“Opportunities for Advanced Technology in Telecommunications"

Invited Talk,
37th IEEE Semiconductor Interface Specialists Conference
Catamaran Resort Hotel,
San Diego, CA
December 7, 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

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The Internet Is Extending Throughout the Physical World
A Mobile Internet Powered by a Planetary Computer

- **Emergence of a Distributed Planetary Computer**
  - Parallel Light Channels Backbone
  - Storage of Data Everywhere
  - Scalable Distributed Computing Power
- **Wireless Access--Anywhere, Anytime**
  - Broadband Speeds
  - "Always Best Connected"
- **Billions of Heterogeneous Wireless End Points**
  - Information Appliances
  - Sensors and Actuators
  - Embedded Processors
- **Transformational From Medicine to Transportation**

"The all optical fibersphere in the center finds its complement in the wireless ethersphere on the edge of the network."
--George Gilder

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Calit2--A Systems Approach to the Future of the Internet and its Transformation of Our Society

Calit2 Has Assembled a Complex Social Network of Over 350 UC San Diego & UC Irvine Faculty Working in Cross-Disciplinary Teams With Staff, Students, Industry, and the Community



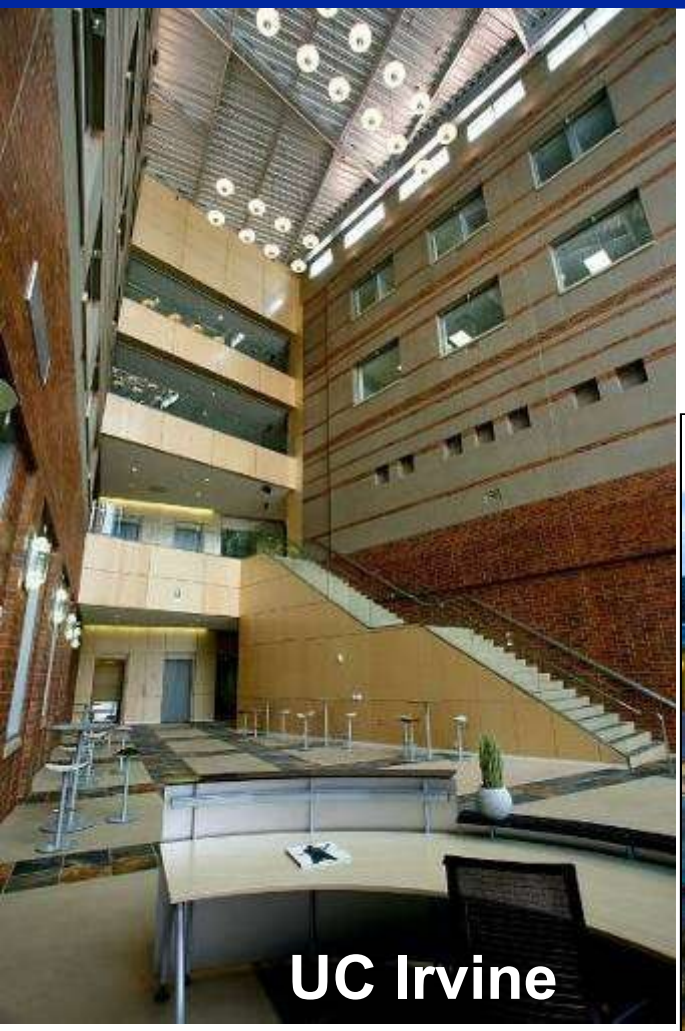
Integrating Technology Consumers and Producers Into "Living Laboratories"

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www.calit2.net

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New Calit2 Buildings Provide Collaboration Space and New Laboratories for "Living in the Future"



- **Over 1000 Researchers in Two Buildings**
  - Faculty From Two Dozen Departments
  - International Conferences and Testbeds
- **New Shared Laboratories**
  - Nanotechnology
  - Photonics, Wireless, Circuits

www.calit2.net



Preparing for a World in Which Distance is Eliminated…

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$100M From State for New Facilities

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Calit2 Industrial Partners
Team with Academic Research and Education

- Funding Faculty Research Projects
- Supporting Graduate/Undergraduate Fellows
- Providing Access to Living Labs Equipment
- Joining on Federal Grants
- Co-Sponsoring Workshops/Conferences
- Hosting Seminars or Lectures
- Endowing Chaired Professorships
- Sending Staff to Live at Calit2

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$85 Million from Industrial Partners in Matching Funds

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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**

