **The OptIPuter Exploits a New World in Which the Central Architectural Element is Optical Networking, NOT Computers - Creating "SuperNetworks"**

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Currently Developing OptIPuter Software to Coherently Drive 100 MegaPixel Displays

- 55-Panel Display
  - 100 Megapixel
- Driven by 30 Dual-Opterons (64-bit)
- 60 TB Disk
- 30 10GE interfaces
  - 1/3 Tera bit/sec!
- Linked to OptIPuter
- We are Working with NASA ARC Hyperwall Team to Unify Software



OptIPuter

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

it²

10GE OptIPuter CAVEWAVE Helped Launch the National LambdaRail



Next Step: Coupling NASA Centers to NSF OptIPuter

NASA

OptIPuter

Source: Tom DeFanti, OptIPuter co-PI

Interactive Retrieval and Hyperwall Display of Earth Sciences Images on a National Scale

Enables Scientists To Perform Coordinated Studies Of Multiple Remote-Sensing Or Simulation 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

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

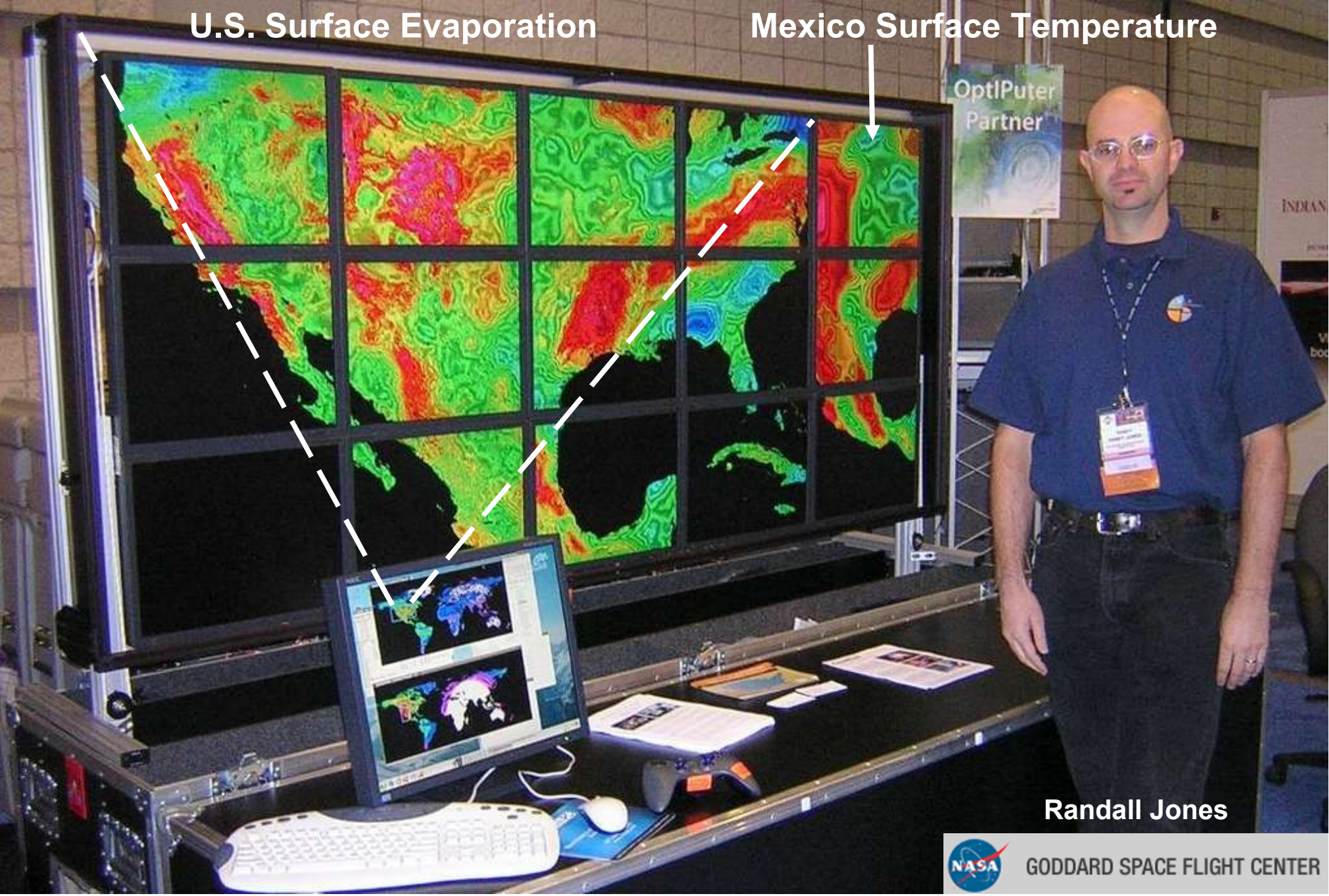
OptIPuter and NLR will Enable Daily Land Information System Assimilations

