“Terabit Applications: What Are They, What is Needed to Enable Them?"

3rd Annual ON*VECTOR Terabit LAN Workshop
Calit2@UCSD
La Jolla, CA
February 28, 2007

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

OptIPuter

it2

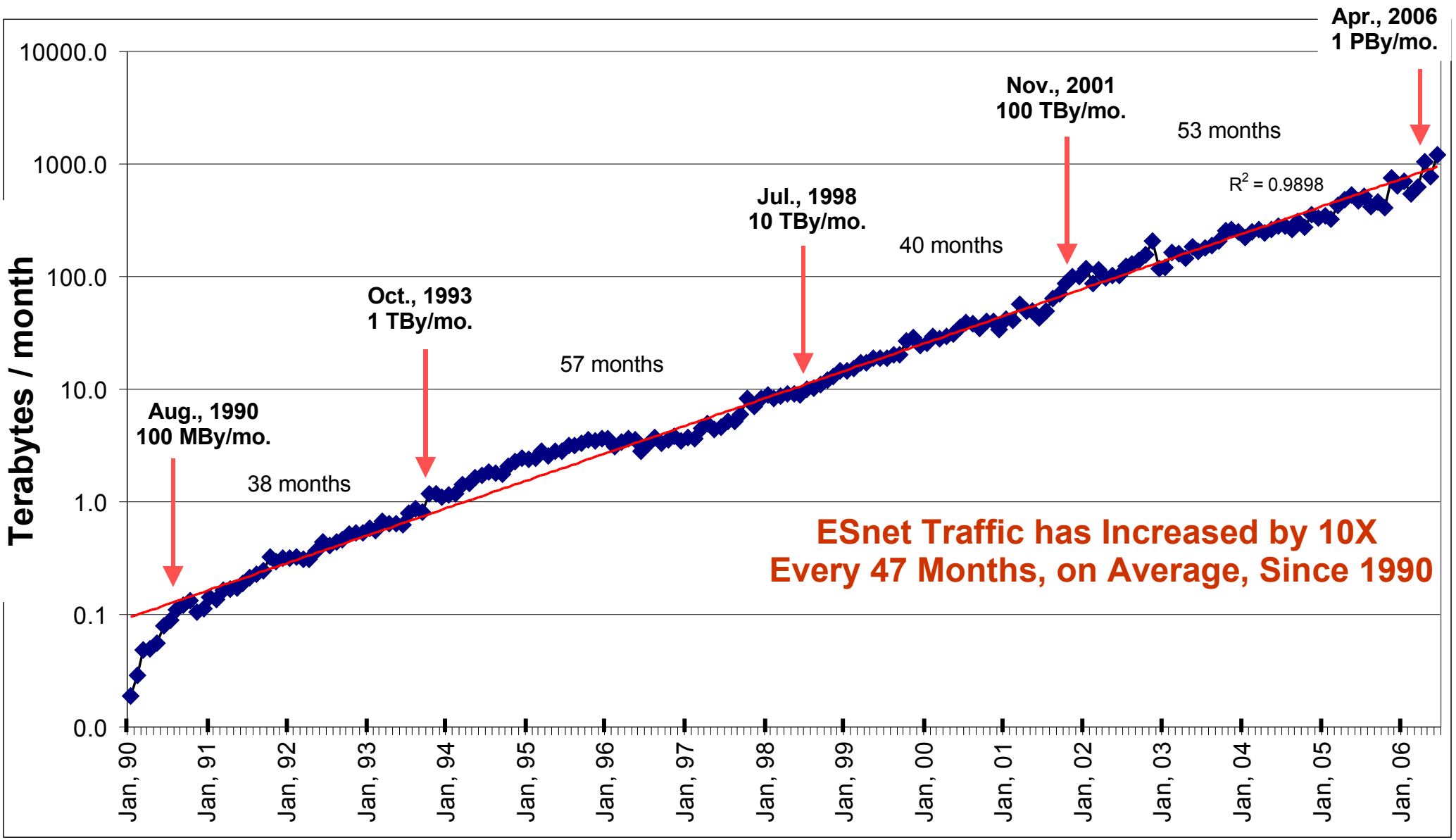
Toward Terabit Applications: Four Drivers

- Data Flow
  - Global Particle Physics
- GigaPixel Images
  - Terabit Web
- Supercomputer Simulation Visualization
  - Cosmology Analysis
- Parallel Video Flows
  - Terabit LAN OptIPuter CineGrid