Calit2 is Connected to Global University Research Centers at 10Gbps

Maxine Brown, Tom DeFanti, Co-Chairs

iGrid 2005

THE GLOBAL LAMBDA INTEGRATED FACILITY

www.igrid2005.org

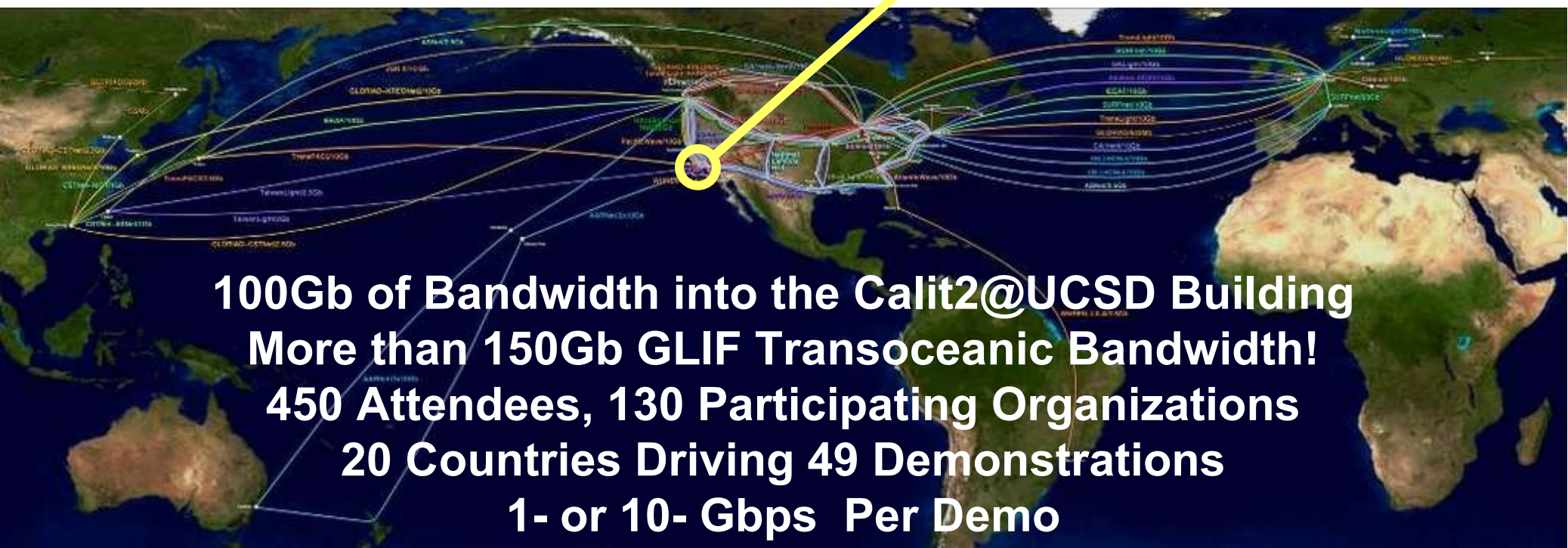


the UC Discovery Grant

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

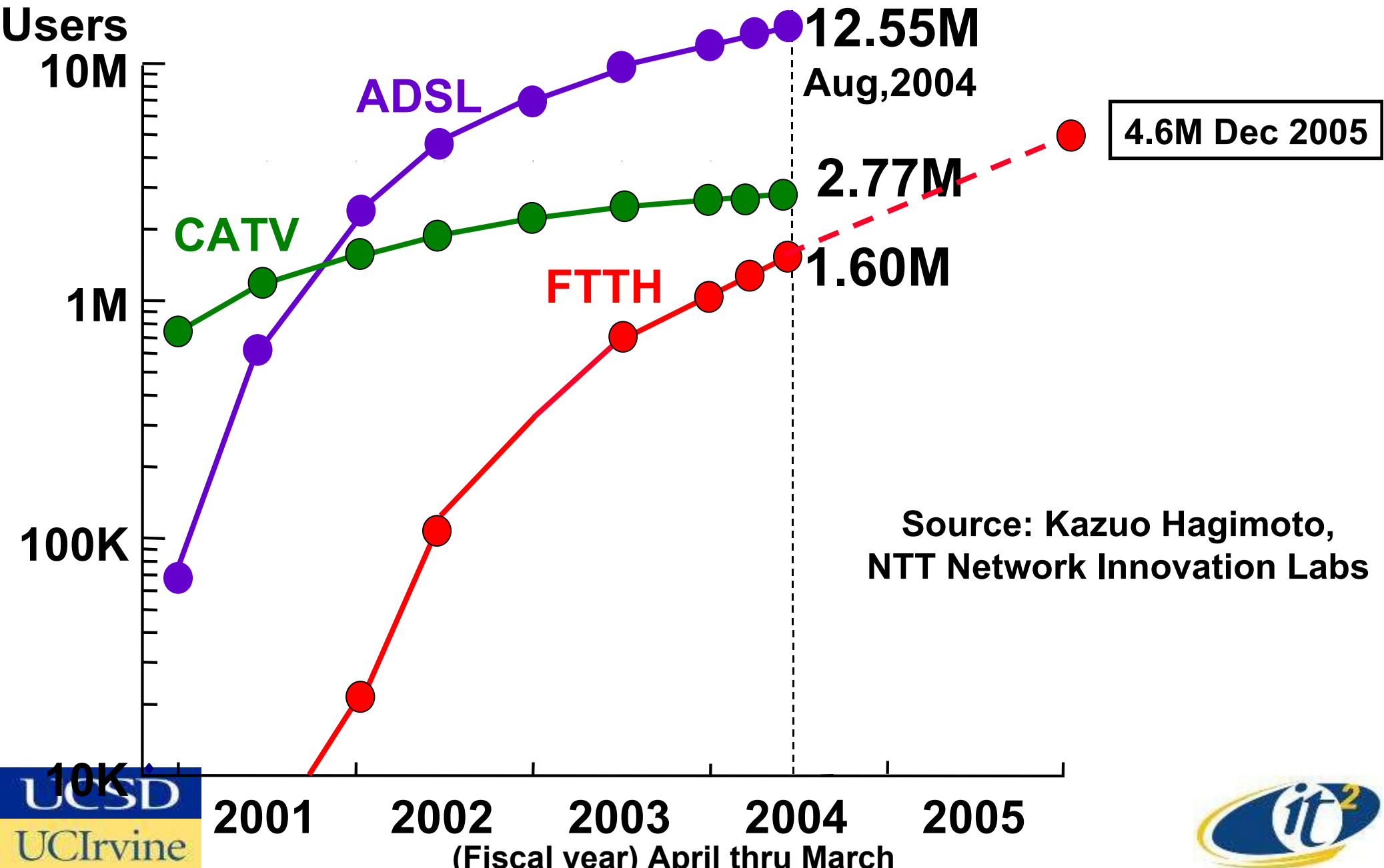
More than 150Gb GLIF Transoceanic Bandwidth!

