Living in a World of Nanobioinfotechnology

Invited Talk

OVP Venture Partners Technology Summit

Seattle, WA

May 7, 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

UCSD

UCIrvine

it²

A Mobile Internet Powered by a Planetary Computer

- **Wireless Access--Anywhere, Anytime**
  - Broadband Speeds
  - "Always Best Connected"
- **Billions of New Wireless Internet End Points**
  - Information Appliances
  - Sensors and Actuators
  - Embedded Processors
- **Emergence of a Distributed Planetary Computer**
  - Optical Backplane
  - Storage of Data Everywhere
  - Scalable Distributed Computing Power
- **Brilliance is Distributed Throughout the Grid**

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

UCSD
UCIrvine

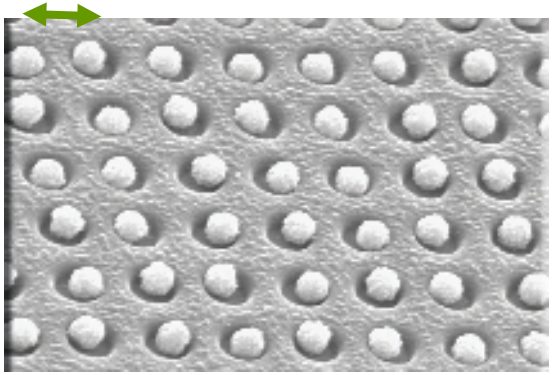
it²

Accelerator: The Perfect Storm-- Convergence of Engineering with Bio, Physics, & IT

1000x Magnification

MEMS

2 micron

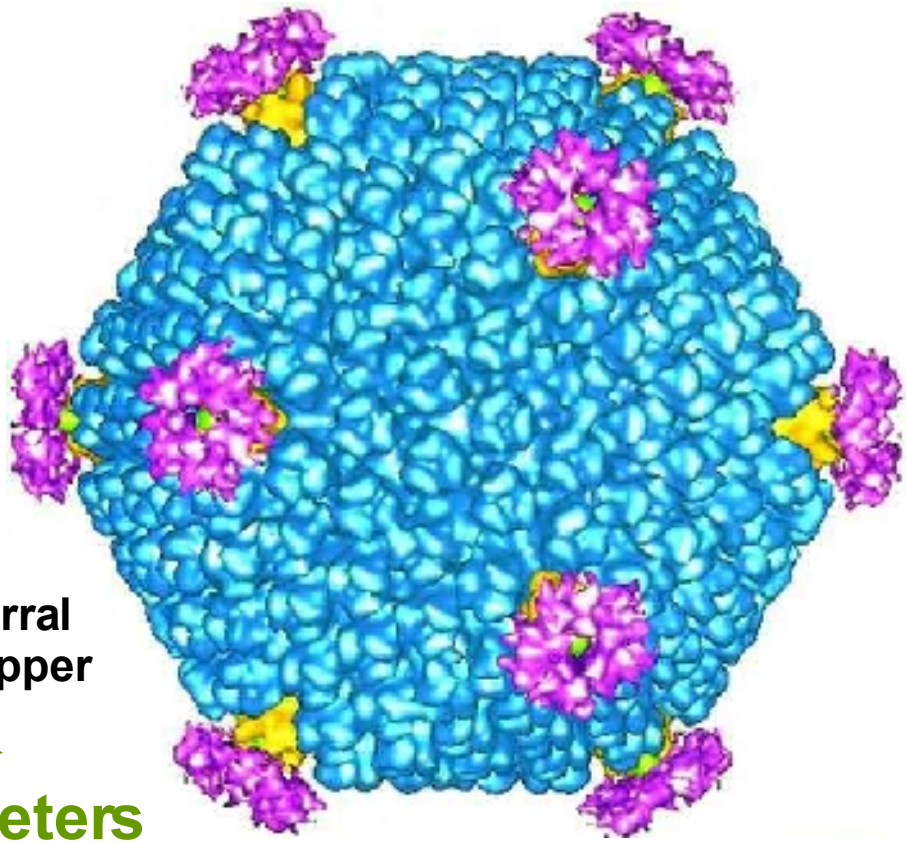


DNA-Conjugated Microbeads

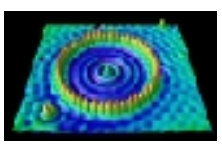


2 mm

400,000 x !