OptIPuter

it²

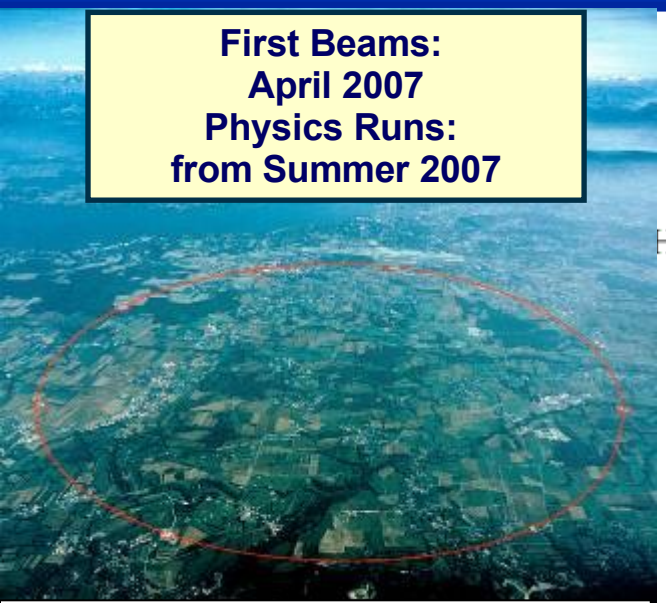
The Growth of the DoE Office of Science Large-Scale Data Flows



Source: Bill Johnson, DoE

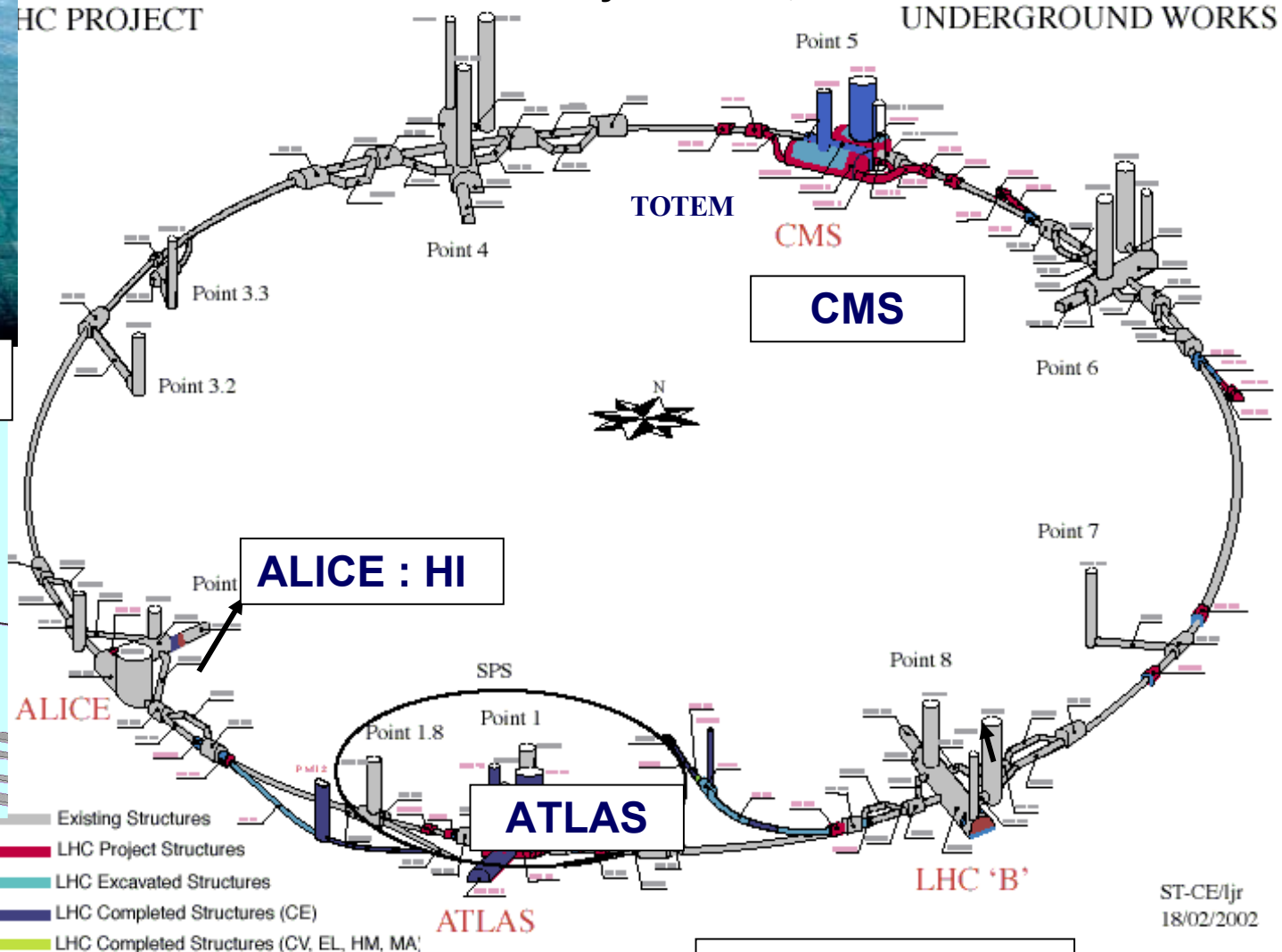
Large Hadron Collider (LHC)
e-Science Driving Global Cyberinfrastructure