450 Attendees, 130 Participating Organizations

20 Countries Driving 49 Demonstrations

1- or 10- Gbps Per Demo

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



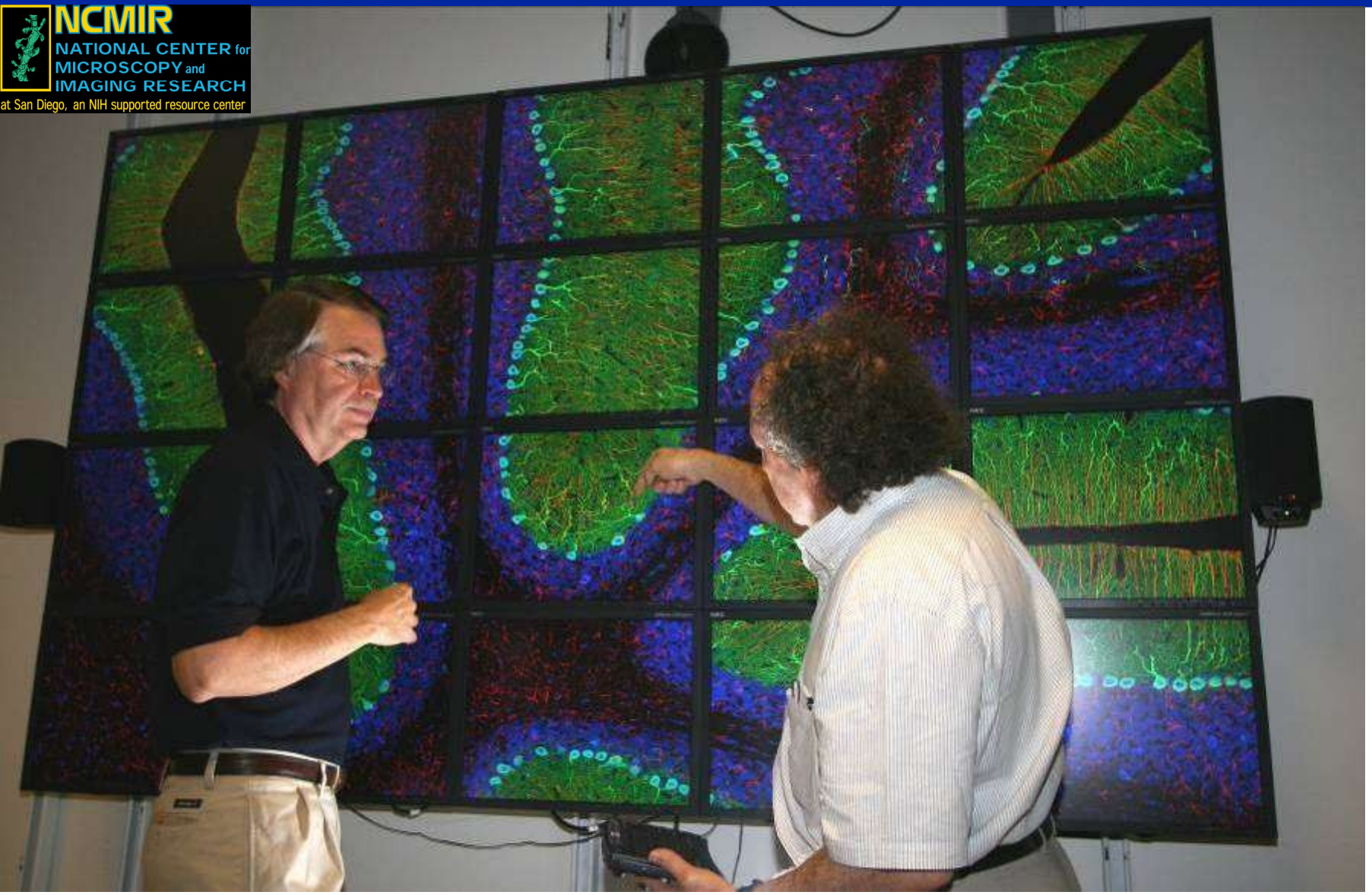
Source: Kazuo Hagimoto, NTT Network Innovation Labs

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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



$13.5M Over Five Years

Picture Source: Mark Ellisman, David Lee, Jason Leigh

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Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
Univ. Partners: SDSC, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST
Industry: IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent

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

Landsat7 Imagery
100 Foot Resolution
Draped on elevation data





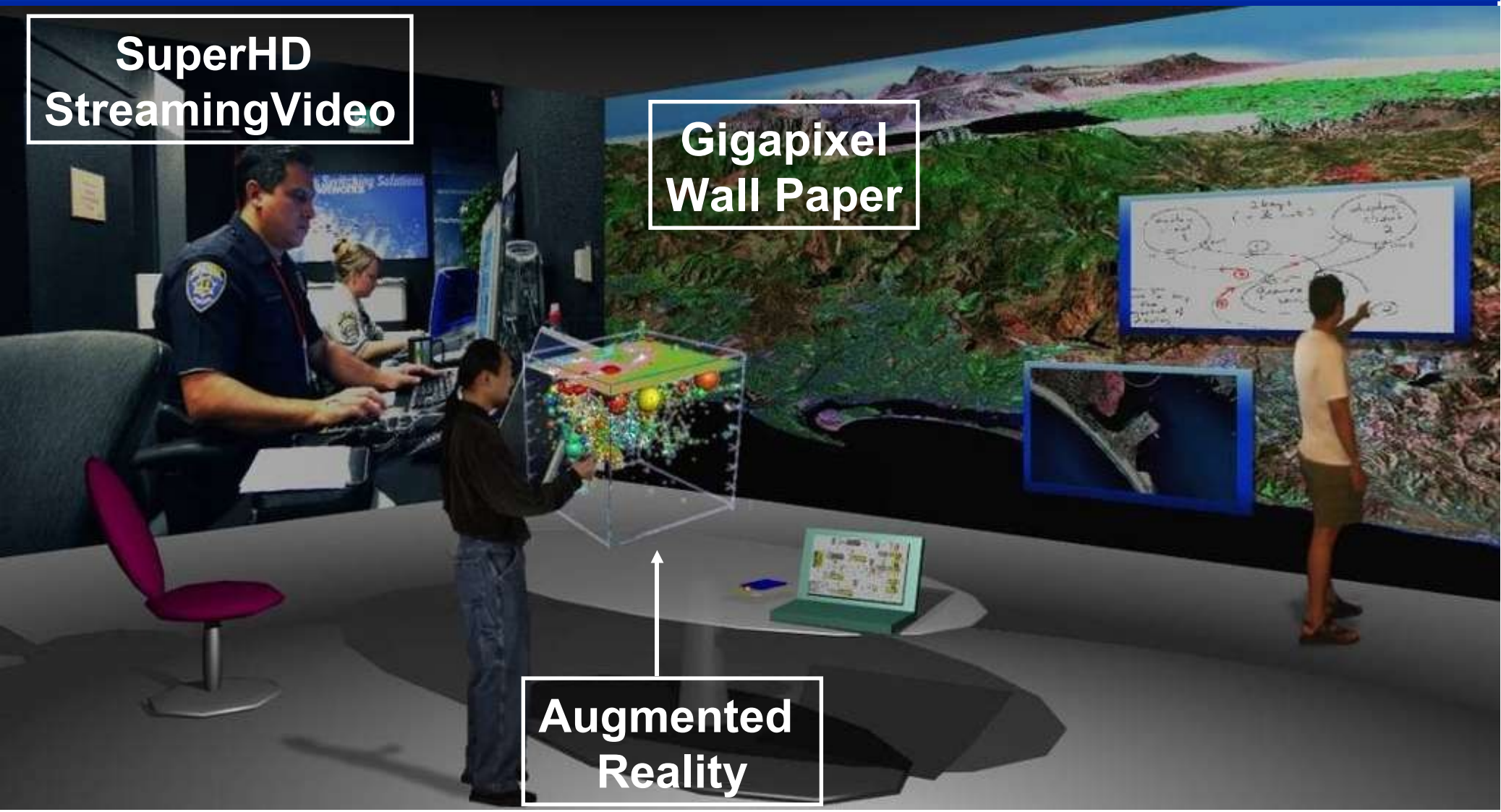
New USGS Aerial Imagery
At 1-Foot Resolution

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

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

Goals by 2007:

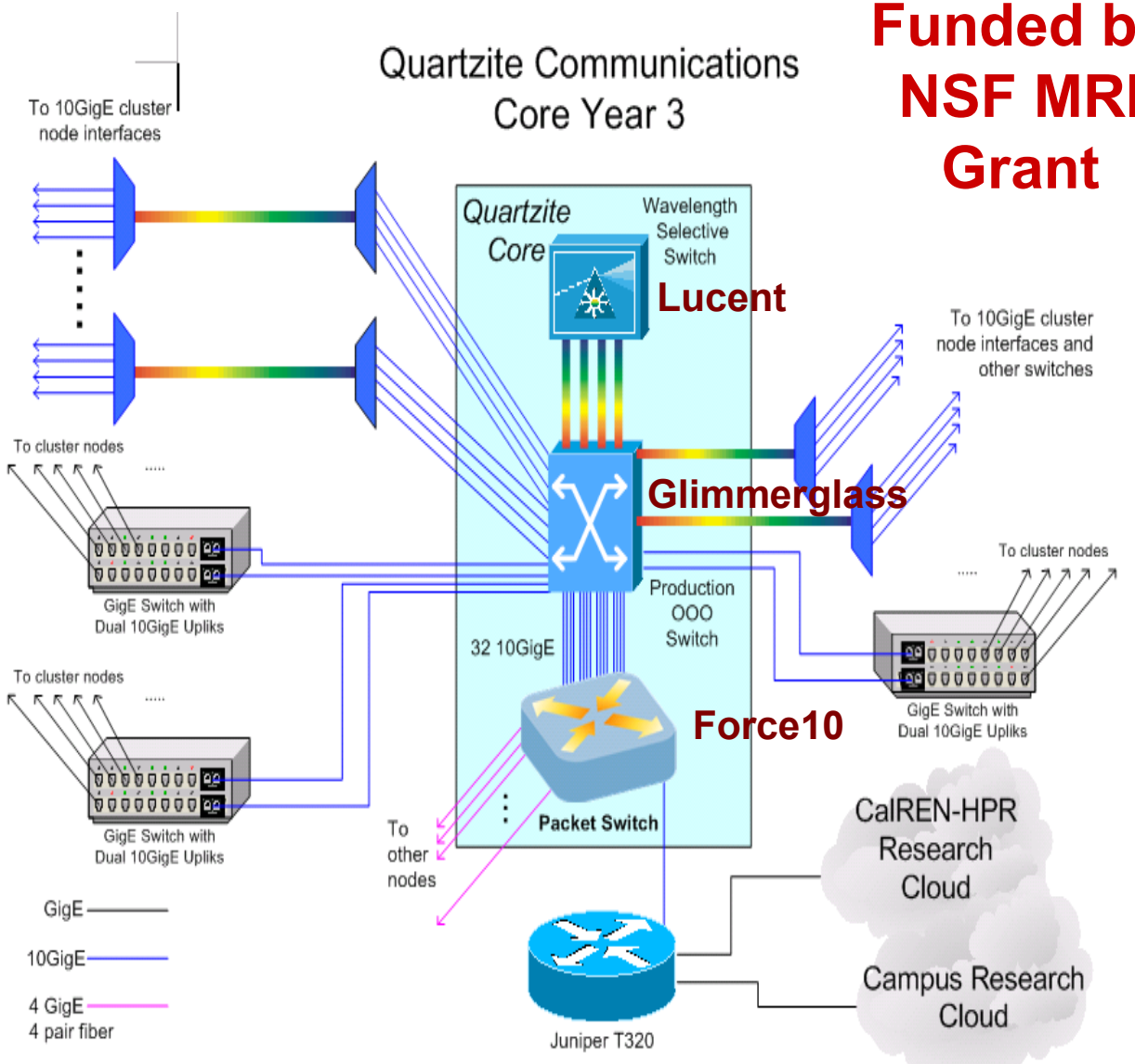
>= 50 endpoints at 10 GigE

>= 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

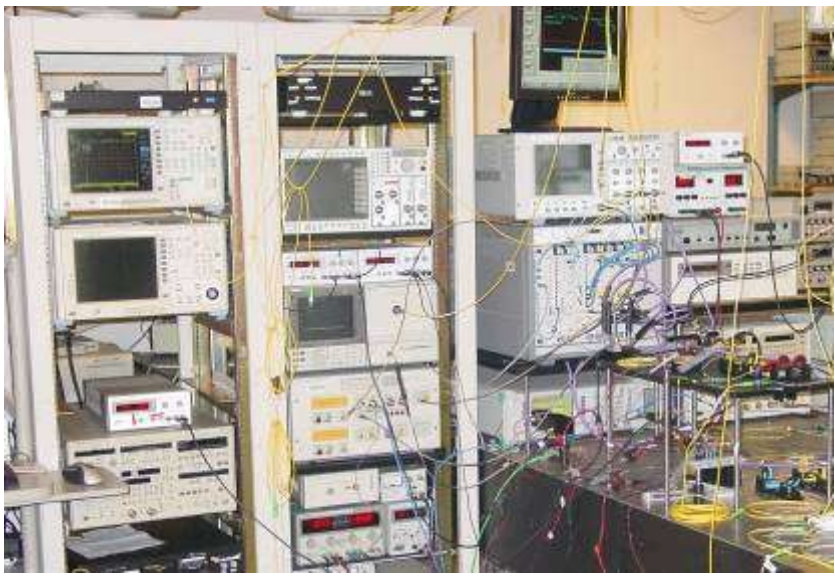


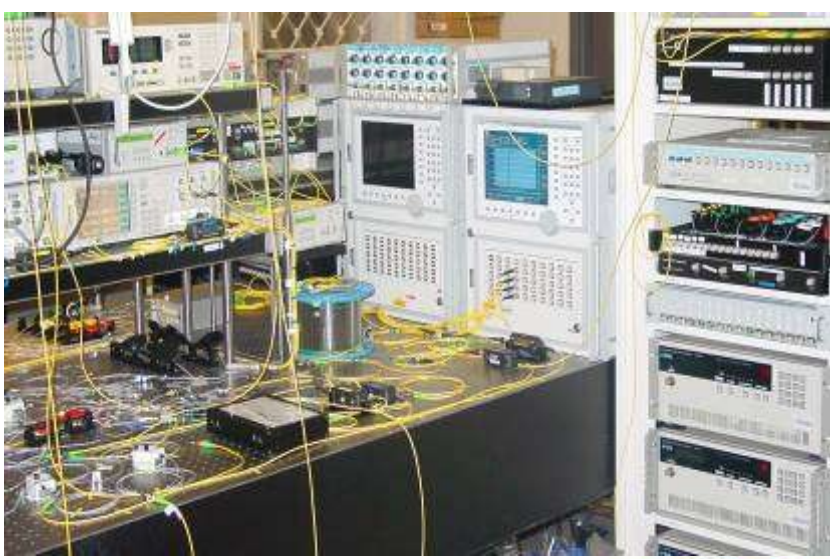
Funded by NSF MRI Grant

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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.