- **The Challenge:**
  - More Than Dozen Parameters, Produced Six Times A Day, Need to be Analyzed
- **The LambdaGrid Solution:**
  - Sending this Amount of Data to NASA Goddard from Project Columbia at NASA Ames for Human Analysis Would Require < 15 Minutes/Day Over NLR
- **The Science Result:**
  - Making Feasible Running This Land Assimilation System Remotely in Real Time

OptIPuter

Source: Milt Halem, NASA GSFC

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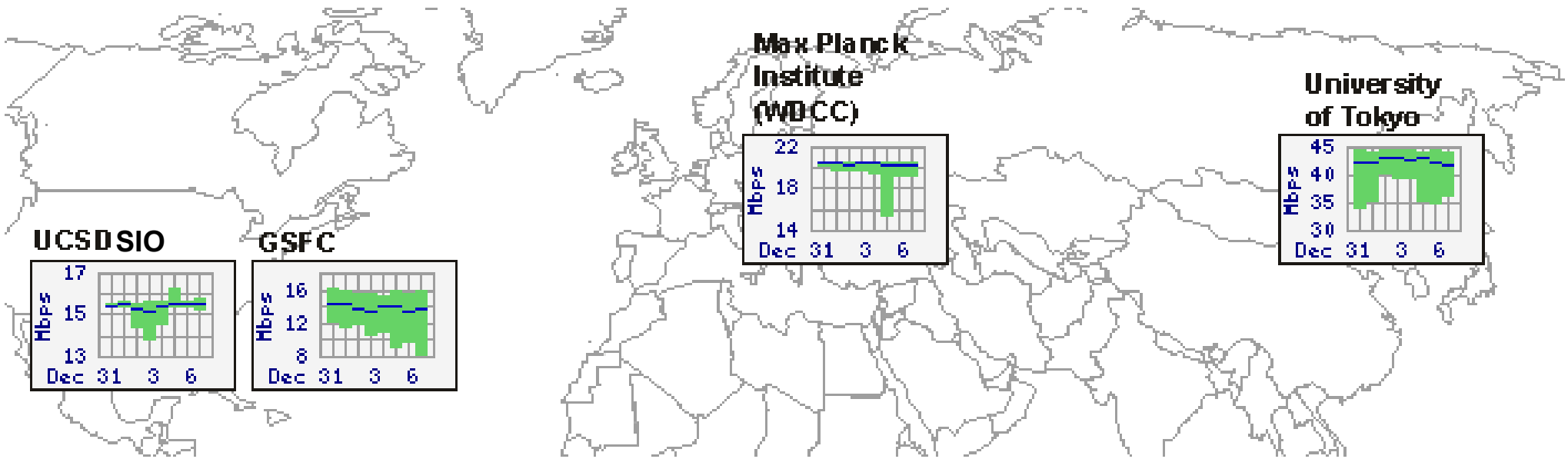
Global 1 km x 1 km Assimilated Surface Observations Analysis
Remotely Viewing ~ 50 GB per Parameter

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Next Step: 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



