“A Gigabit in Every Home—
The Emergence of True Broadband"

Keynote
FirstMile.US Spring 2006 Conference
Calit2@UCSD
La Jolla, CA
March 22, 2006

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





From Bleeding Edge Research to Your Home
15 Years ~ 1000x with Moore's Law

- **1990 Leading Edge University Research Center-NCSA**
  - **Supercomputer GigaFLOPS Cray Y-MP ($15M)**
  - **Megabit/s NSFnet Backbone**



- **2005 Mass Consumer Market**
  - **PCs are Multi-Gigahertz ($1.5k)**
  - **Megabit/s Home DSL or Cable Modem**

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"The future is already here, it's just not evenly distributed"
William Gibson, Author of Neuromancer



- **Home Broadband**
  - **1-5 Mbps**



- **University Dorm Room Broadband**
  - **10-100 Mbps**



- **Calit2 Global Broadband**
  - **1,000-10,000 Mbps**

The Broadband Agenda Has Reached the White House



President George W. Bush discusses the benefits of broadband and wireless technology during a demonstration of such technologies at the U.S. Department of Commerce Thursday, June 24, 2004.

Promoting Innovation and Economic Security through Broadband Technology:

The President has called for universal, affordable access for broadband technology by the year 2007 and wants to make sure we give Americans plenty of technology choices when it comes to purchasing broadband.

www.whitehouse.gov/infocus/technology/

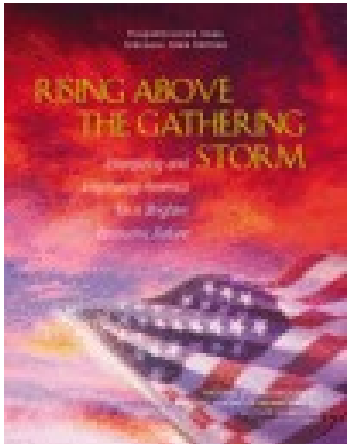
What Actions Should America Take in Economic and Technology Policy to Remain Prosperous in The 21st Century:

Incentives For Innovation

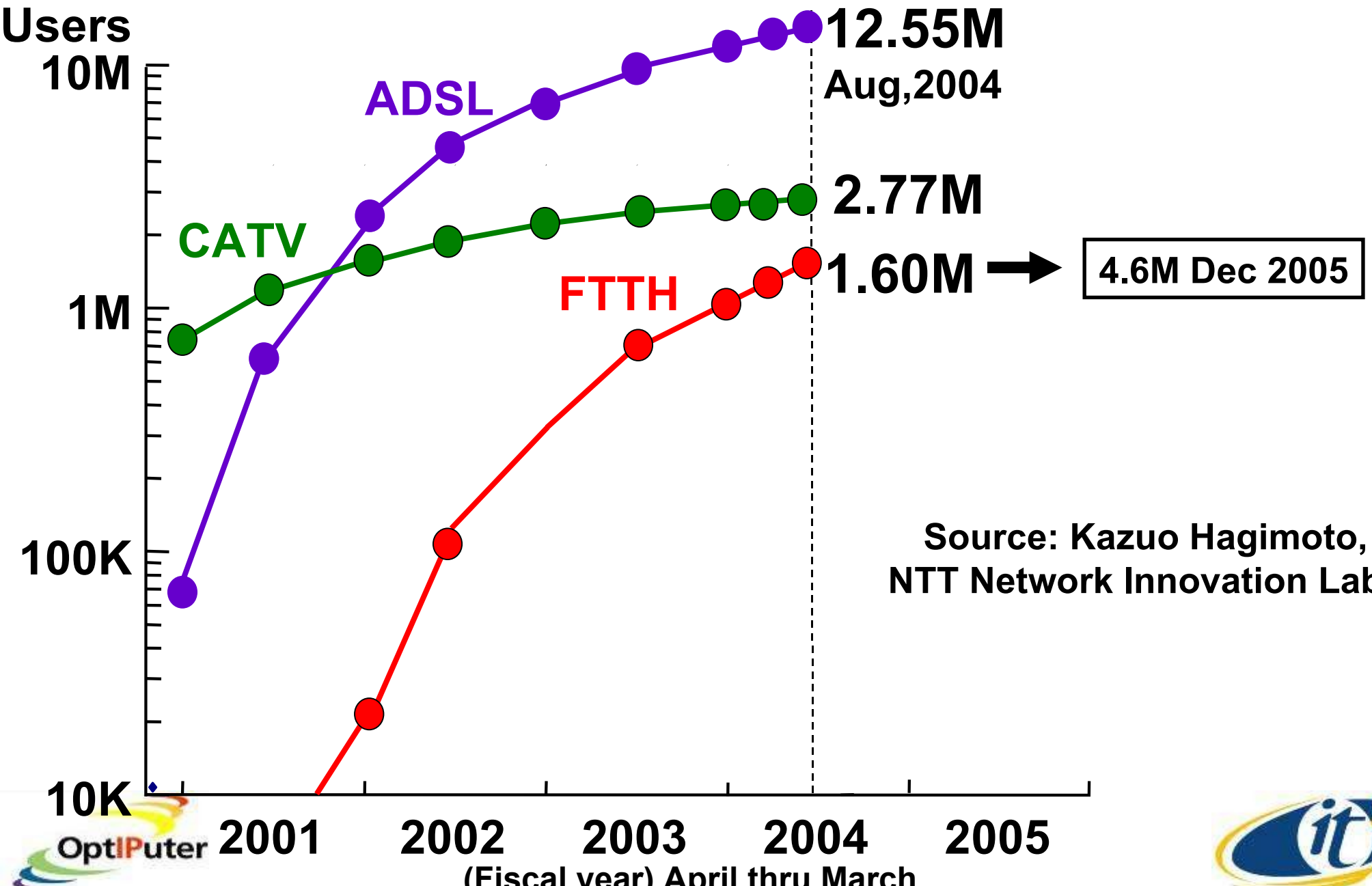
Action D-4: Ensure Ubiquitous Broadband Internet Access.

Several nations are well ahead of the United States in providing broadband access for home, school, and business. That capability can be expected to do as much to drive innovation, the economy, and job creation in the 21st century as did access to the telephone, interstate highways, and air travel in the 20th century. Congress and the administration should take action—mainly in the regulatory arena and in spectrum management—to ensure widespread affordable broadband access in the very near future.

Rising Above The Gathering Storm:
Energizing and Employing America for a Brighter Economic Future
Committee on Prospering in the Global Economy of the 21st Century:
An Agenda for American Science and Technology—NAS, NAE, IOM