Human Adenovirus



IBM Quantum Corral
Iron Atoms on Copper

5 nanometers

400x Magnification

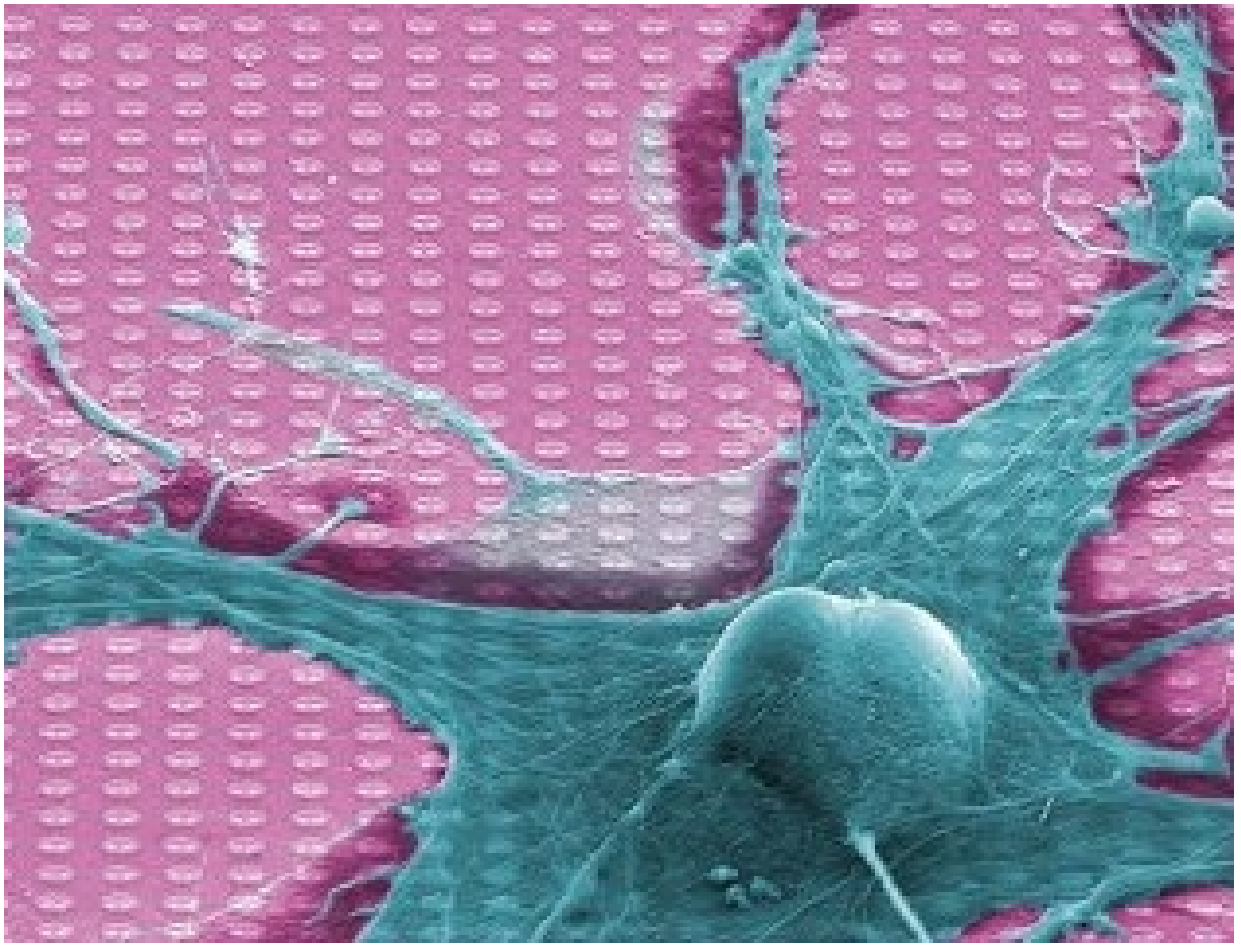
NANO

UCSD
UCIrvine

Nanobioinfotechnology

it²

The Intersection of Solid State and Biological Information Systems



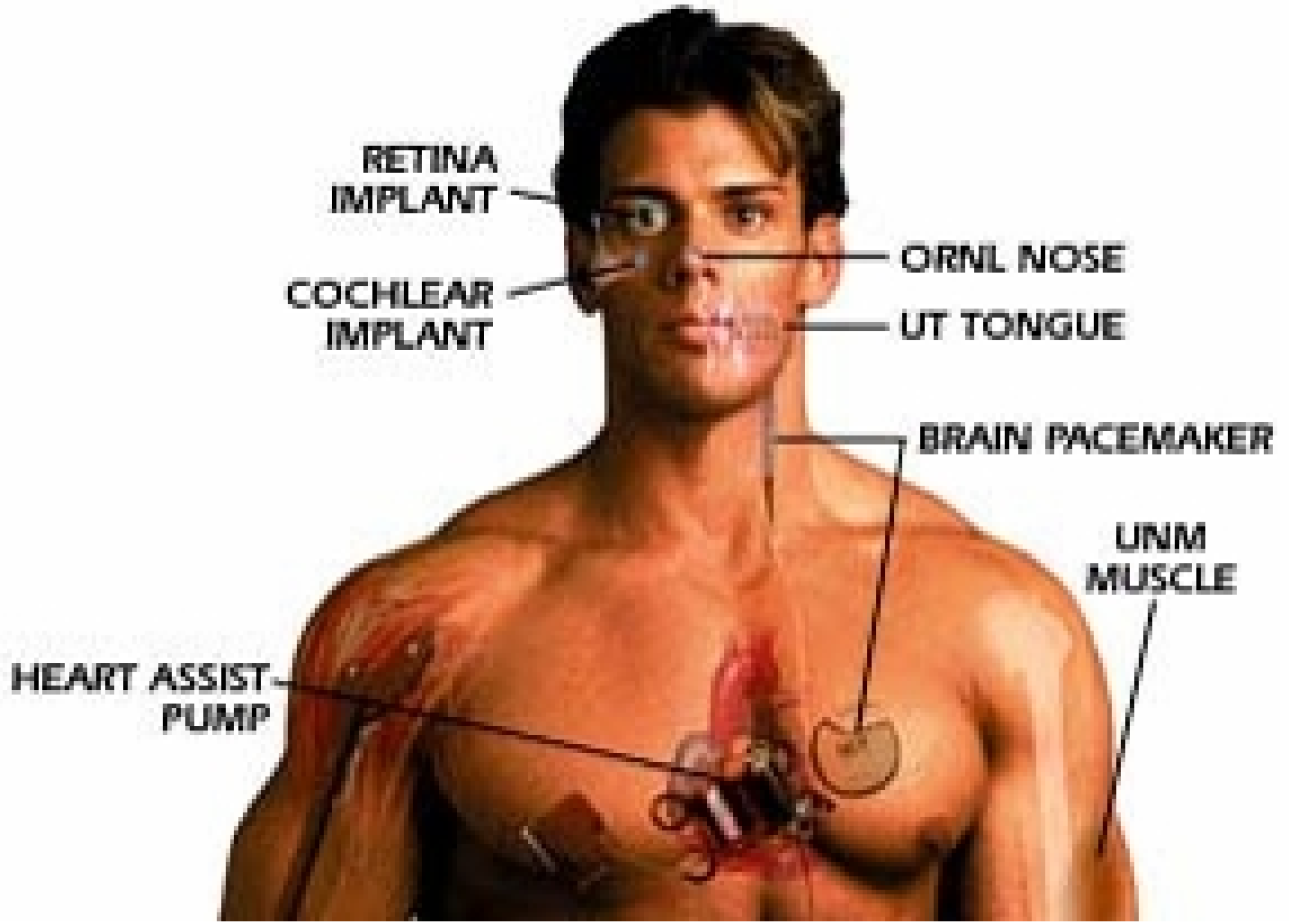
**Snail neuron grown on a CMOS chip with 128x128 Transistors.
The electrical activity of the neuron is recorded by the chip.
(Chip fabricated by Infineon Technologies)**

UCSD
UCIrvine

www.biochem.mpg.de/en/research/rd/fromherz/publications/03eve/index.html

it²