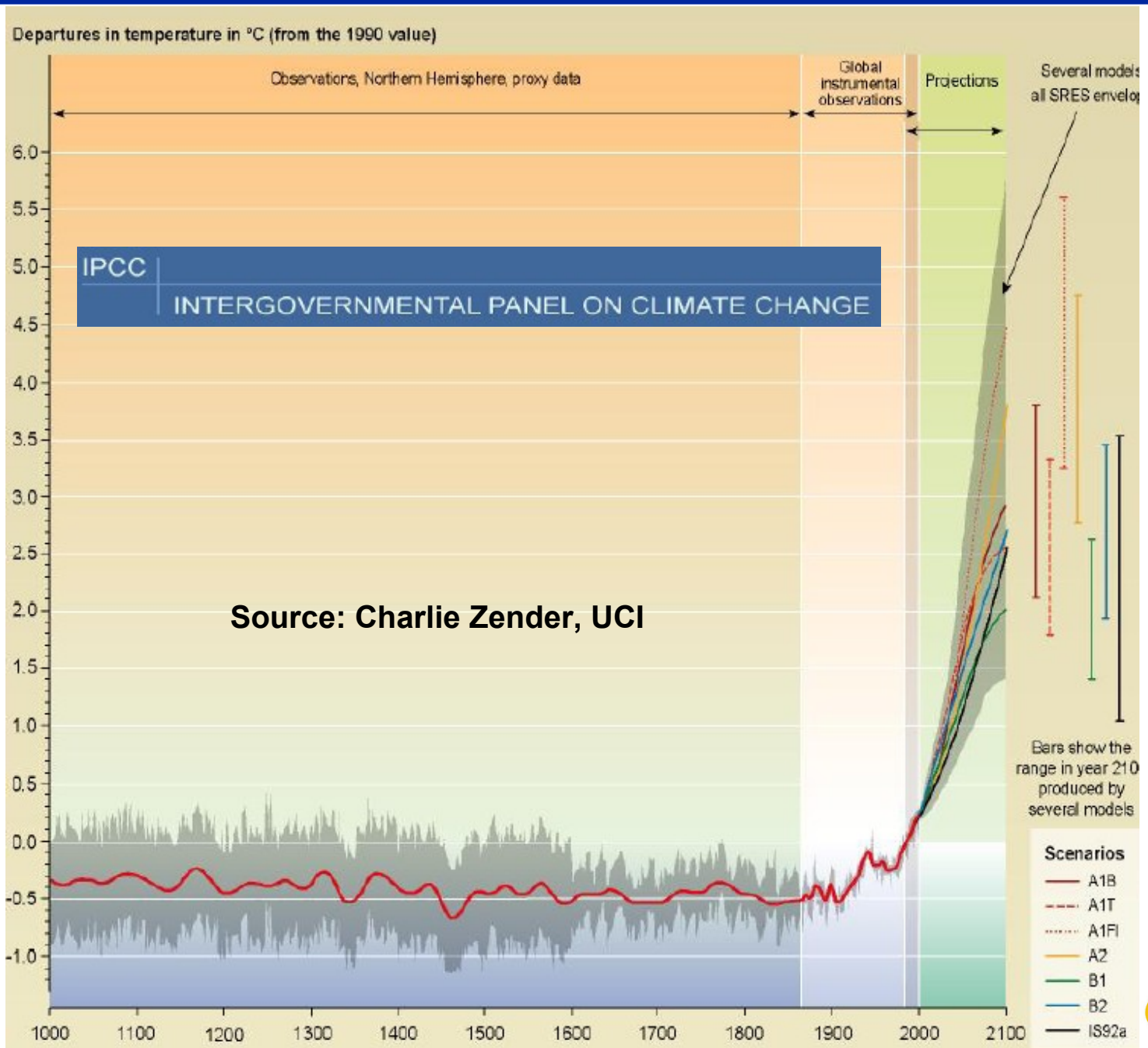
Note Current Throughput 15-45 Mbps:
OptIPuter 2005 Goal is ~1-10 Gbps!

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

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Variations of the Earth Surface Temperature Over One Thousand Years



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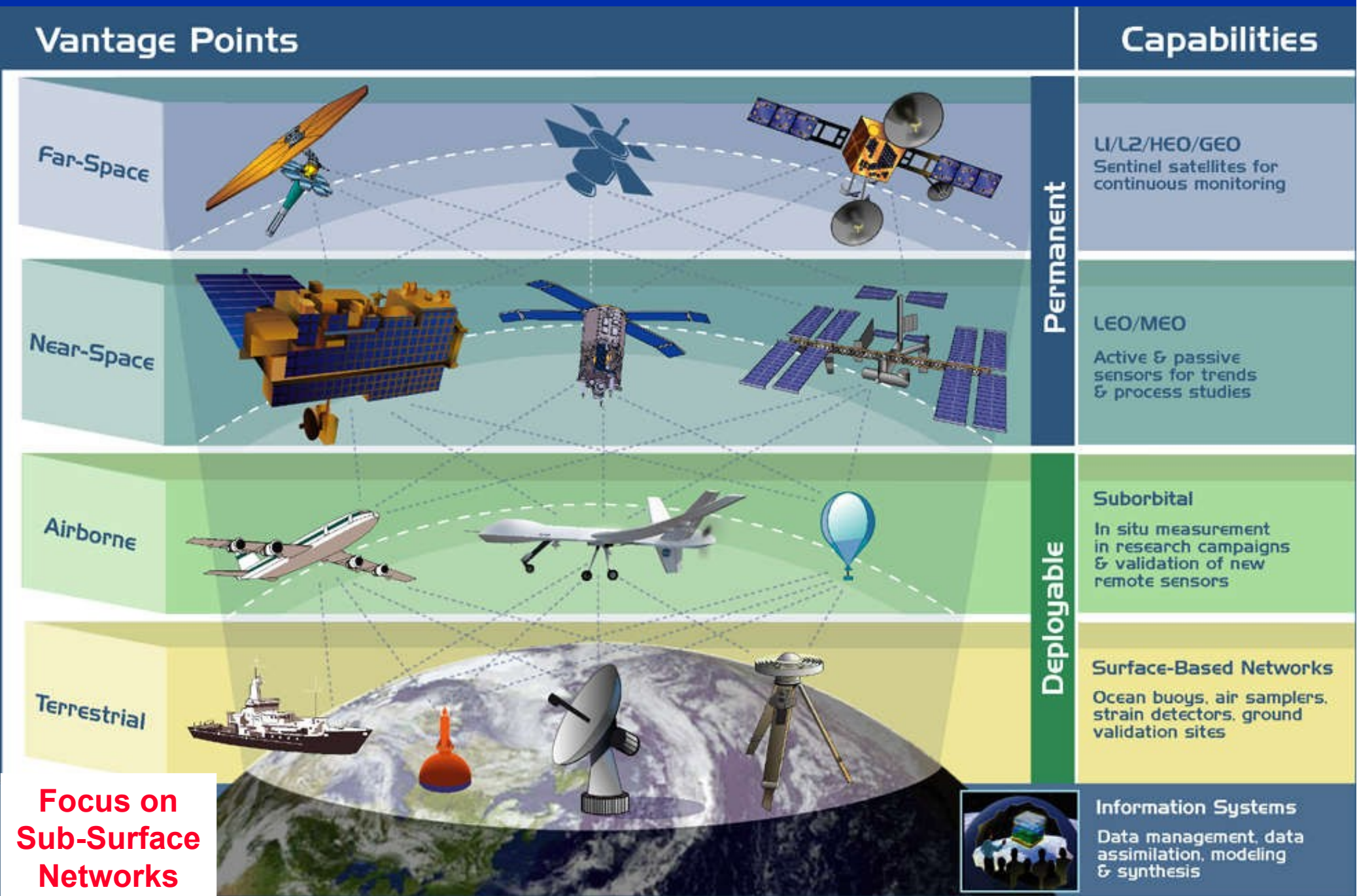
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Prototyping OptIPuter Technologies in Support of the IPCC