Broadband Service Users in Japan: Moving Quickly to Fiber to the Home

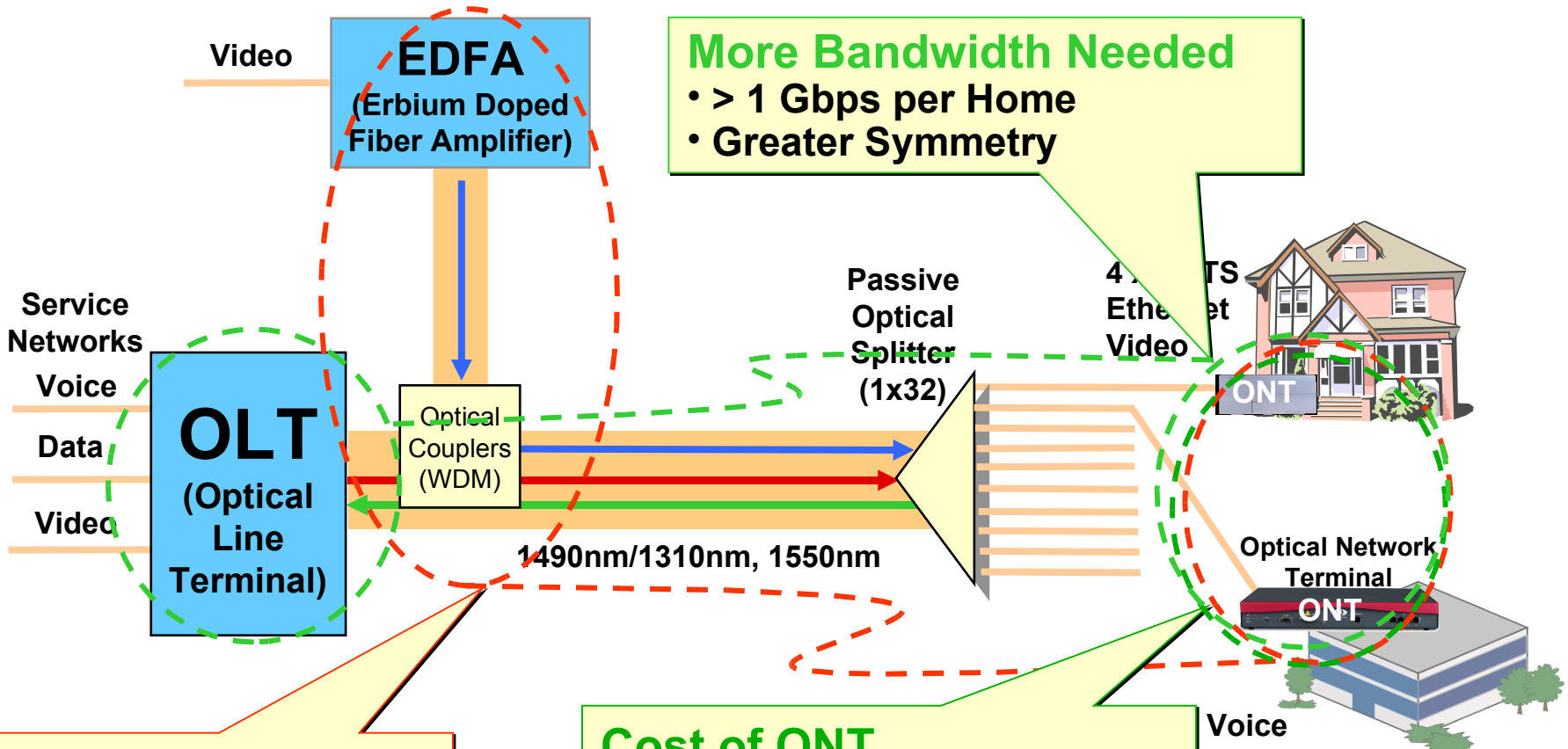


Source: Kazuo Hagimoto, NTT Network Innovation Labs

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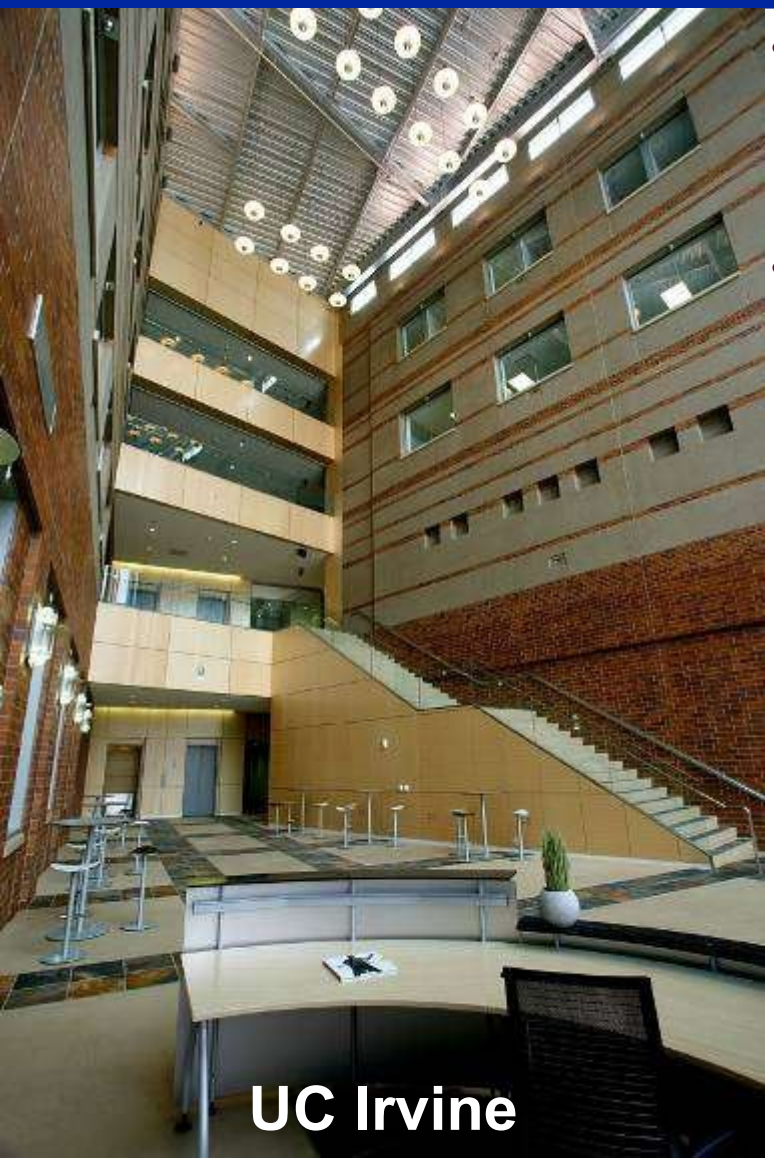
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Verizon Fiber to the Premise: Bringing Gigabit/s to the Home



Source: Stuart Elby
VP – Network Architecture, Verizon Technology Org
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Information contained herein is subject to change without notice.

Two New Calit2 Buildings Will Provide Major New Laboratories to Their Campuses



- New Laboratory Facilities
  - Nanotech, BioMEMS, Chips, Radio, Photonics, Grid, Data, Applications
  - Virtual Reality, Digital Cinema, HDTV, Synthesis
- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks
  - International Conferences and Testbeds

Richard C. Atkinson Hall Dedication Oct. 28, 2005

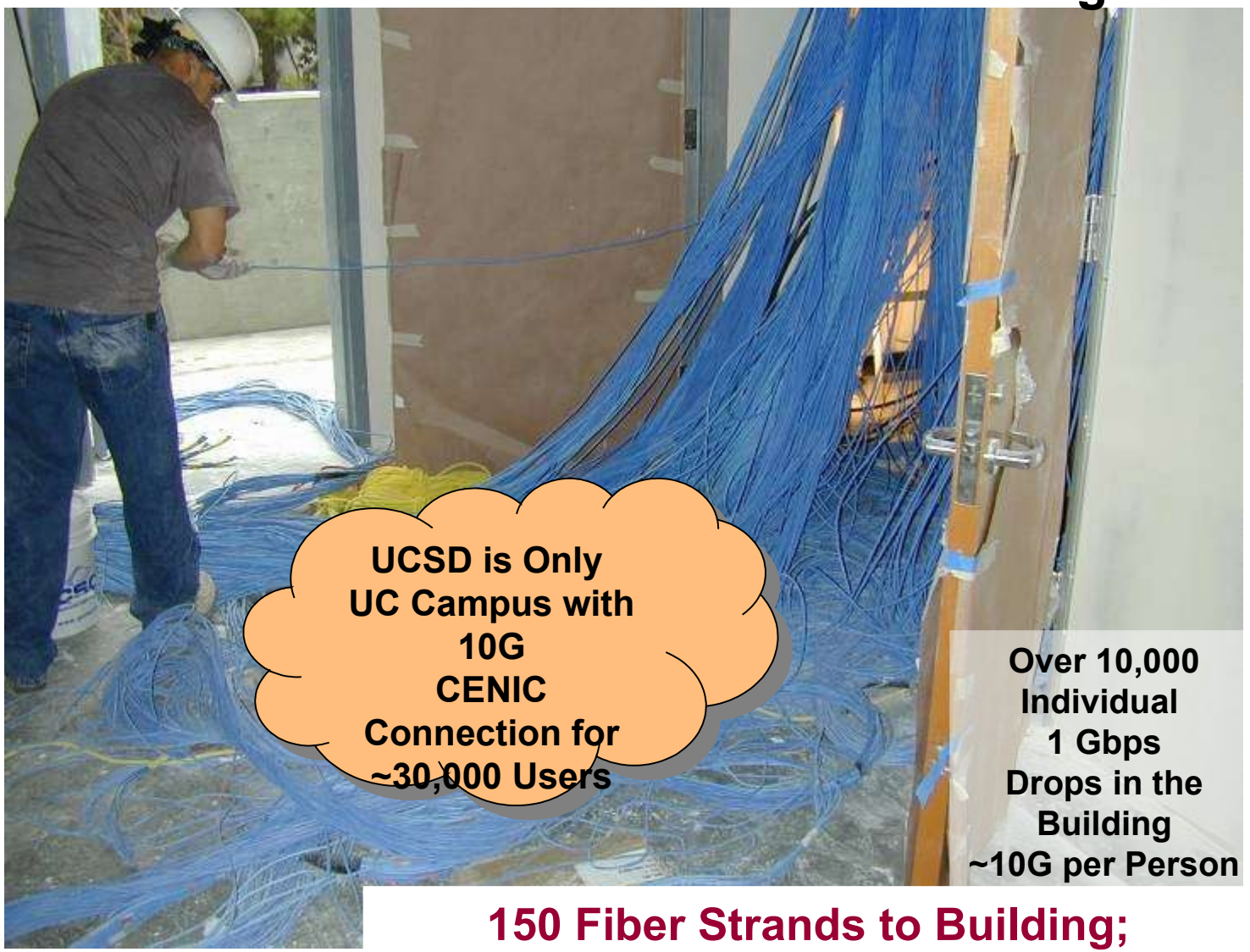


www.calit2.net

Preparing for an World in Which Distance Has Been Eliminated…

The Calit2@UCSD Building is Designed for Prototyping Extremely High Bandwidth Applications