First Beams:
April 2007
Physics Runs:
from Summer 2007

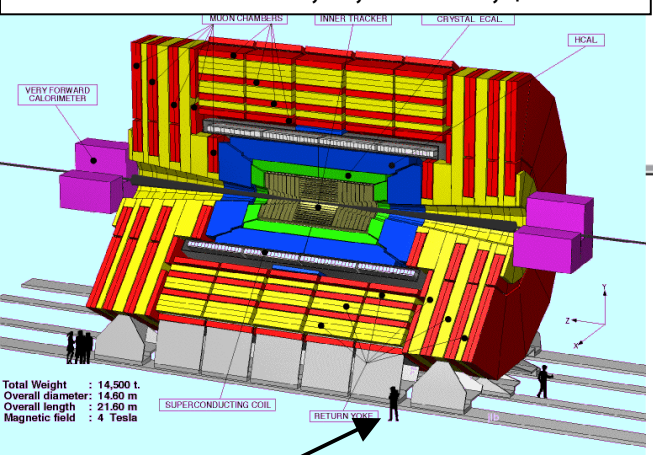


- **pp $\sqrt{s}$ =14 TeV L=10^{34} cm^{-2} s^{-1}**
- **27 km Tunnel in Switzerland & France**

Source: Harvey Newman, Caltech



LHC CMS detector
15m X 15m X 22m,12,500 tons, $700M



human (for scale)

LHCb: B-physics

OptIPuter

High Energy and Nuclear Physics
A Terabit/s WAN by 2013!

Year	Production	Experimental	Remarks
2001	0.155	0.622-2.5	SONET/SDH
2002	0.622	2.5	SONET/SDH DWDM; GigE Integ.
2003	2.5	10	DWDM; 1 + 10 GigE Integration
2005-6	10-20	2-4 X 10	λ Switch; λ Provisioning
2007-8	30-40	~100 or 2 X 40 Gbps	1st Gen. λ Grids
2009-10	60-80	~5 X 40 or ~2 X 100	40 or 100 Gbps λ Switching
2011-12	~5 X 40 or ~2 X 100	~25 X 40 or ~10 X 100	2nd Gen λ Grids Terabit Networks
2013-14	~Terabit	~MultiTbps	~Fill One Fiber

Source: Harvey Newman, Caltech

OptIPuter

Imagine a Terabit Web

- **Current Megabit Web**
  - **Personal Bandwidth ~50 Mbps**
  - **Interactive Data Objects ~1-10 Megabytes**
- **Future Terabit Web**
  - **Personal Bandwidth ~500,000 Mbps**
  - **Interactive Data Object ~ 10-100 Gigabytes**

OptIPuter

it²

Terabit Networks Would Make Remote Gigapixel Images Interactive



OptIPuter

The Gigapxl Project
http://gigapxl.org

it²

People Watching
From Torrey Pines Glider Port



This is 1/2500 of the Pixels on the Full Image!