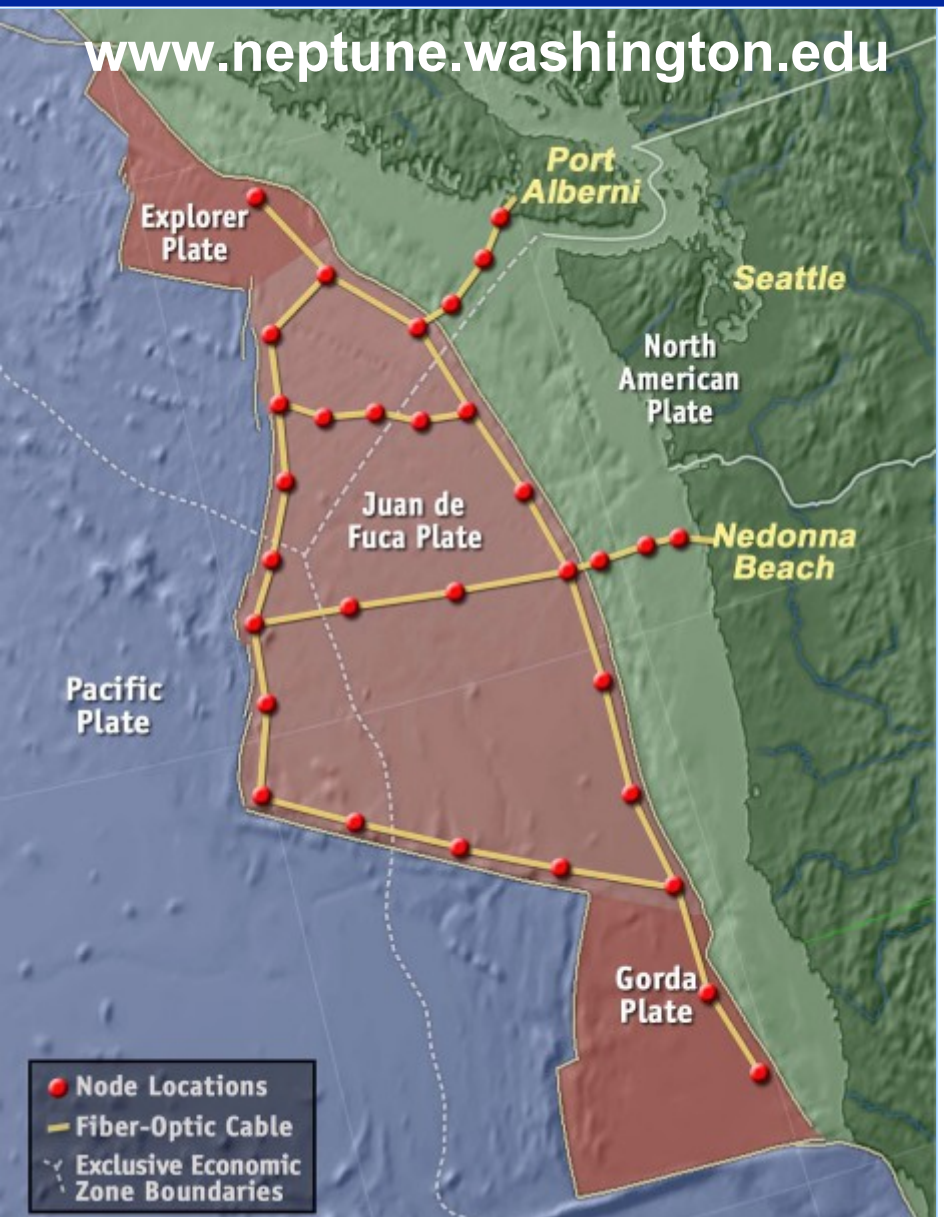
- **UCI Earth System Science Modeling Facility**
  - **Calit2 is Adding ESMF to the OptIPuter Testbed**
- **ESMF Challenge:**
  - **Improve Distributed Data Reduction and Analysis**
  - **Extending the NCO netCDF Operators**
    - **Exploit MPI-Grid and OPeNDAP**
  - **Link IBM Computing Facility at UCI over OptIPuter to:**
    - **Remote Storage**
      - at UCSD
      - Earth System Grid (LBNL, NCAR, ONRL) over NLR
- **Support Next IPCC Assessment Report**