1.8 Million Feet of Cat6 Ethernet Cabling



24 Fiber Pairs to Each Lab

150 Fiber Strands to Building;
Experimental Roof Radio Antenna Farm
Ubiquitous WiFi

Photo: Tim Beach, Calit2

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Prototyping the PC of 2015
One Hundred Million Pixels Connected at 10Gbps

Calit2 Working with NASA, USGS, NOAA, NIEHS, EPA, SDSU, SDSC, Duke, …

100M Pixel Tiled Wall in Calit2@UCSD Building



Source: Jason Leigh, EVL, UIC

Global Connections
Between University Research Centers at 10Gbps

Maxine Brown, Tom DeFanti, Co-Chairs

iGrid 2005

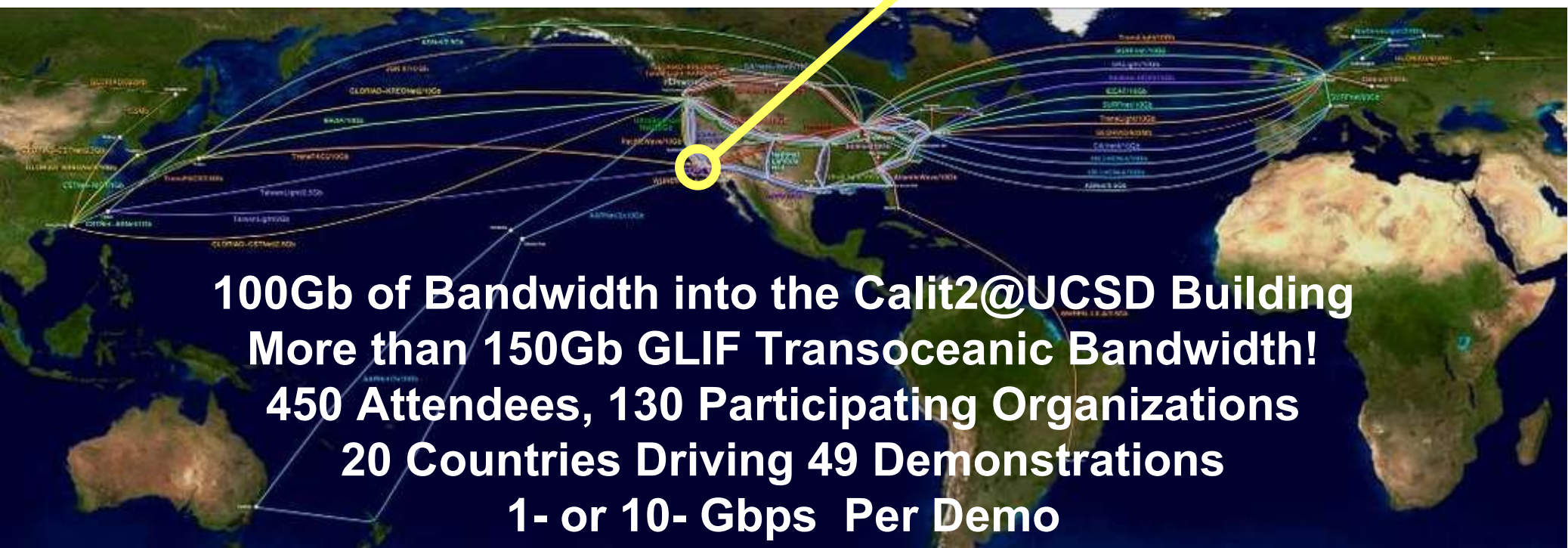
THE GLOBAL LAMBDA INTEGRATED FACILITY

www.igrid2005.org



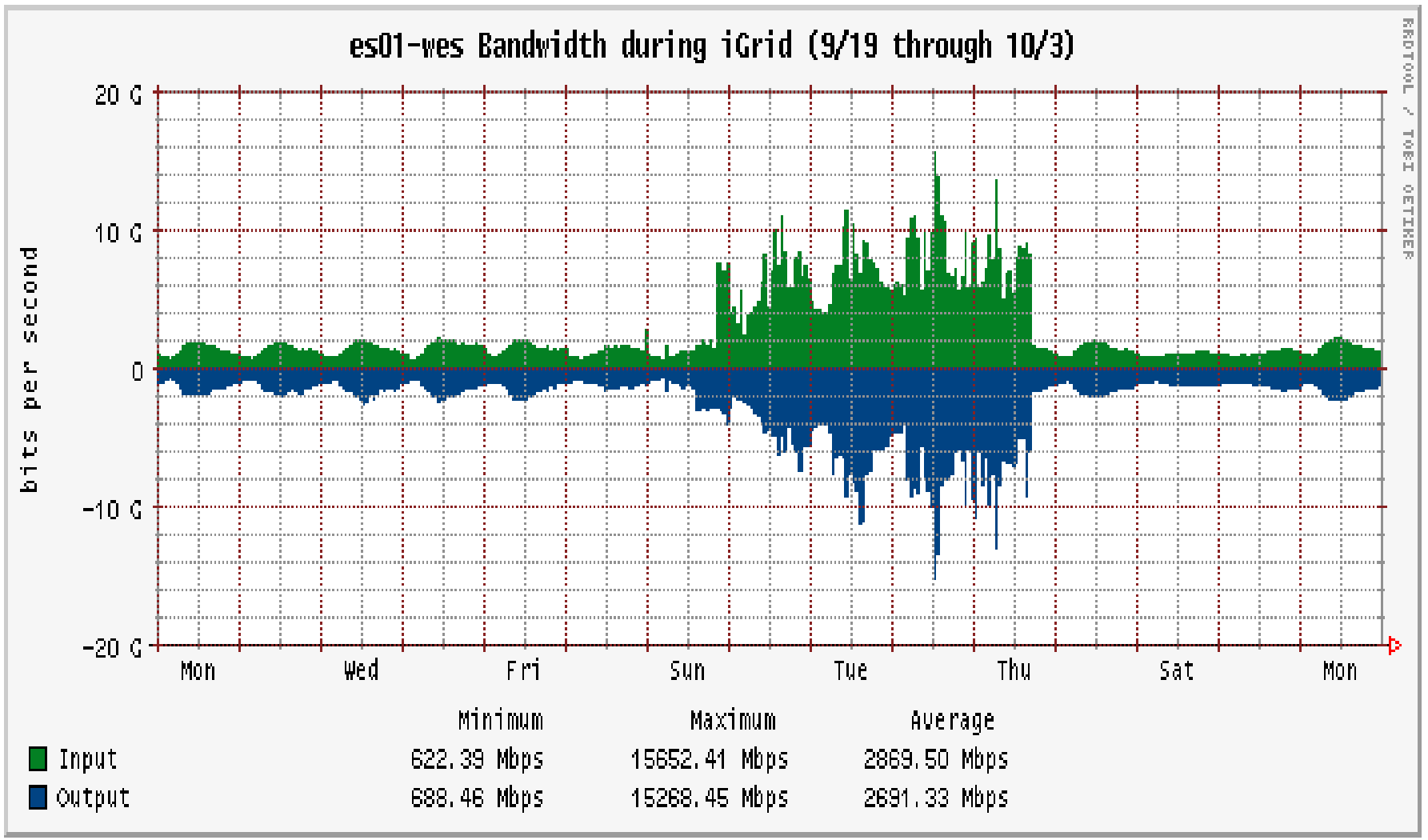
the UC Discovery Grant

September 26-30, 2005
Calit2 @ University of California, San Diego
California Institute for Telecommunications and Information Technology



100Gb of Bandwidth into the Calit2@UCSD Building
More than 150Gb GLIF Transoceanic Bandwidth!
450 Attendees, 130 Participating Organizations
20 Countries Driving 49 Demonstrations
1- or 10- Gbps Per Demo

iGrid2005 Data Flows Multiplied Normal Flows by Five Fold!