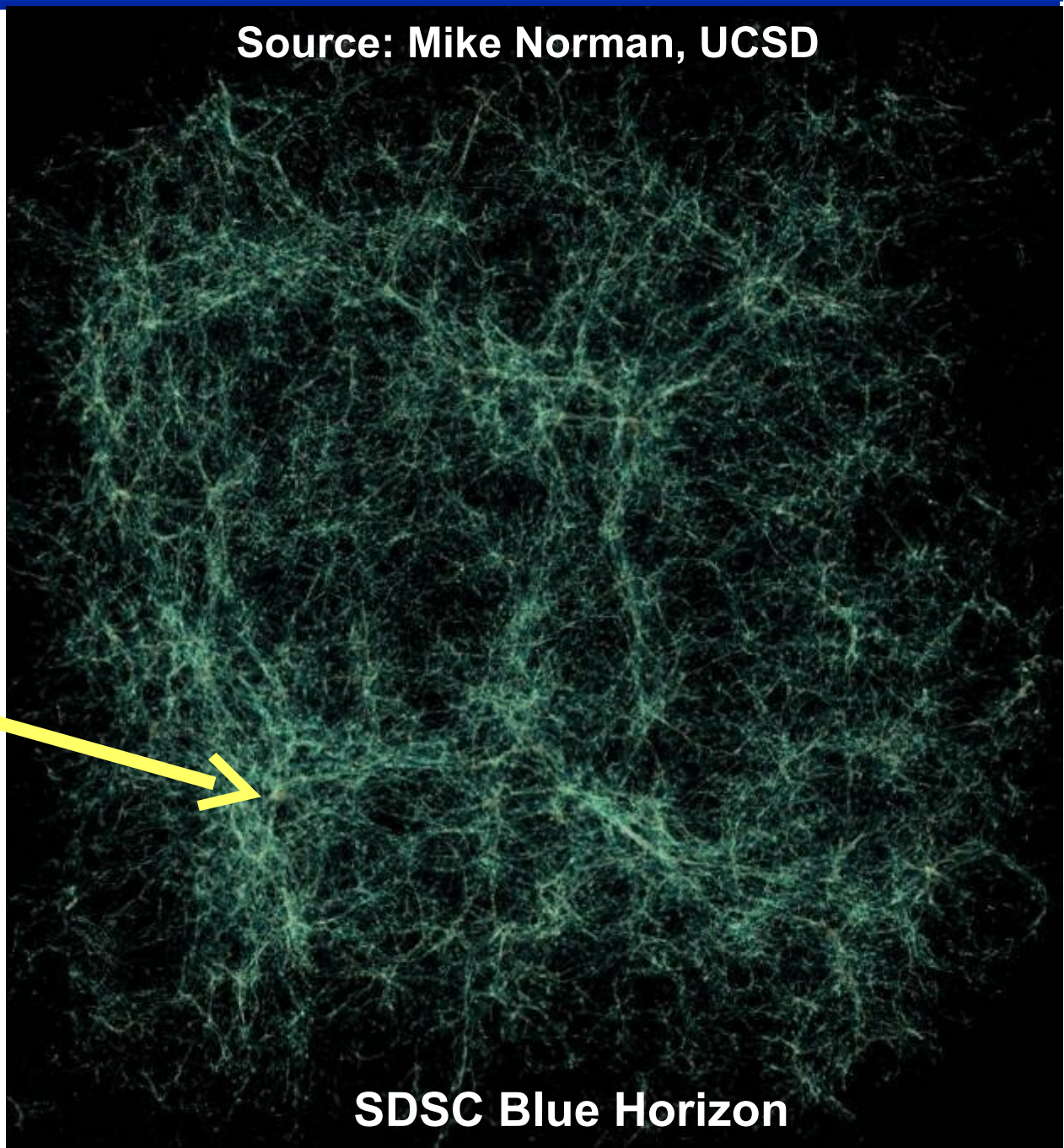
OptIPuter

The Gigapxl Project
http://gigapxl.org

it²

Cosmic Simulator with a Billion Zone and Gigaparticle Resolution

Problem with Uniform Grid--Gravitation Causes Continuous Increase in Density Until There is a Large Mass in a Single Grid Zone