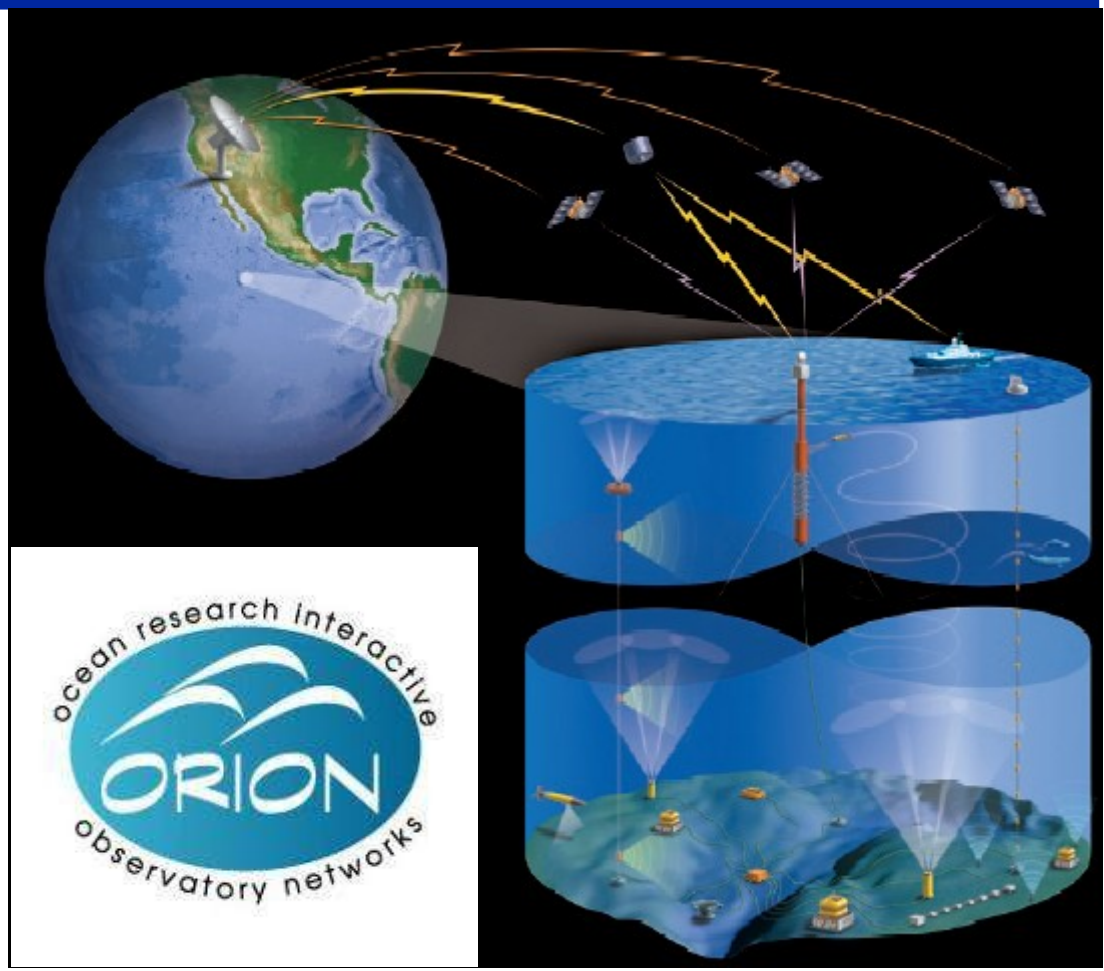
Source: Charlie Zender, UCI

Creating an Integrated Interactive Information System for Earth Exploration



New OptIPuter Driver: Gigabit Fibers on the Ocean Floor
Adding Web Services to LambdaGrids





LOOKING (Laboratory for the Ocean Observatory Knowledge Integration Grid) – Integrates Sensors From Canada and Mexico