Data Flows Through the Seattle PacificWave International Switch

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CENIC 2006 Innovation Award for Experimental/Developmental Applications



iGrid2005 www.igrid2005.org

iGrid 2005: Demonstrating Emerging LambdaGrid Services

- Data
- High-Definition Video & Digital Cinema Streaming
- Distributed High-Performance Computing
- Lambda Control
- Lambda Security
- Scientific Instruments
- Visualization And Virtual Reality
- e- Science

Maxine Brown Has Classified All 49 iGrid2005 Demonstrations Into These Categories

Source: Maxine Brown-EVL, UIC

iGrid Lambda Data Services: Sloan Sky Survey Data Mining and Visualizing Data Using OptIPuter

- **SDSS-I**
  - Imaged 1/4 of the Sky in Five Bandpasses
    - 8000 sq-degrees at 0.4 arc sec Accuracy
  - Detecting Nearly 200 Million Celestial Objects
  - Measured Spectra Of:
    - > 675,000 galaxies
    - 90,000 quasars
    - 185,000 stars
- **SDSS-II**
  - Underway till 2008

~200 GigaPixels!

iGRID2005
From Federal Express to Lambdas: Transporting Sloan Digital Sky Survey Data Using UDT
Robert Grossman, UIC with

Johns Hopkins University, USA; Korea Astronomy and Space Science Institute, KISTI, Korea; University of Tokyo, Japan; National Astronomical Observatory, Chinese Academy of Sciences, China; University of Melbourne, Australia; Max-Planck-Institut fur Plasmaphysik, Germany

SDSS

Sloan Digital Sky Survey



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www.sdss.org

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iGrid Lambda Control Services: Transform Batch to Real-Time Global e-Very Long Baseline Interferometry

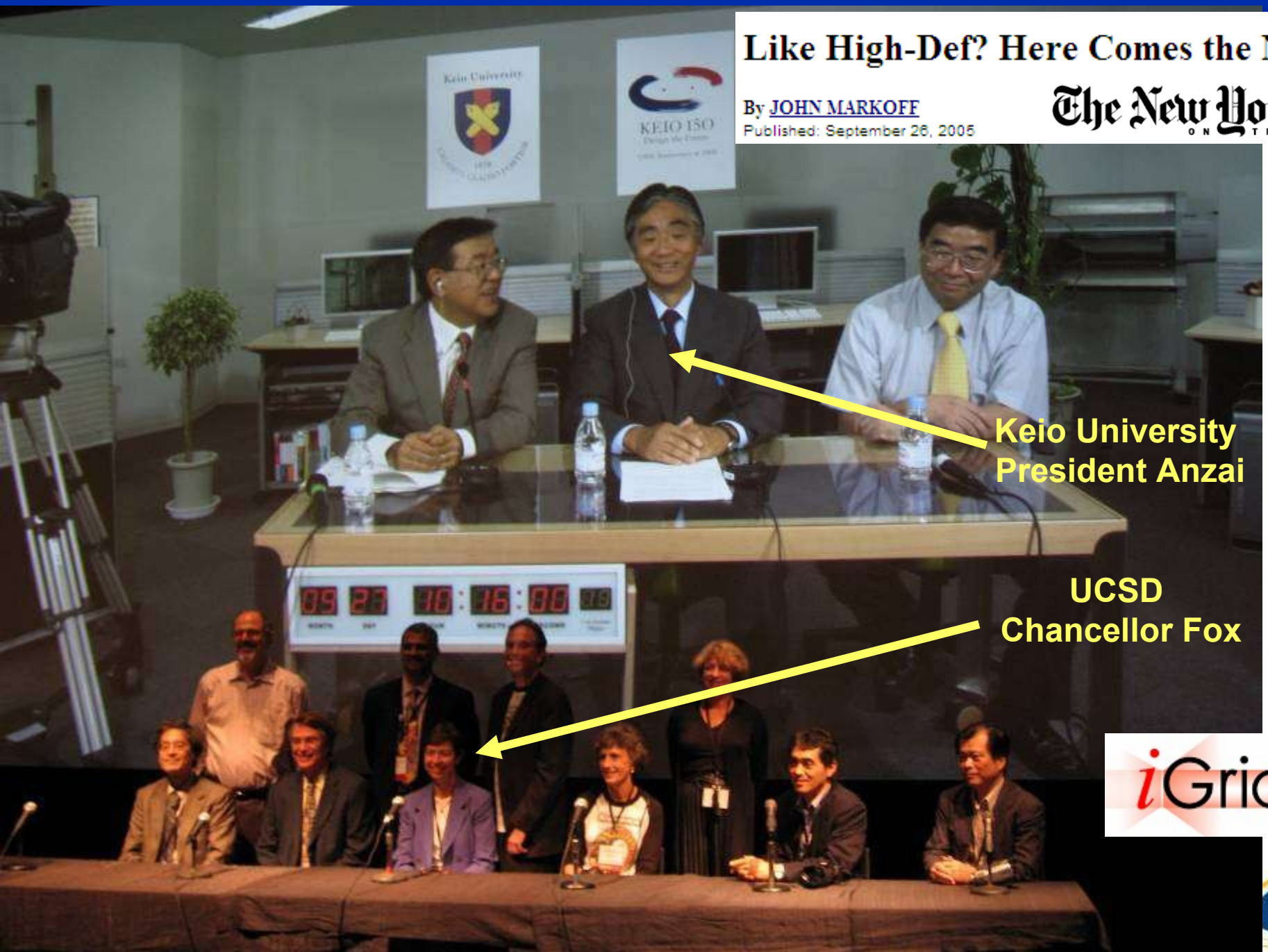


- Goal: Real-Time VLBI Radio Telescope Data Correlation
- Achieved 512Mb Transfers from USA and Sweden to MIT
- Results Streamed to iGrid2005 in San Diego

Optical Connections Dynamically Managed Using the DRAGON Control Plane and Internet2 HOPI Network

Source: Jerry Sobieski, DRAGON

iGrid Lambda Digital Cinema Streaming Services: Telepresence Meeting in Calit2 Digital Cinema Auditorium



Like High-Def? Here Comes the Next Level

By JOHN MARKOFF
Published: September 26, 2005

The New York Times ON THE WEB

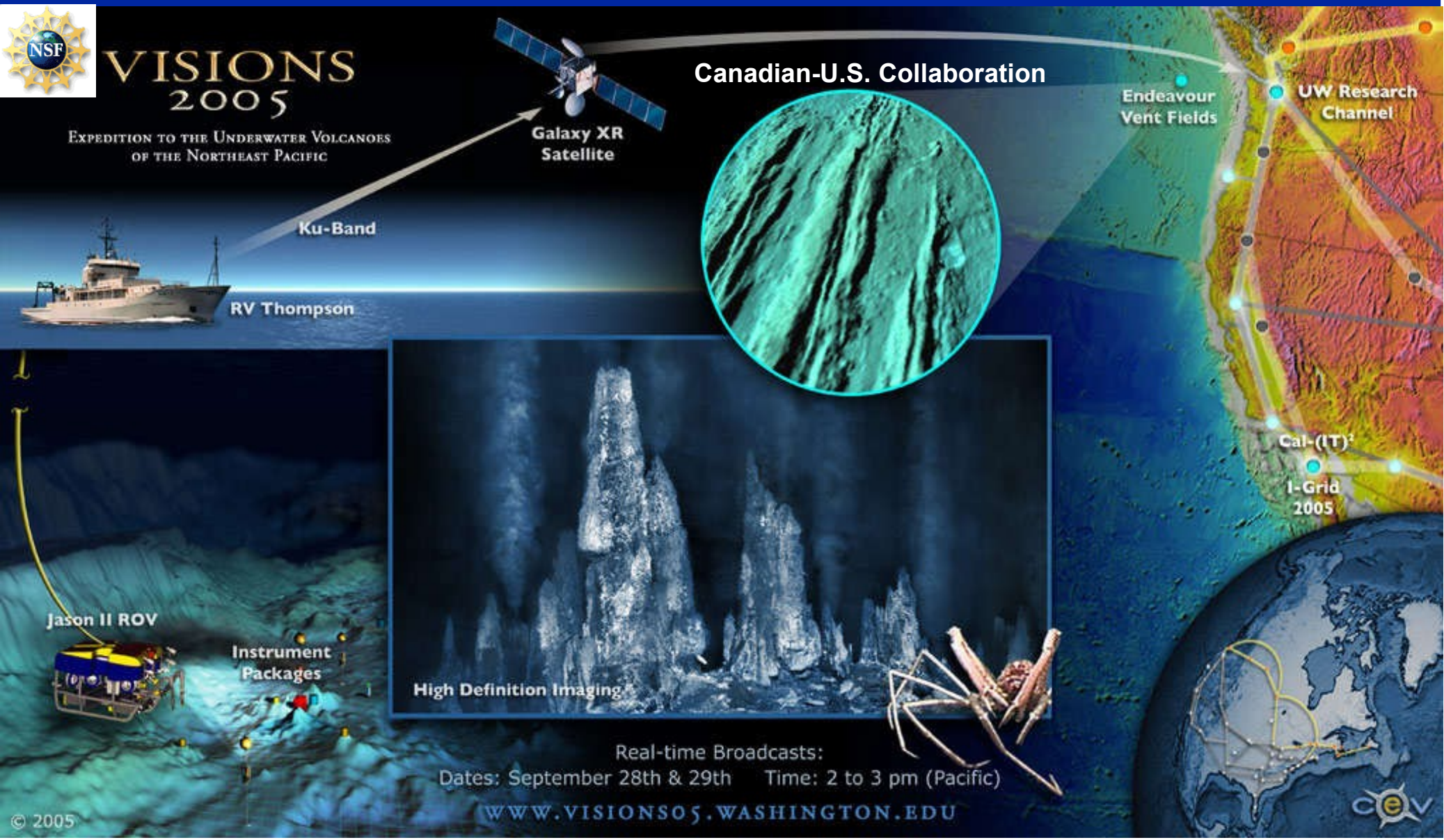
Lays Technical Basis for Global Digital Cinema