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UCSD Photonics

UCSD Parametric Processing Laboratory

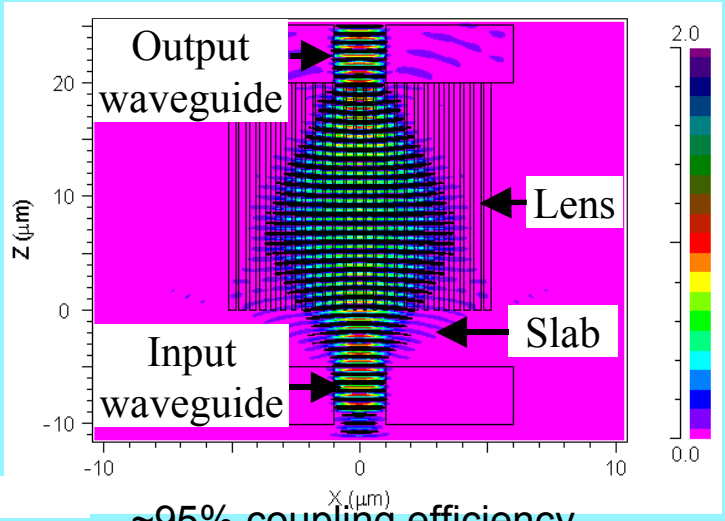
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Silicon Photonics
In collaboration with SUN Microsystems HPCS Project

Motivation: Develop Next Generation On-Chip Interconnection Technology for HPCS (High Productivity Computing Systems)

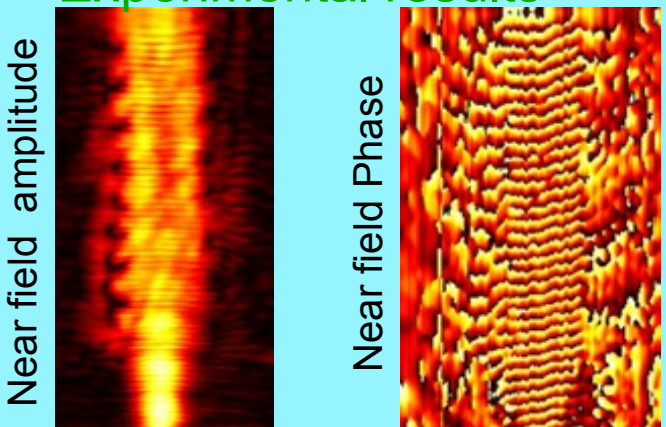
Approach: Develop CMOS Compatible Library of Nano- and Microphotonic Devices (e. g., Modulators, Filters, Couplers Mode Converters, MUX-DEMUX)