OptIPuter

(Funded by NSF ITR- John Delaney, UWash, PI)

LOOKING -- Cyberinfrastructure for Interactive Ocean Observatories

- Laboratory for the Ocean Observatory Knowledge INtegration Grid
- NSF Information Technology Research (ITR) Grant 2004-2008
  - Cooperative Agreements with UW and Scripps/UCSD
  - Largest ITR Awarded by NSF in 2004
- Principal Investigators
  - John Orcutt & Larry Smarr - UCSD
  - John Delaney & Ed Lazowska --UW, Mark Abbott – OSU
  - Collaborators at MBARI, WHOI, NCSA, UIC, CalPoly, CANARIE, Microsoft, UVic, NEPTUNE-Canada
- Develop A Working Prototype Cyberinfrastructure for NSF's ORION
  - Fully Autonomous Robotic Sensor Network of Interactive Platforms
  - Capable of Evolving and Adapting to Changes in:
    - User Requirements,
    - Available Technology
    - Environmental Stresses
  - During The Life Cycle Of The Ocean Observatory

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LOOKING will Partner with the Southern California Coastal Ocean Observing System

- Cal Poly, San Luis Obispo
- Cal State Los Angeles
- CICESE
- NASA JPL
- Scripps Institution of Oceanography, University of California, San Diego
- Southern California Coastal Water Research Project Authority
- UABC
- University of California, Santa Barbara
- University of California, Irvine
- University of California, Los Angeles
- University of Southern California



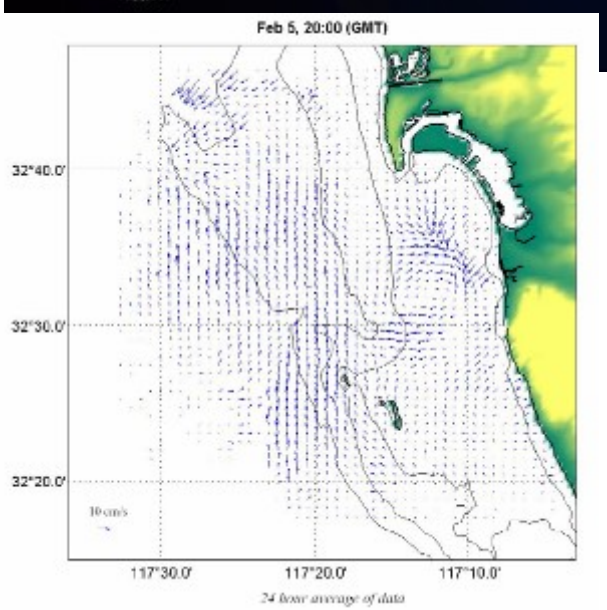
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SCCOOS
Pilot Project Components

- 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





ROADNet

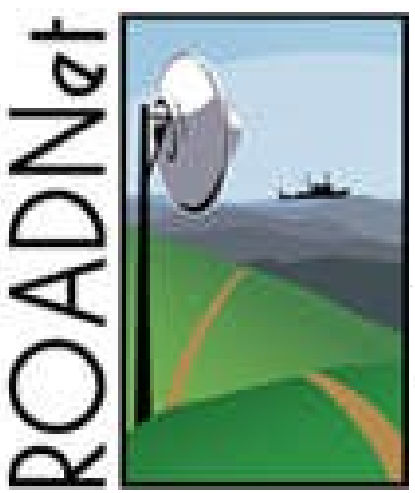
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www.sccoos.org/