Sony
NTT
SGI

iGrid 2005

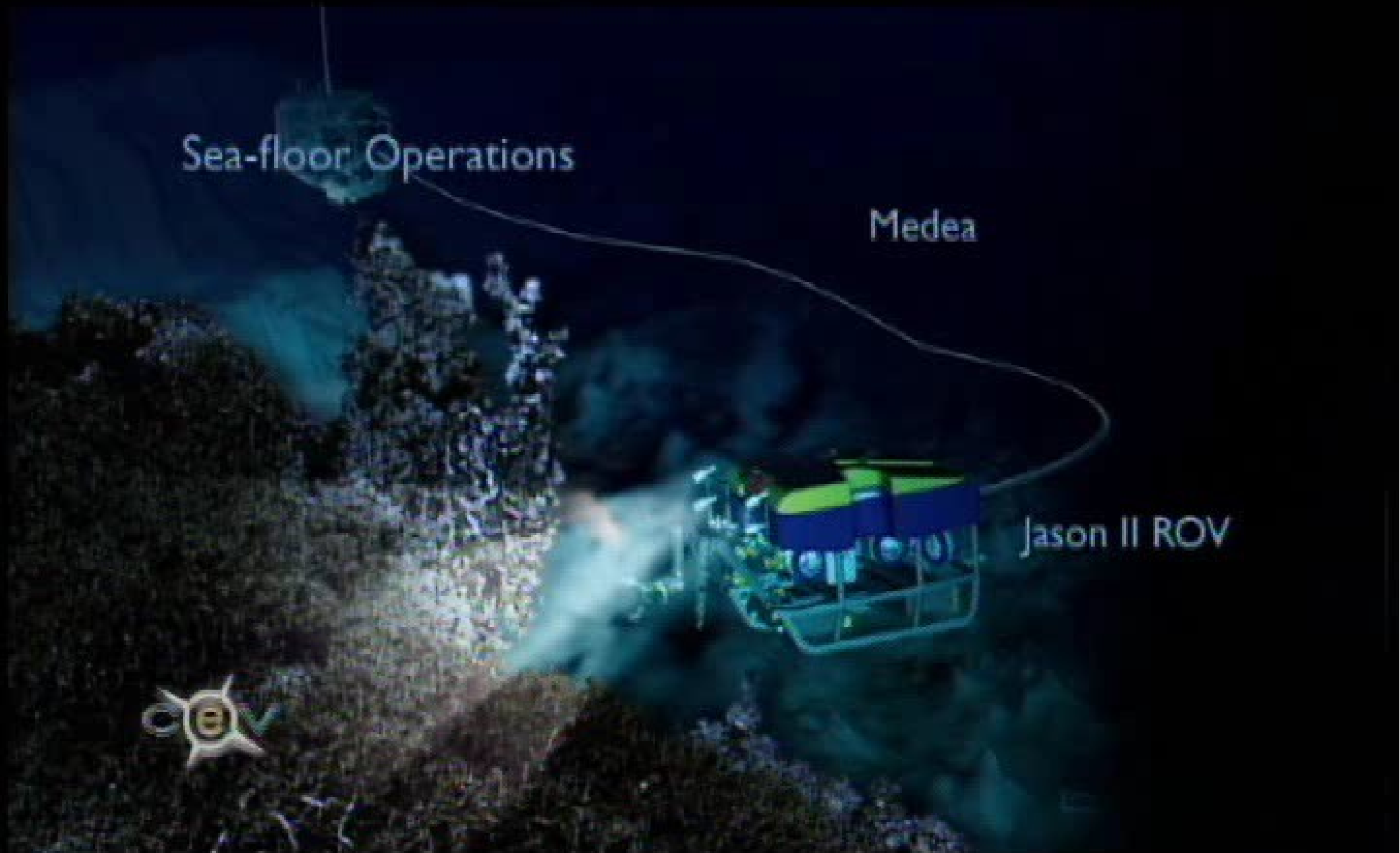
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iGrid Scientific Instrument Services: Enable Remote Interactive HD Imaging of Deep Sea Vent



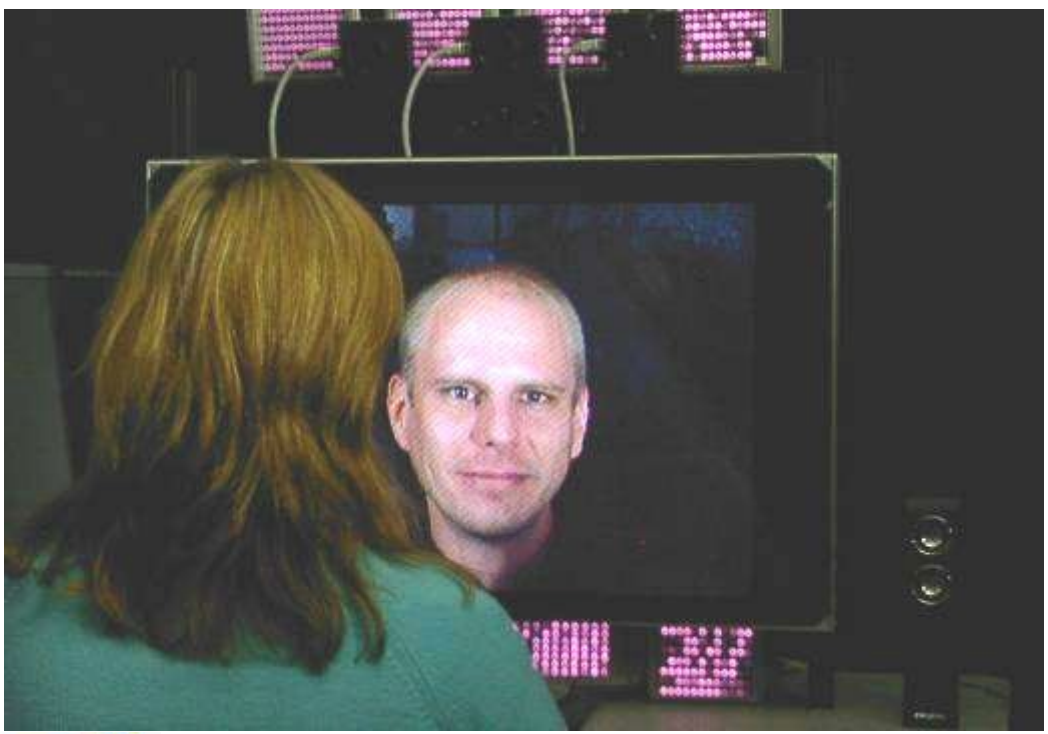
Source John Delaney & Deborah Kelley, UWash

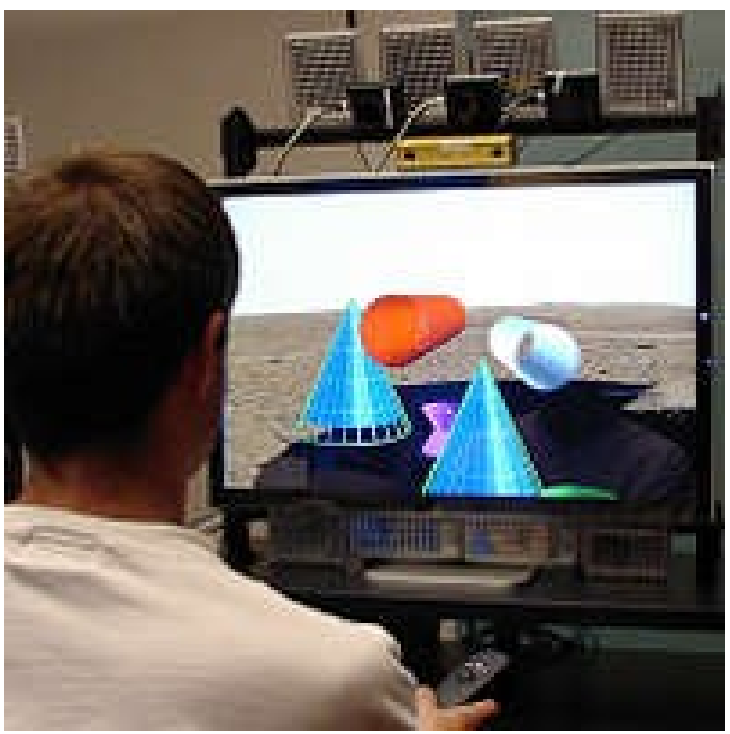
High Definition Video - 2.5 km Below the Ocean Surface



iGrid Lambda Visualization Services: 3D Videophones Are Here! The Personal Varrier Autostereo Display