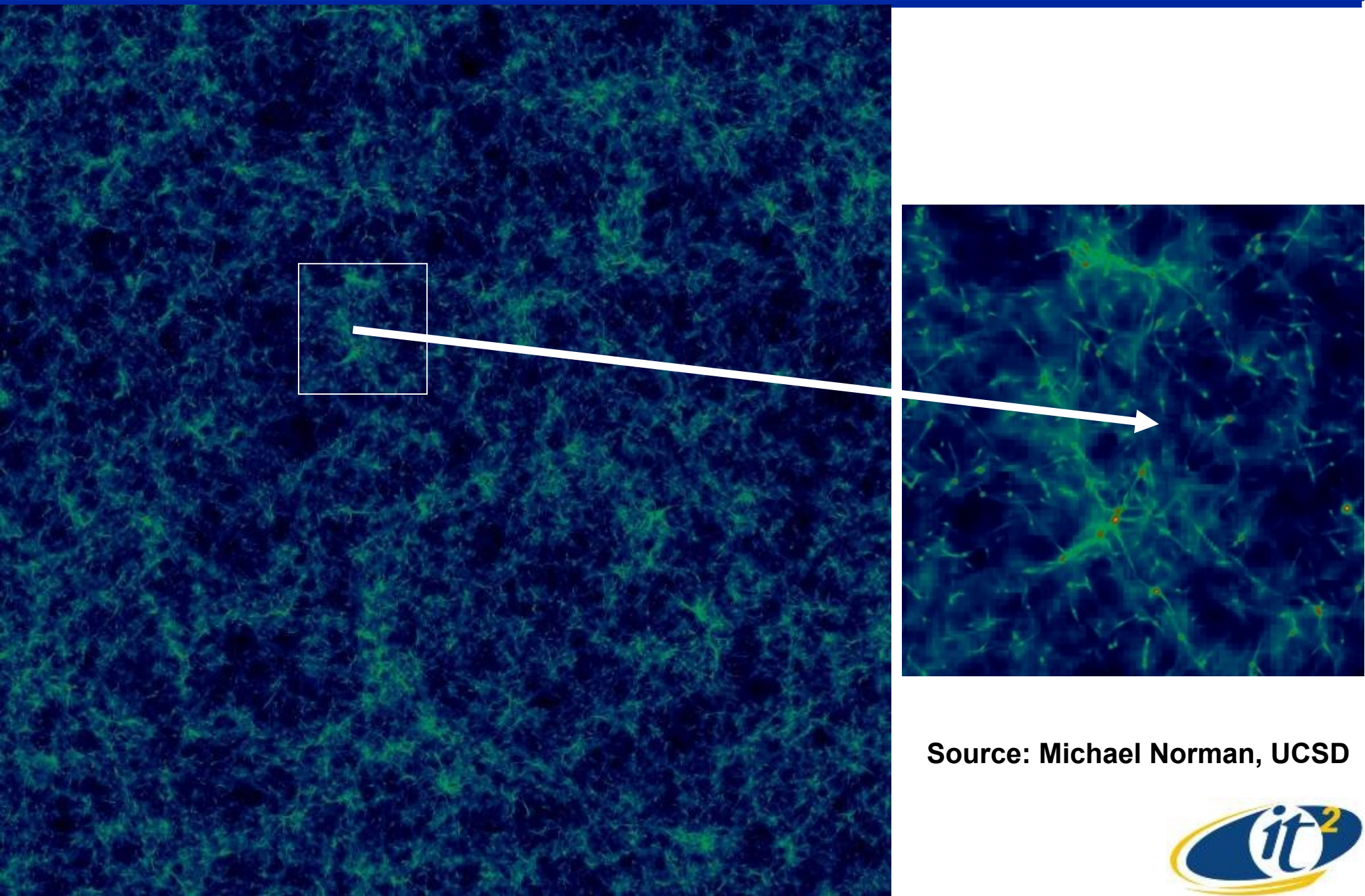
OptIPuter

AMR Allows Digital Exploration of Early Galaxy and Cluster Core Formation

- **Background Image Shows Grid Hierarchy Used**
  - Key to Resolving Physics is More Sophisticated Software
  - Evolution is from 10Myr to Present Epoch
- **Every Galaxy > 10^{11} M_{solar} in 100 Mpc/H Volume Adaptively Refined With AMR**
  - 256^3 Base Grid
    - Over 32,000 Grids At 7 Levels Of Refinement
    - Spatial Resolution of 4 kpc at Finest
    - 150,000 CPU-hr On 128-Node IBM SP
- **512^3 AMR or 1024^3 Unigrid Now Feasible**
  - 8-64 Times The Mass Resolution
  - Can Simulate First Galaxies
  - One Million CPU-Hr Request to LLNL
    - Bottleneck--Network Throughput from LLNL to UCSD

Source: Mike Norman, UCSD

AMR Cosmological Simulations Generate 4kx4k Images and Needs Interactive Zooming Capability