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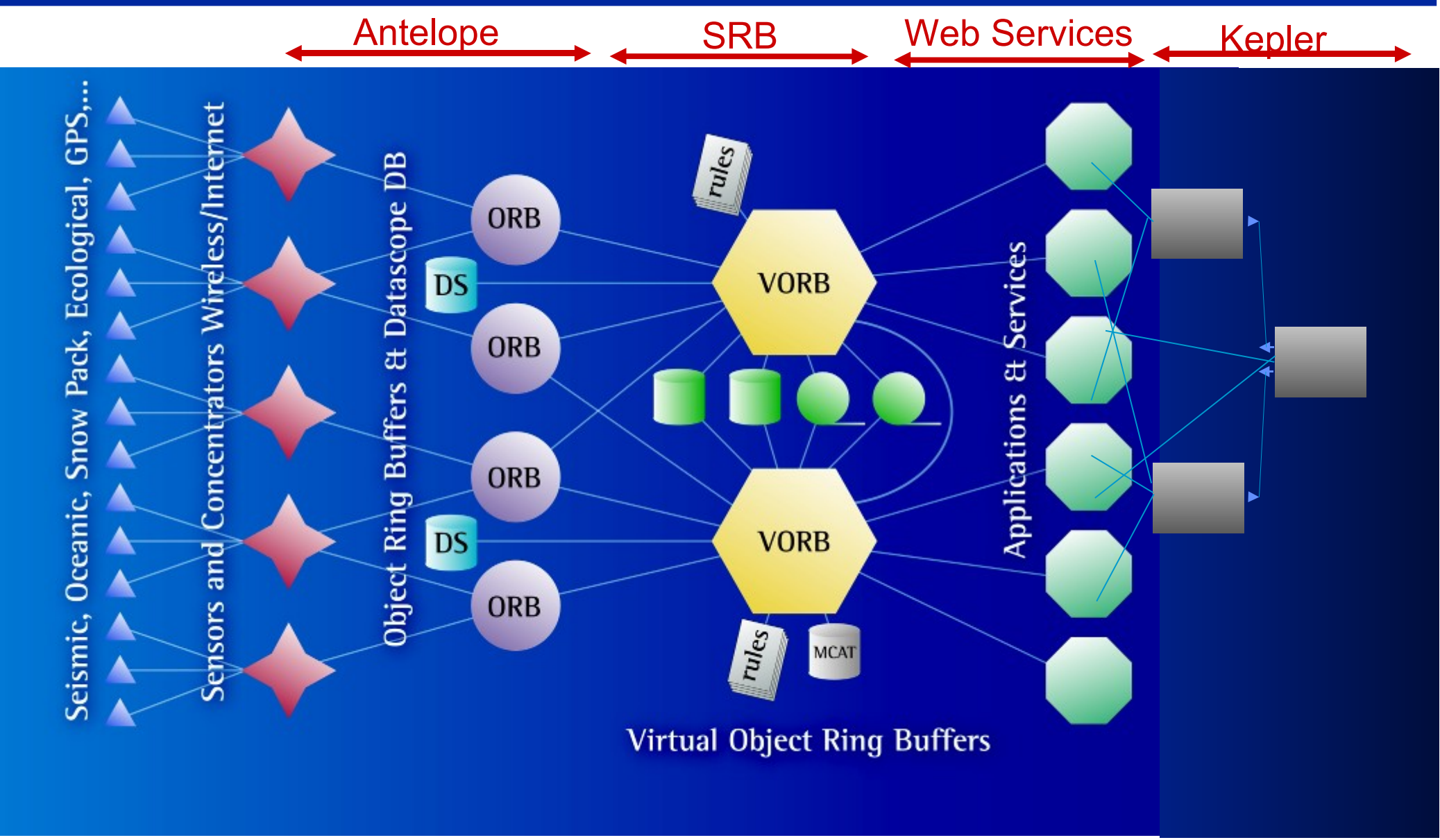
ROADNet Sensor Types

- Seismometers
- Accelerometers
- Displacement
- Barometric pressure
- Temperature
- Wind Speed
- Wind Direction
- Infrasound
- Hydroacoustic
- Differential Pressure Gauges
- Strain
- Solar Insolation
- pH
- Electric Current
- Electric Potential
- Dilution of oxygen
- Still Camera Images
- Codar