- Varrier is a Head-Tracked Autostereo Virtual Reality Display
  - 30” LCD Widescreen Display with 2560x1600 Native Resolution
  - A Photographic Film Barrier Screen Affixed to a Glass Panel
    - The Barrier Screen Reduces the Horizontal Resolution To 640 Lines
- Cameras Track Face with Neural Net to Locate Eyes
- The Display Eliminates the Need to Wear Special Glasses





Source: Daniel Sandin, Thomas DeFanti, Jinghua Ge, Javier Girado, Robert Kooima, Tom Peterka—EVL, UIC

CalViz--
HD Streaming Internationally



Photo: Courtesy of Harry Ammons

Studio on 4th Floor of Calit2@UCSD Building
Two Talks to Australia in March 2006

Marine Genome Sequencing Project
Measuring the Genetic Diversity of Ocean Microbes



CAMERA will include
All Sorcerer II Metagenomic Data

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MARINE MICROBIOLOGY INITIATIVE

Gordon and Betty MOORE FOUNDATION

J. Craig Venter INSTITUTE

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CAMERA: Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis

National LambdaRail
Direct Connect
Computation and Storage Complex

Funded by: Gordon and Betty Moore Foundation

Joint Partnership of:

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PI Larry Smarr

Calit2's Direct Access Core Architecture Will Create Next Generation Metagenomics Server

Sargasso Sea Data

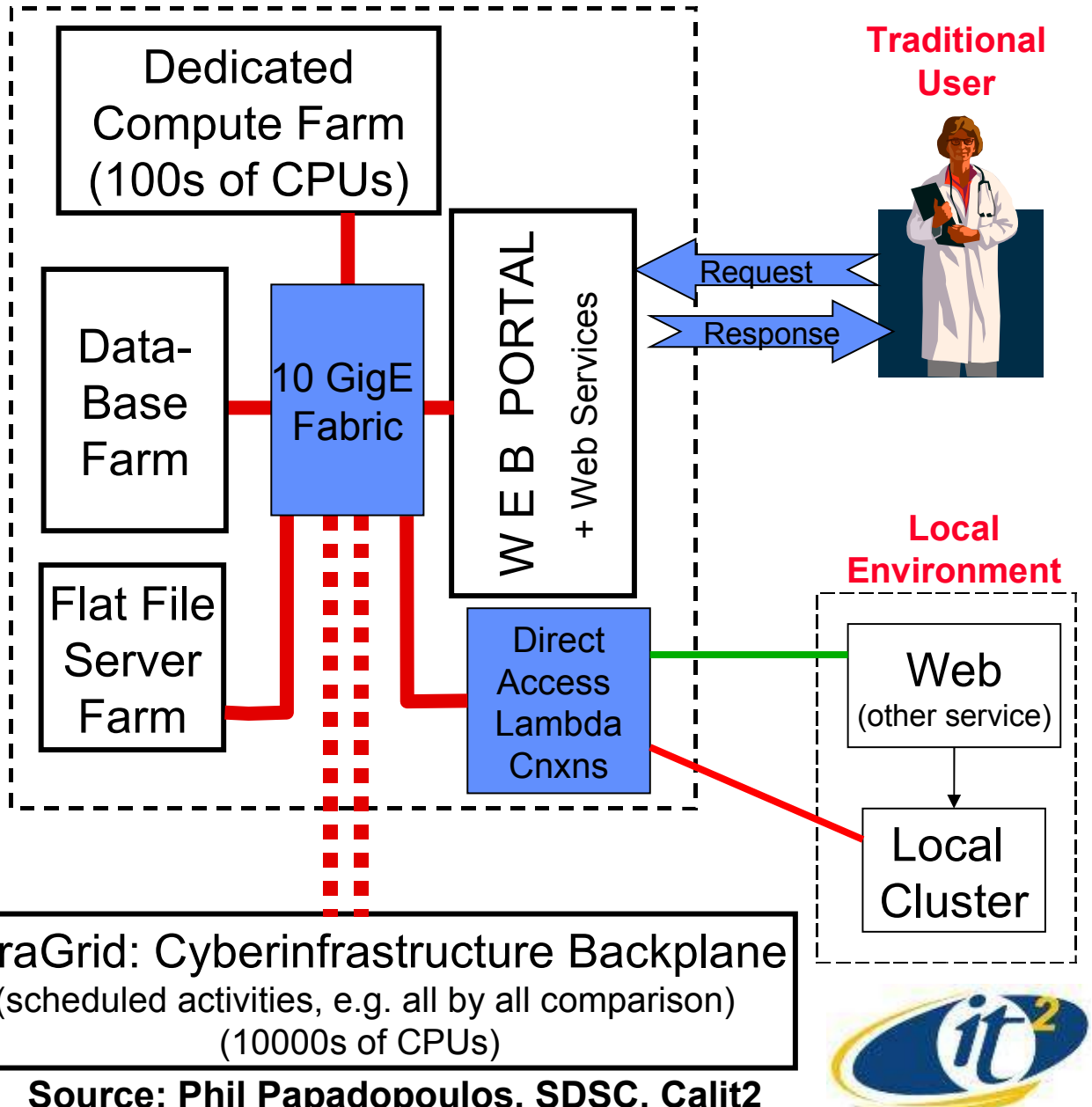
Sorcerer II Expedition (GOS)

JGI Community Sequencing Project

Moore Marine Microbial Project

NASA Goddard Satellite Data

Community Microbial Metagenomics Data

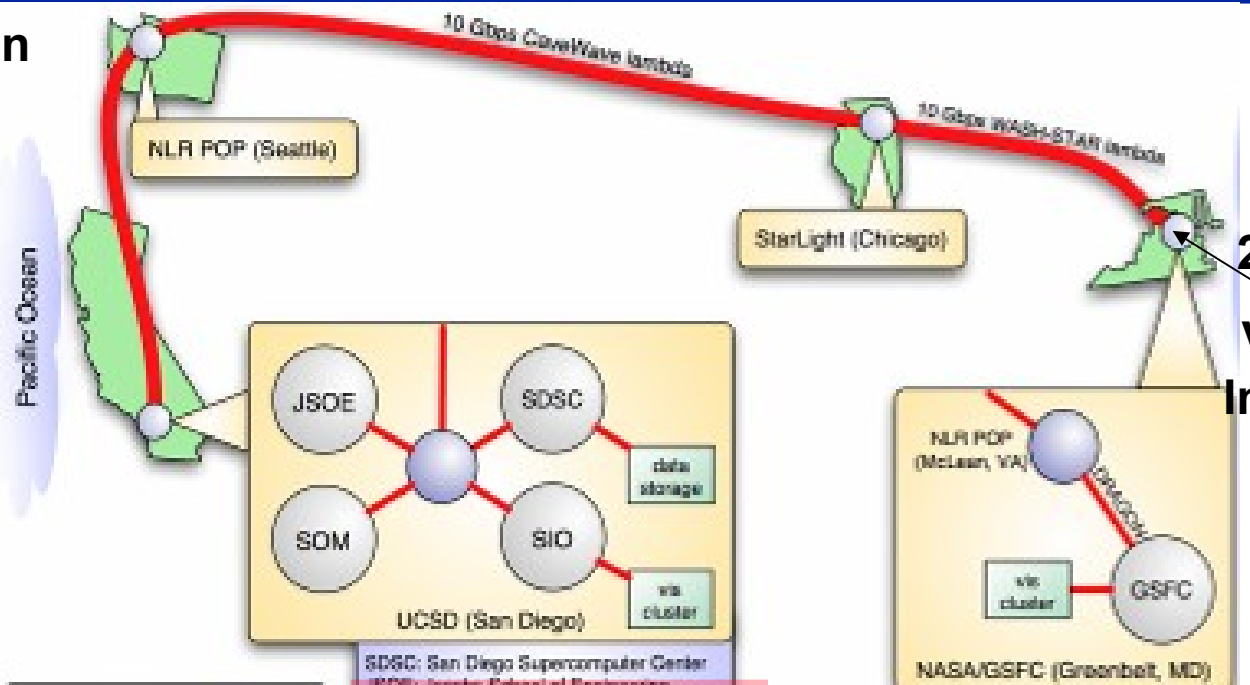


Source: Phil Papadopoulos, SDSC, Calit2

Calit2 and the Venter Institute Will Combine Telepresence with Remote Interactive Analysis

Live Demonstration

of 21st Century National-Scale Team Science



25 Miles

Venter Institute



OptIPuter Visualized Data

HDTV Over Lambda



Scripps Institution of Oceanography, UCSD, La Jolla, CA

Goddard Space Flight Center, Maryland

The Optical Core of the UCSD Campus-Scale Testbed -- Evaluating Packet Routing versus Lambda Switching

Goals by 2007:

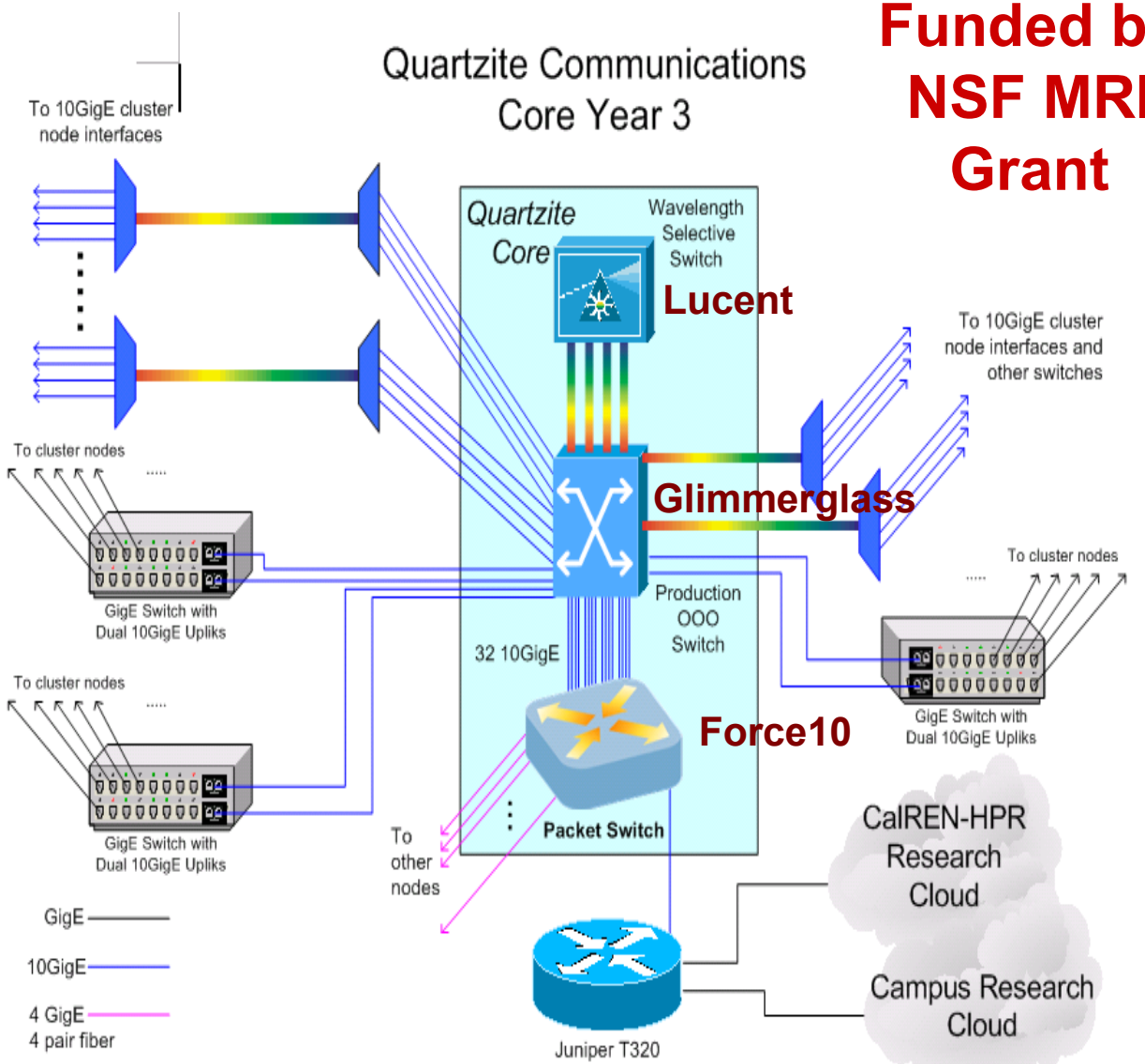
>= 50 endpoints at 10 GigE

>= 32 Packet switched

>= 32 Switched wavelengths

>= 300 Connected endpoints

Approximately 0.5 TBit/s Arrive at the "Optical" Center of Campus
Switching will be a Hybrid Combination of:
Packet, Lambda, Circuit -- OOO and Packet Switches Already in Place



Funded by NSF MRI Grant

NSF

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New Calit2 Photonics Testbed Core Facility-- Inventing the Optics World of 2015



UCSD Photonics

ECE Testbed Faculty



Stojan Radic
Optical communication networks; all-optical processing; parametric processes in high-confinement fiber and semiconductor devices.



George Papen
Advanced photonic systems including optical communication systems, optical networking, and environmental and atmospheric remote sensing.



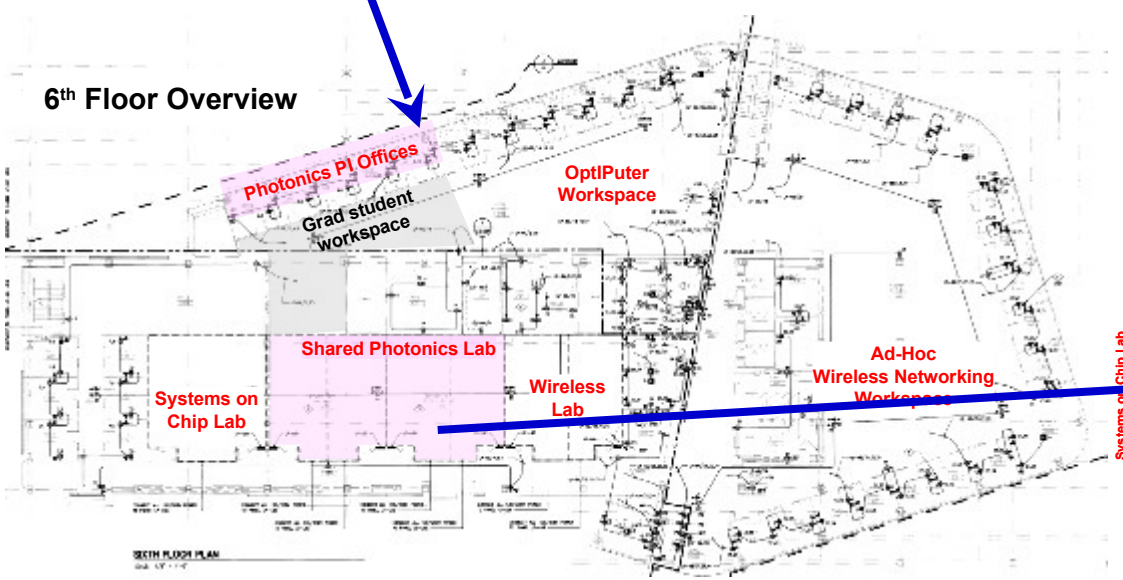
Joseph Ford
Optoelectronic subsystems integration (MEMS, diffractive optics, VLSI); Fiber optic and free-space communications.



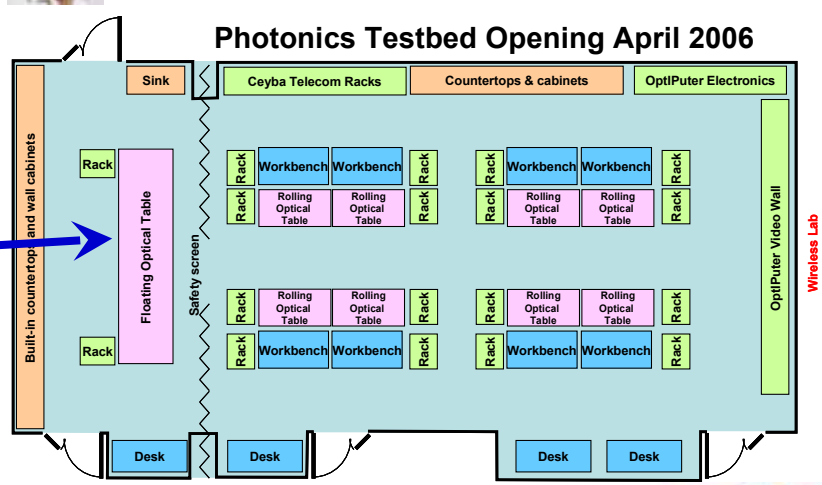
Shaya Fainman
Nanoscale science and technology; ultrafast photonics and signal processing



Shayan Mookherjea
Optical devices and optical communication networks, including photonics, lightwave systems and nano-scale optics.