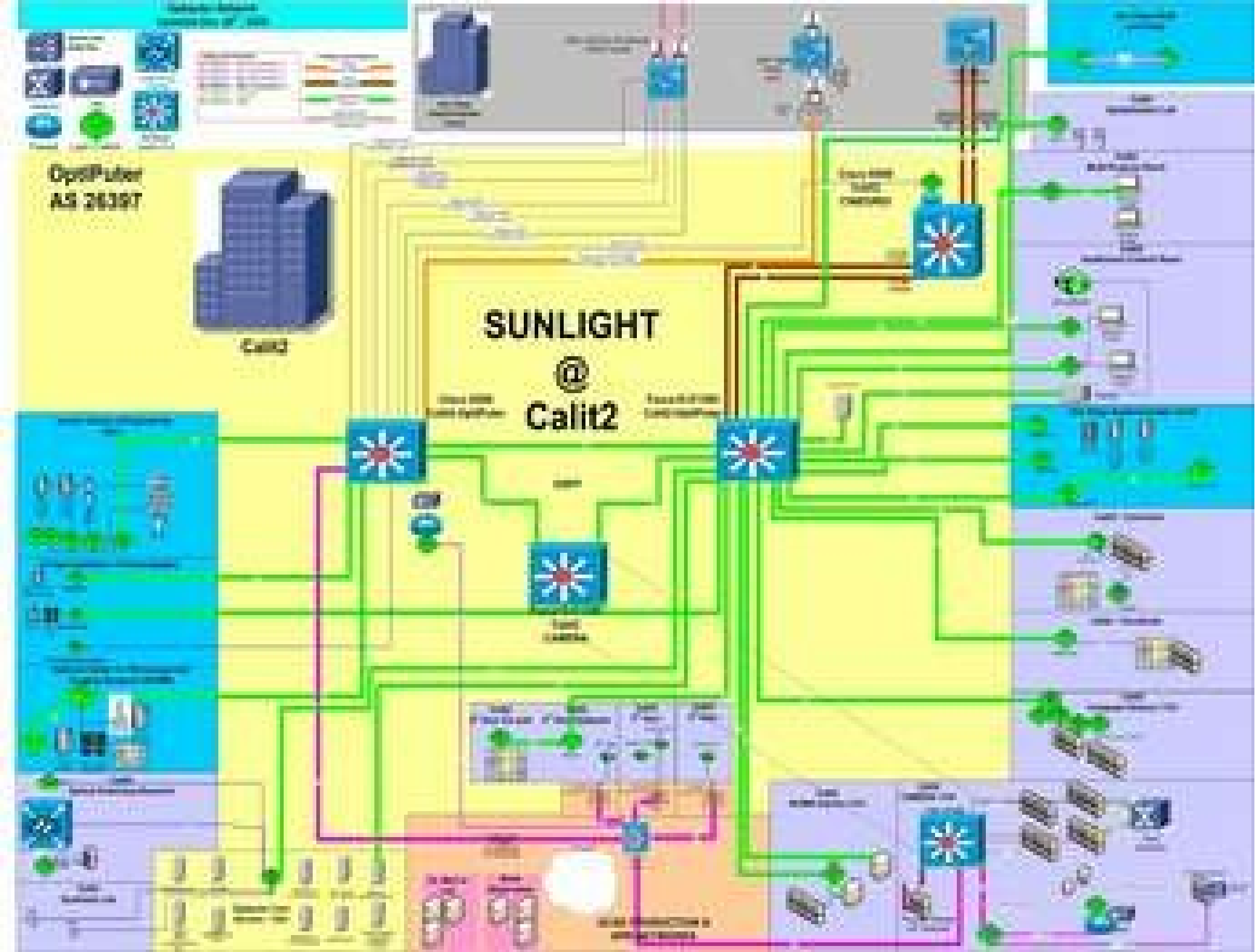
Source: Michael Norman, UCSD

Why Does the Cosmic Simulator Need Terabit LAN?

- One Gigazone Uniform Grid or 512^3 AMR Run:
  - Generates ~10 TeraByte of Output
  - A "Snapshot" is 100s of GB
  - Need to Visually Analyze as We Create SpaceTimes
- Visual Analysis Daunting
  - Single Frame is About 8GB
  - A Smooth Animation of 1000 Frames is 1000 x 8 GB=8TB
    - One Minute Movie ~ 1 Terabit per Second!
- Can Run Evolutions Faster than We Can Archive Them
  - File Transport Over Shared Internet ~50 Mbit/s
    - 4 Hours to Move ONE Snapshot!
- AMR Runs Require Interactive Visualization Zooming Over 16,000x!

Source: Mike Norman, UCSD

Building a Terabit LAN at Calit2


OptiPuter
AS 26397
Calit2
SUNLIGHT
@
Calit2

The New Optical Core of the UCSD Campus-Scale Testbed: Moving to Parallel Lambdas in 2007

Goals by 2007:

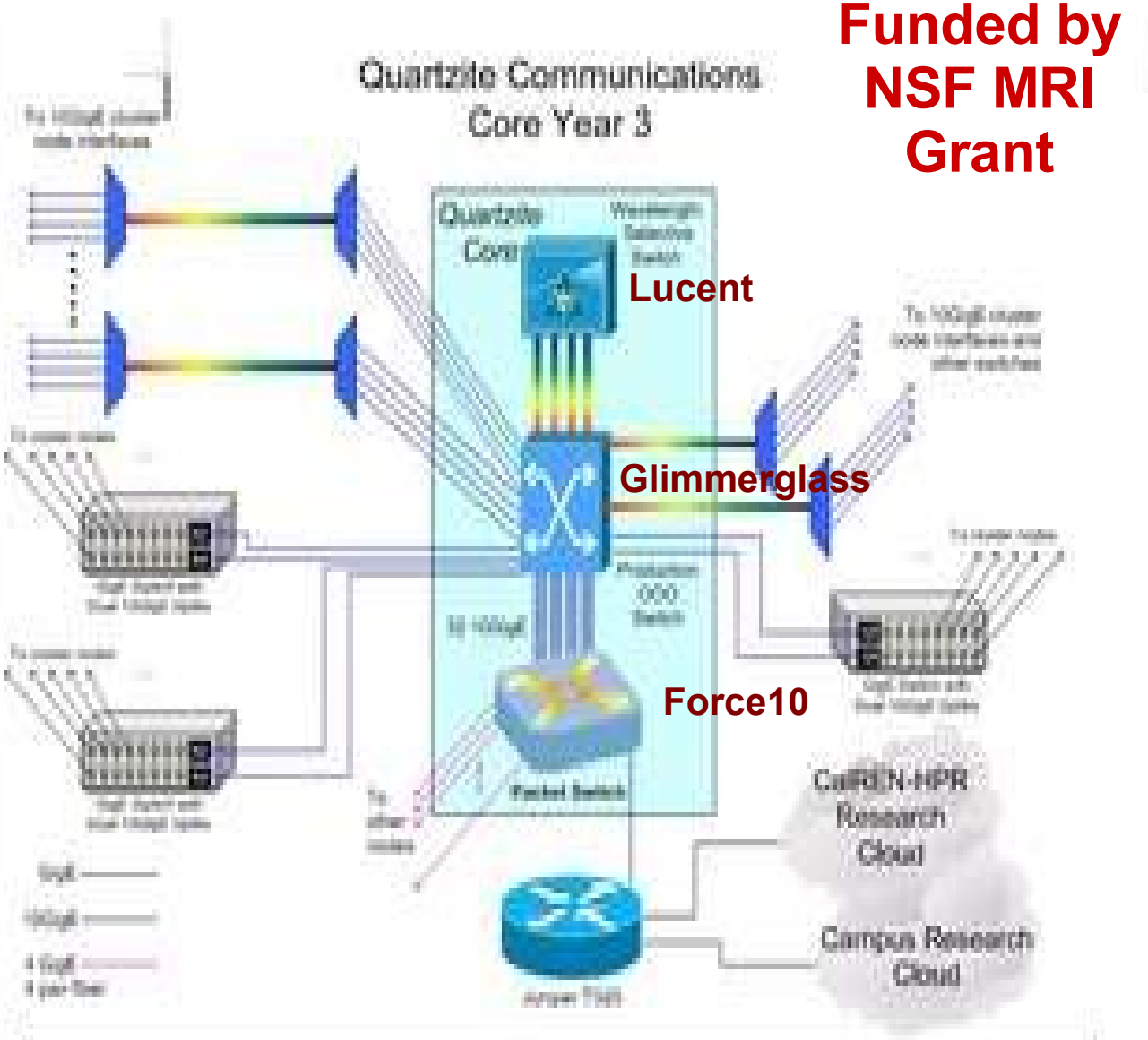
>= 50 endpoints at 10 GigE

>= 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

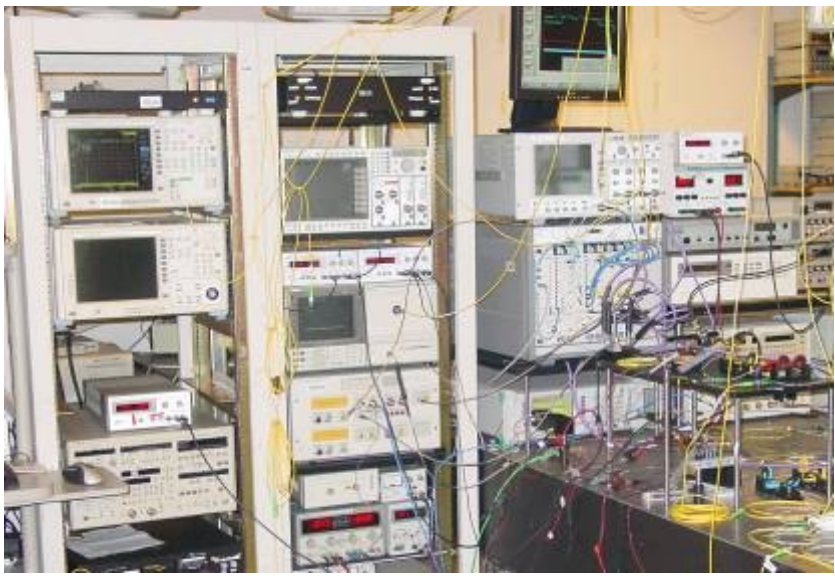


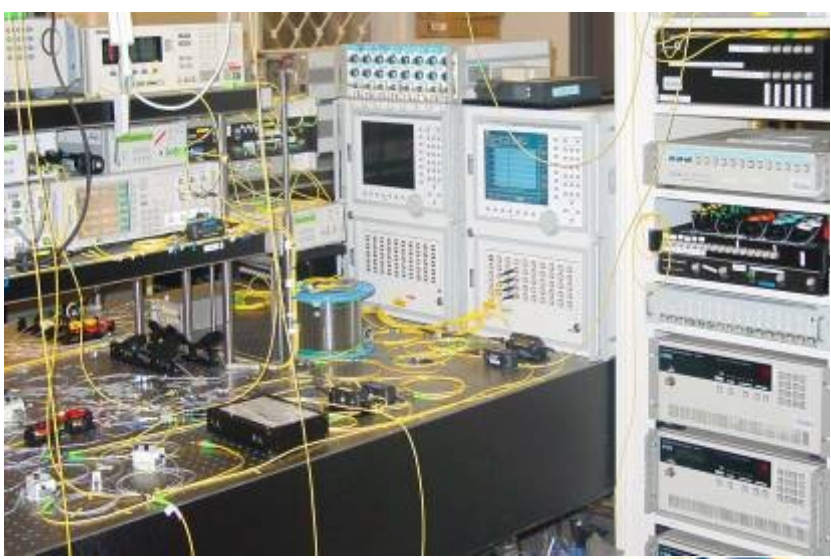
Funded by NSF MRI Grant

Source: Phil Papadopoulos, SDSC, Calit2

Leading Edge Photonics Networking Laboratory Has Been Created in the Calit2@UCSD Building

- **Networking "Living Lab" Testbed Core**
  - Parametric Switching
  - 1000nm Transport
  - Universal Band Translation
  - True Terabit/s Signal Processing
- **Interconnected to OptIPuter**
  - Access to Real World Network Flows
  - Allows System Tests of New Concepts





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.



UCSD Parametric Processing Laboratory

The World's Largest Tiled Display Wall—Calit2@UCI's HIPerWall



Calit2@UCI Apple Tiled Display Wall
Driven by 25 Dual-Processor G5s
50 Apple 30" Cinema Displays
200 Million Pixels of Viewing Real Estate!