SOI Nanophotonic mode converter

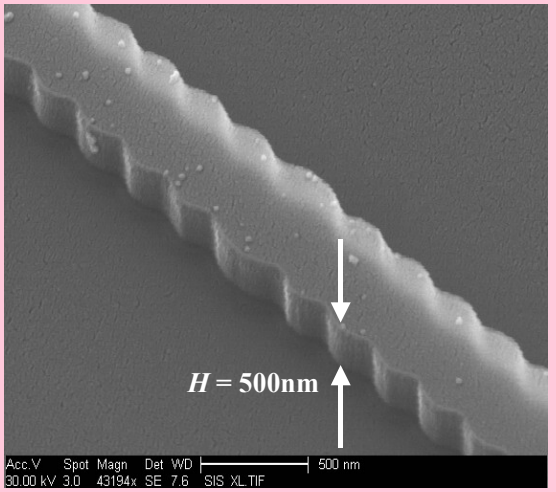


~95% coupling efficiency

Experimental results

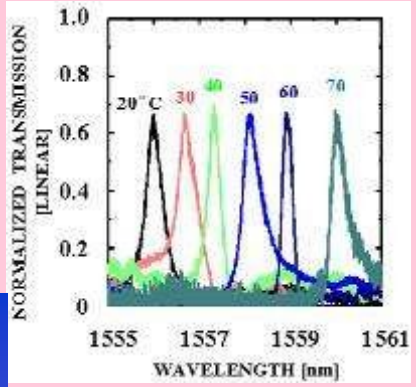


SOI 1-D photonic crystal modulator

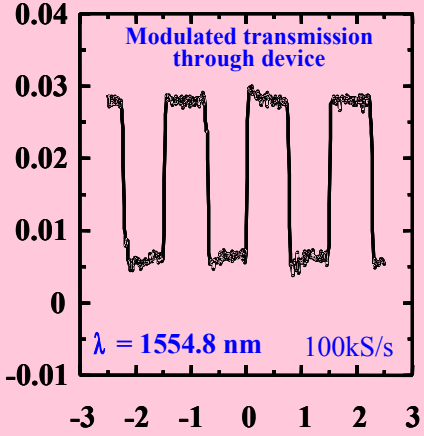


Experimental results

WDM Tuning

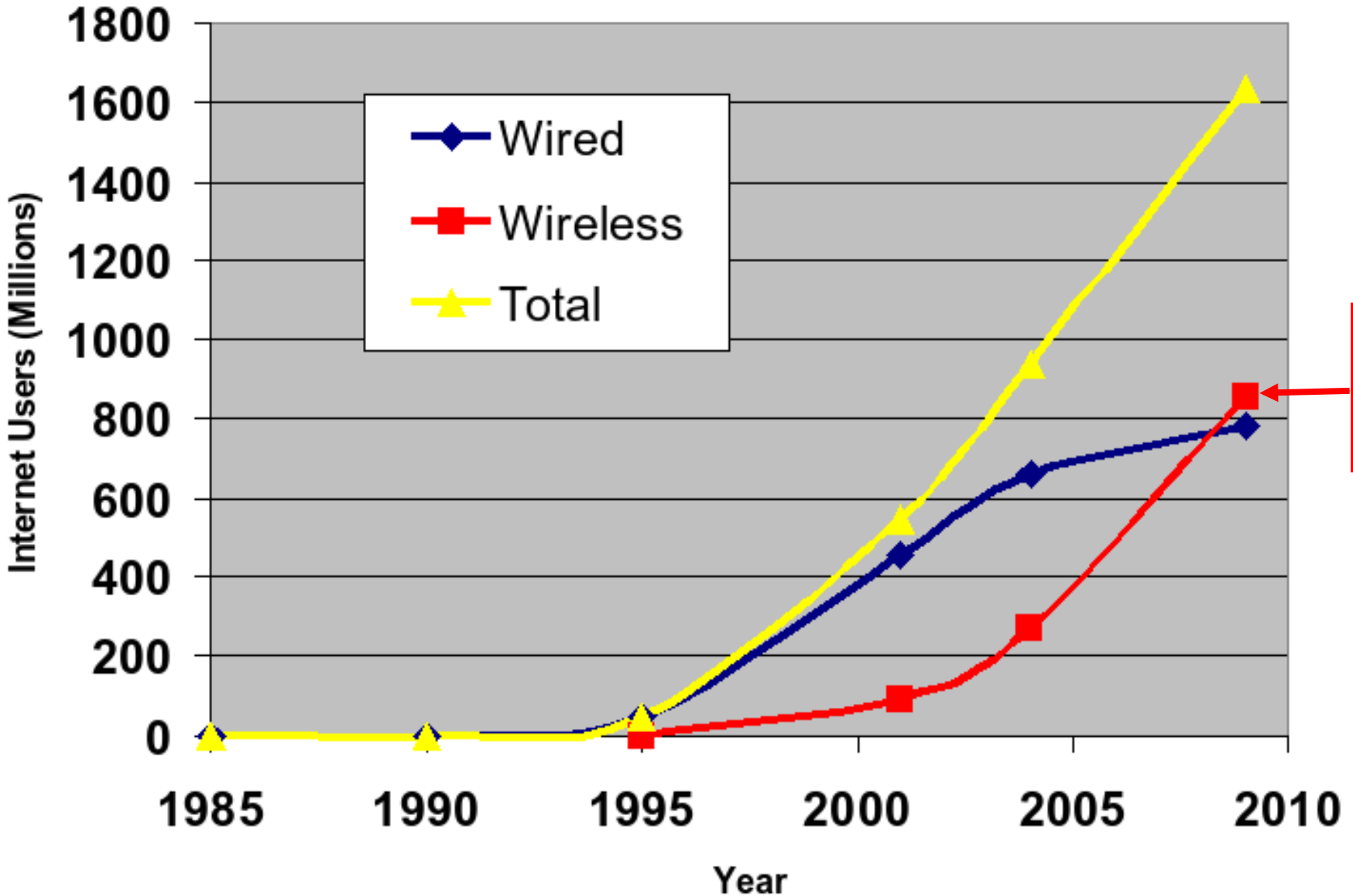


Modulation



UCSD Photonics

Transitioning to the "Always-On" Mobile Internet



http://www.etforecasts.com/products/ES_intusersv2.htm

Calit2 Has Established an Interdisciplinary Program on Automotive Software Engineering

- **Cars Have Separate Integrated Networks For:**
  - Power Train
  - Central Locking System
  - Crash Management
  - Multimedia
  - Body/Comfort Functions etc.

90 % of All Auto Innovations are Now Software-Driven!

- **50-100 Electronic Control Units Supporting up to 1,000 Features**
  - Increasing Interaction Between Different Sub-Systems
- **Next Step: Linking Car to Internet**
  - Movement to Service-Oriented Middleware—i.e. Grids!
  - Paves the Way for Integration of On-Board and Off-Board Information Systems



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Source: Ingolf Krueger, Calit2

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Wireless SensorNets Are Critical for Emergency Response

Wireless Internet Information System for Medical Response in Disasters

Calit2 is Working Closely with the First Responder Community



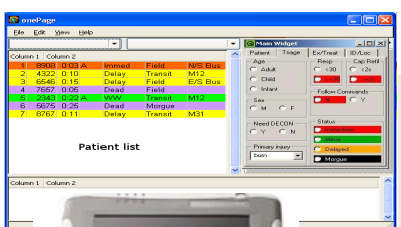




Triage

First Tier



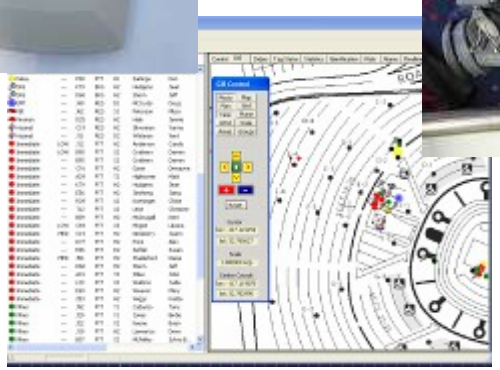




802.11 pulse ox







Reality Flythrough
Mobile Video

Mid Tier

Wireless Networks

Command Center

Calit2 Has Extensive Circuits and Systems Labs

- **Millimeter Wave Lab:**
  - 20mHz–110GHz, uProbe Stations
  - Low Noise Shield Room
  - Micro-Amps & Micro-Meters
- **Power Lab Testbeds:**
  - 200mW – 2000W Amplifiers
  - Battery Management
- **Assembly and Wet Etch Lab**
- **Wireless Platforms Lab:**
  - DSP & FPGA Development Tools
  - System Integration
  - Interoperability Testbed
- **Basestation Lab:**
  - Rooftop, On-the-Air Cellular Lab and Experimental Licenses





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Wireless Power Amplifier Industry Funding Partners & Calit2's Cooperative Test Bed



Power Transistor Tradeoffs

Si-LDMOS & GaN

Price & Performance

Eudyna



Power Amplifier Tradeoffs

WiMAX & 3GPP LTE

Efficiency & Linearity

NOKIA

ERICSSON

Digital Signal Processing Tradeoffs

Pre-Distortion, Memory Effects & Power Control

MIPS & Memory

QUALCOMM

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Broadcom, Conexant, Mindspeed, and Skyworks Support the Center for Pervasive Communications and Computing

www.cpcc.uci.edu

Center for Pervasive Communications and Computing

408 Engineering Tower
University of California, Irvine
Irvine, CA 92697-2625



Nikil Dutt (left) and Sudeep Pasricha (center) receiving their best paper award at ASPDAC.