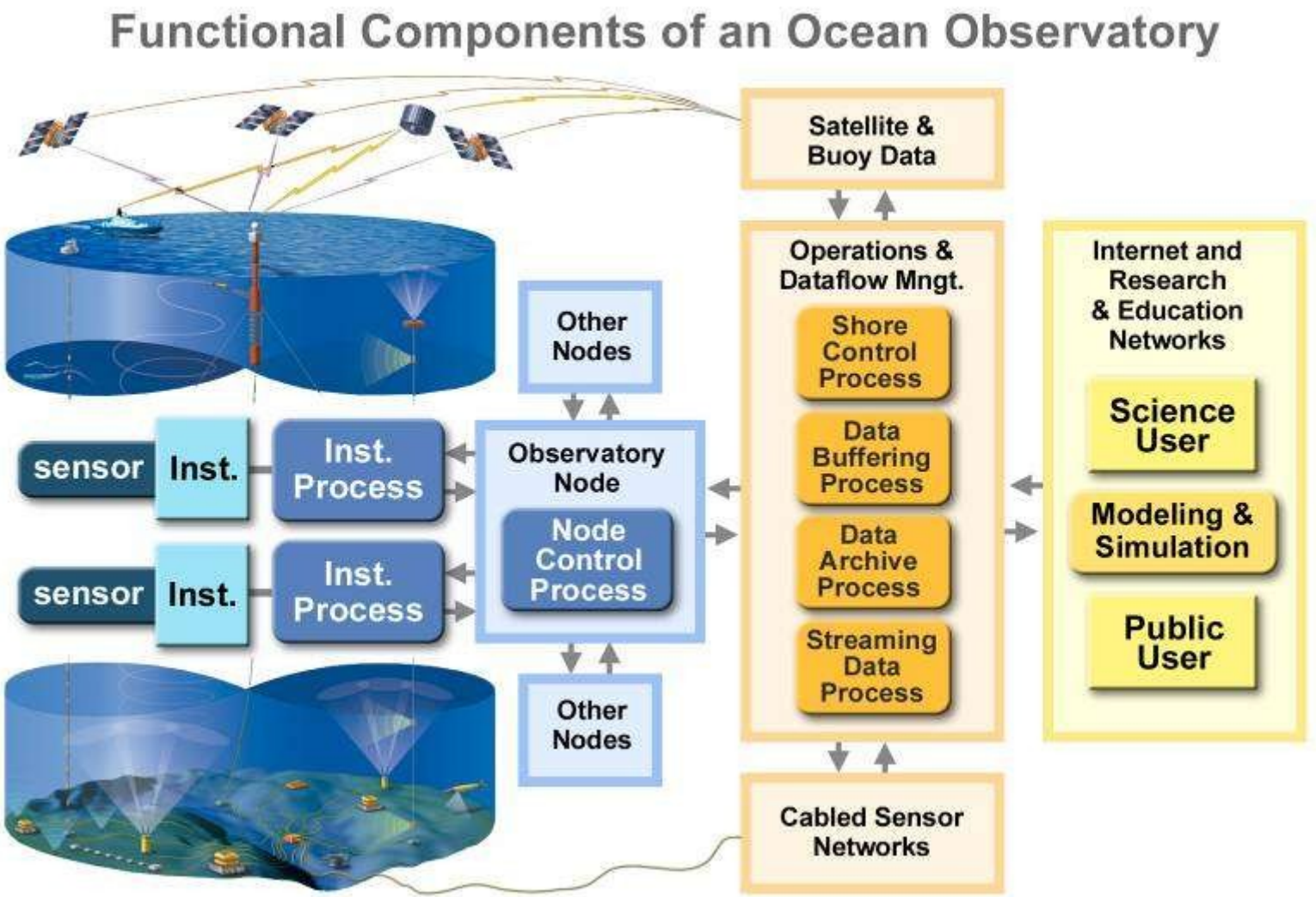


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ROADNet Architecture



Applying Web Services to the Interactive Earth Observing Vision



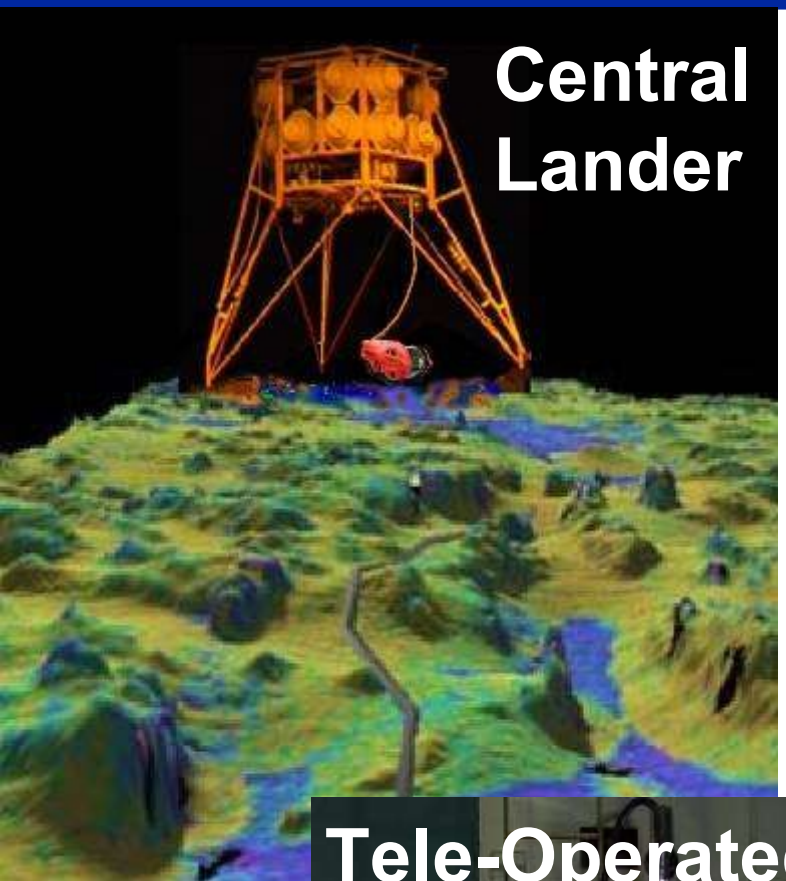
Federated System of Ocean Observatory Networks
Extending from the Wet Side to a Shore-Based Observatory
Control Facilities onto the Internet Connecting to Scientists
and Their Virtual Ocean Observatories

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MARS New Gen Cable Observatory Testbed - Capturing Real-Time Basic Environmental Data





Source:
Jim
Bellingham,
MBARI

OptIPuter