Zeiss Scanning Electron Microscope Center of Excellence in Calit2@UCI
Albert Yee, PI



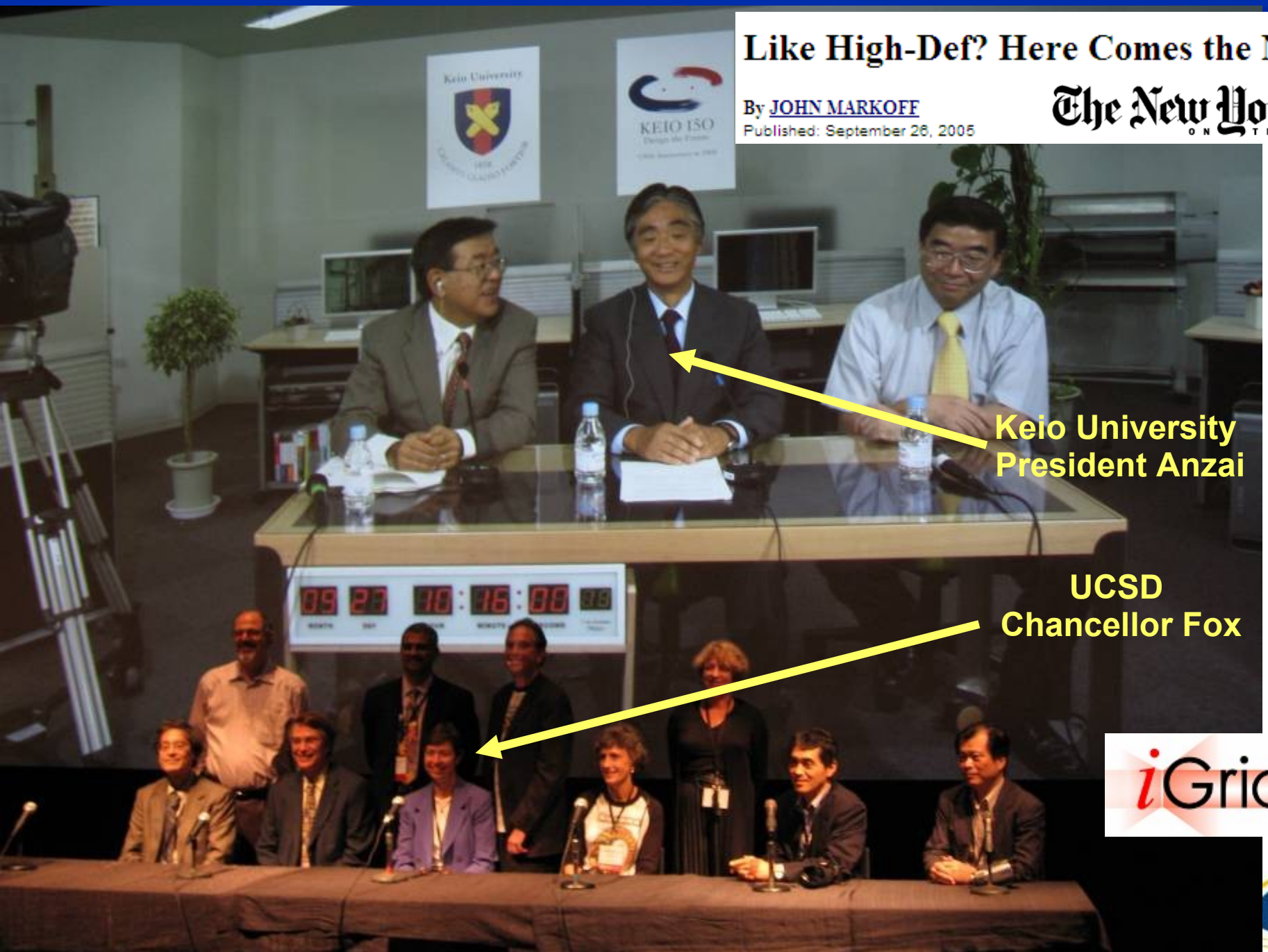
Falko Kuester and Steve Jenks, PIs Featured in Apple Computer's "Hot News"

OptIPuter

it² Center of GRAVITY
Center of Graphics, Visualization and Imaging Technology

it²

First Trans-Pacific Super High Definition Telepresence Digital Cinema 4K Flows Camera to Projector



Like High-Def? Here Comes the Next Level

By JOHN MARKOFF
Published: September 26, 2005

The New York Times ON THE WEB

Keio University President Anzai

UCSD Chancellor Fox

Lays Technical Basis for Global Digital Cinema

Sony
NTT
SGI

iGrid 2005

it²

The Calit2 Terabit LAN OptIPuter Supporting Highly Parallel 4k CineGrid

- 4k Sources
  - Disk Precomputed Images
  - 128 4k Cameras
  - 512 HD Cameras

Source: Larry Smarr, Calit2



128 Node Cluster

Each Node Drives 4k Stream

Uncompressed 4k 6 Gbps Flows

Each LCD Displays 4k

128 10G NICs

128 WDM Fiber

128 10G NICs



16’

64’

One Billion Pixel Wall
128 (16x8) 4k LCDs

OptIPuter

it2