Photonics Testbed Opening April 2006



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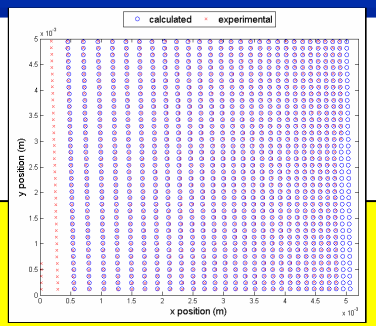
Multi-Wavelength Array For 1000+ Channel Systems
Multichannel Operation To 55 Gb/s

it2

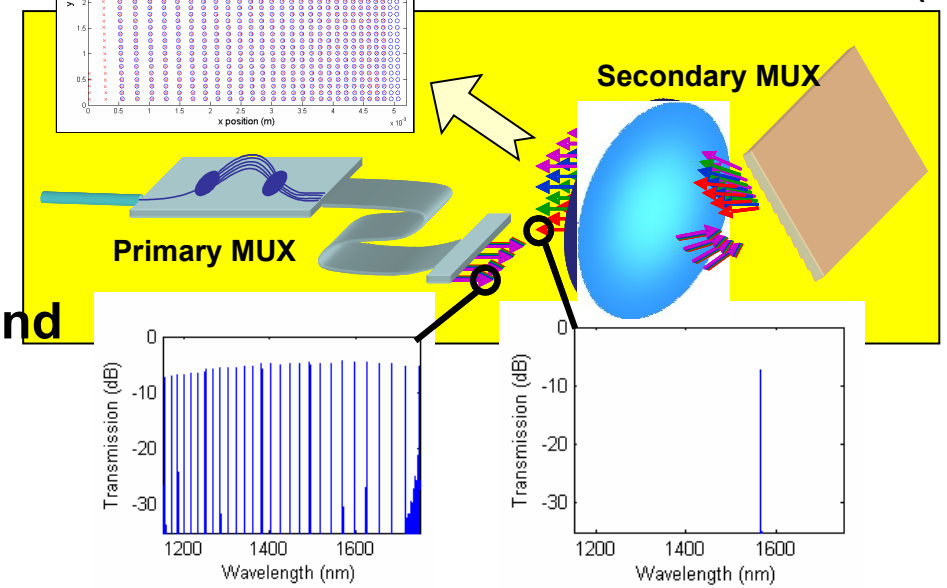
Beyond Terabits/s---"Extreme" WDM
1092 Parallel Channels @ >10 GHz Each

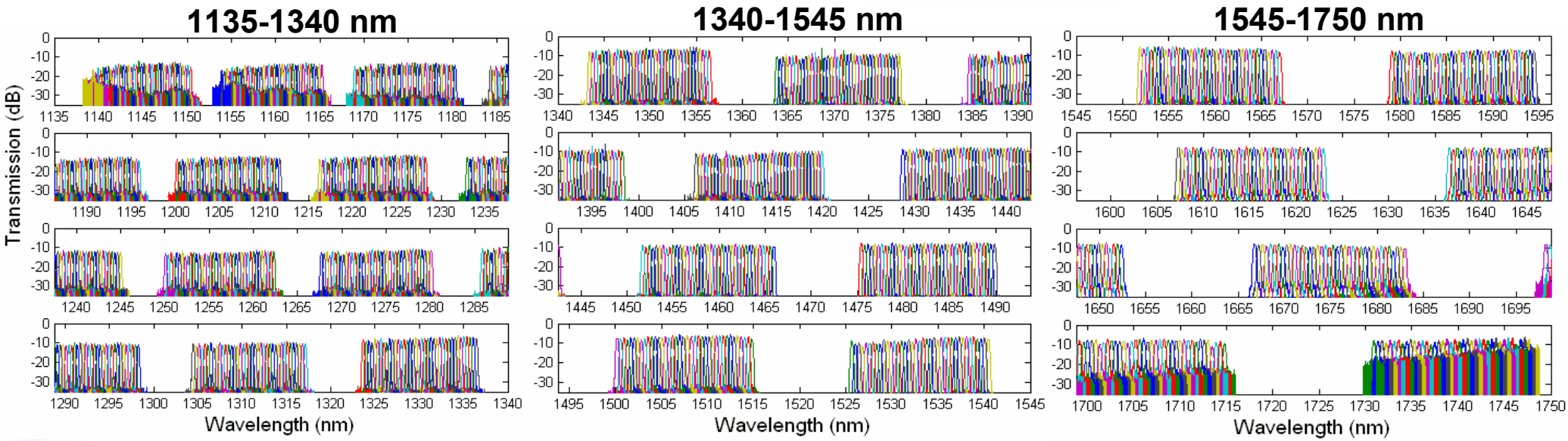
- Hybrid 2-D Array Spectra MUX
- Primary DeMUX:
  - 1x40 AWG, 50 GHz pitch,
  - >28 orders each
- Secondary DeMUX:
  - 1x28 Free-space optics grating
- Final deMUX output
  - 40x28 2-D array, 1140 – 1750 nm Band
- 1092 Demuxed Outputs
  - Single Channels Coupled to SMF
  - Each 30GHz dB Rolloff

UCSD Photonics

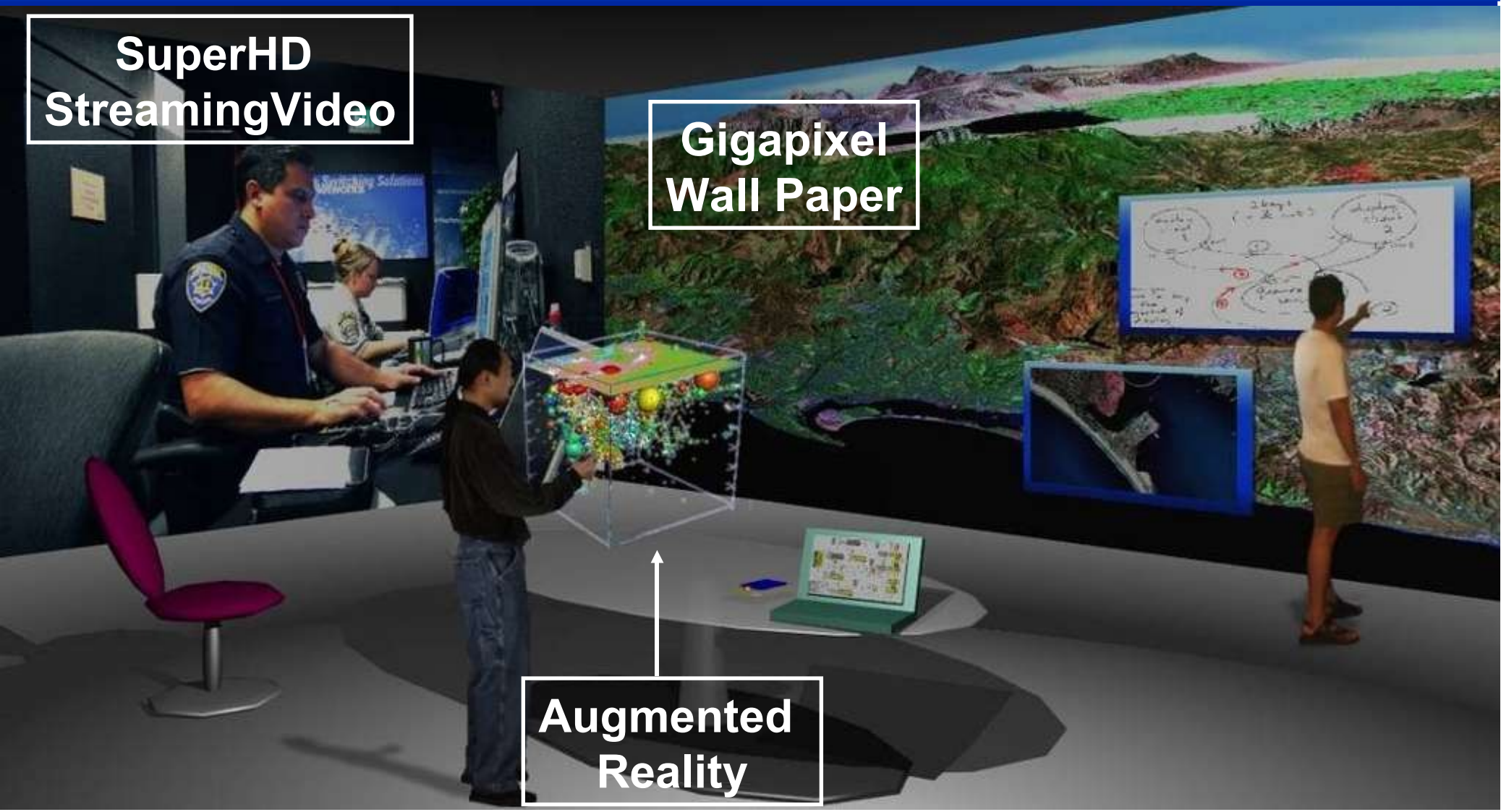


1092 Channel Data Array:
- Output fiber array (mux/demux)
- MEMS array (wavelength switch)
- OE detectors / modulators (TXR)





A Vision for the Future: Towards Gigapixel Displays



1 GigaPixel x 3 Bytes/pixel x 8 bits/byte x 30 frames/sec ~ 1 Terabit/sec!

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Source: Jason Leigh, EVL, UIC

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