Director Ender Ayanoglu

CPCC Authors Win Best Paper Award at 2006 Asia and South Pacific Design Automation Conference

The CWC Provides Calit2 With Deep Research in Many Component Areas



Center for Wireless Communications

Two Dozen ECE and CSE Faculty

LOW-POWERED CIRCUITRY	ANTENNAS AND PROPAGATION	COMMUNICATION THEORY	COMMUNICATION NETWORKS	MULTIMEDIA APPLICATIONS
RF Mixed A/D ASIC Materials	Smart Antennas Adaptive Arrays	Modulation Channel Coding Multiple Access Compression	Architecture Media Access Scheduling End-to-End QoS Hand-Off	Scalable Video Smart Spaces Speech Recognition

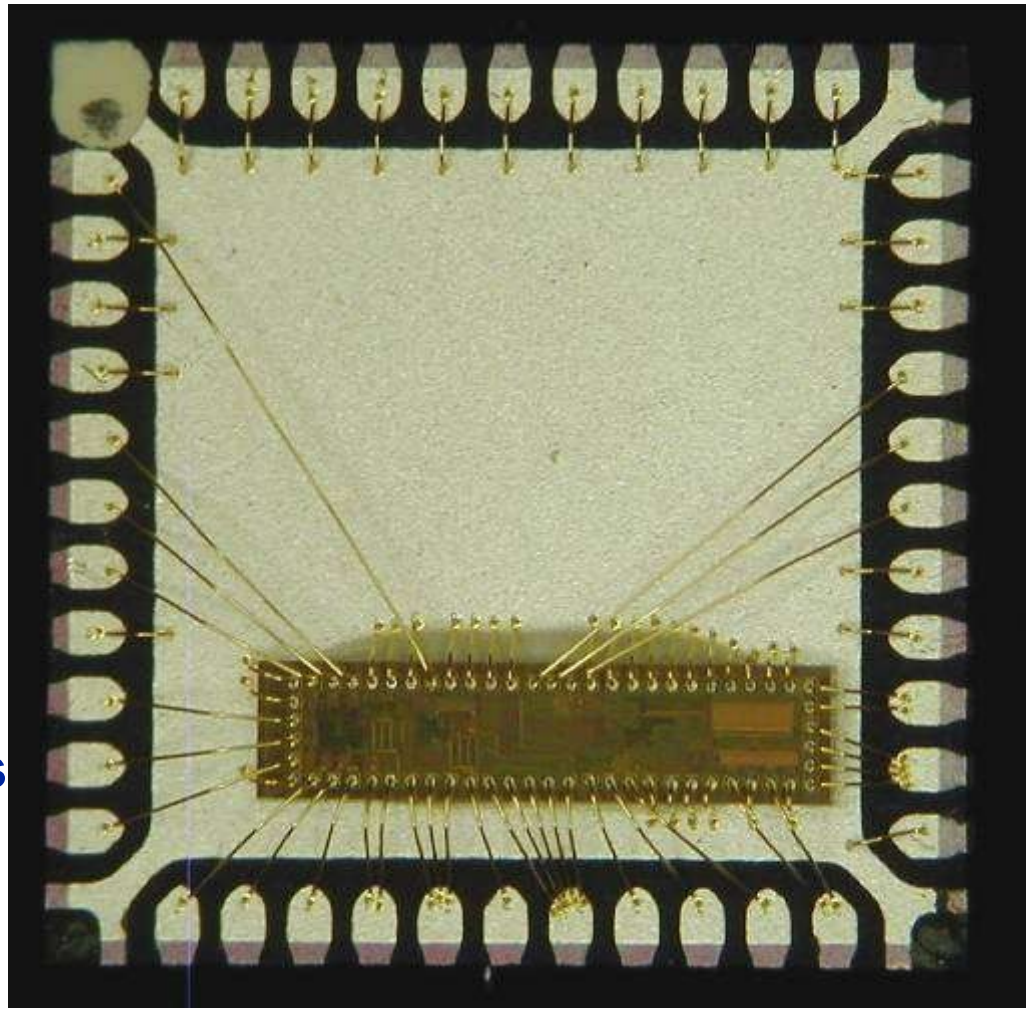
Source: UCSD CWC

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Industrial Partners Provide Fabrication Access to Calit2 Faculty, Students, and Staff

- IBM is Providing UCSD Researchers with Access to Their State-of-the-Art Fabrication Processes in Si/SiGe HBT BiCMOS and RF CMOS Technologies
- The Projects Include
  - High Efficiency Power Amplifiers for Next Generation Cell Phones
  - Ultra-Wideband RF Front-Ends for 500 MB/sec Wireless Data
  - Millimeterwave Wireless Communications at 24 and 60 GHz



IBM SiGe BiCMOS WiFi Power Amplifier with World Record Efficiency

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Source: Larry Larson, CWC, UCSD

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Calit2 Materials and Devices Laboratory: "Nano3"–NanoScience, NanoEngineering, NanoMedicine

10,000 sq. feet State-of-the-Art Materials and Devices Laboratory



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Similar Clean Rooms at UCI

Source: Bernd Fruhberger, Calit2