Lifechips--Merging Two Major Industries: Microelectronic Chips & Life Sciences



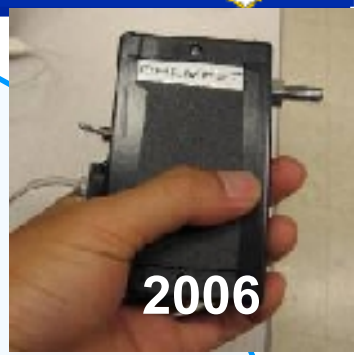
UCSD
UCIrvine

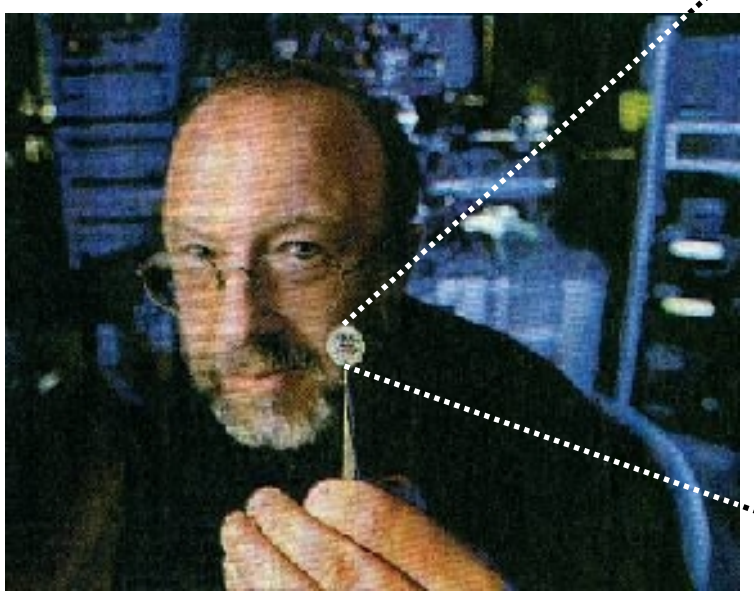
lifechips
university of california, irvine
www.ifechips.org

it²

A World of Distributed Sensors Starts with Integrated Nanosensors

Developing Multiple Nanosensors on a Single Chip, Integrated with Local Processing and Wireless Communications





Ivan Schuller holding the first prototype in 2004

Technology Transfer:
RedX (Explosive Sensors), RheVision (Fauvation Optics)

UCSD
UCIrvine

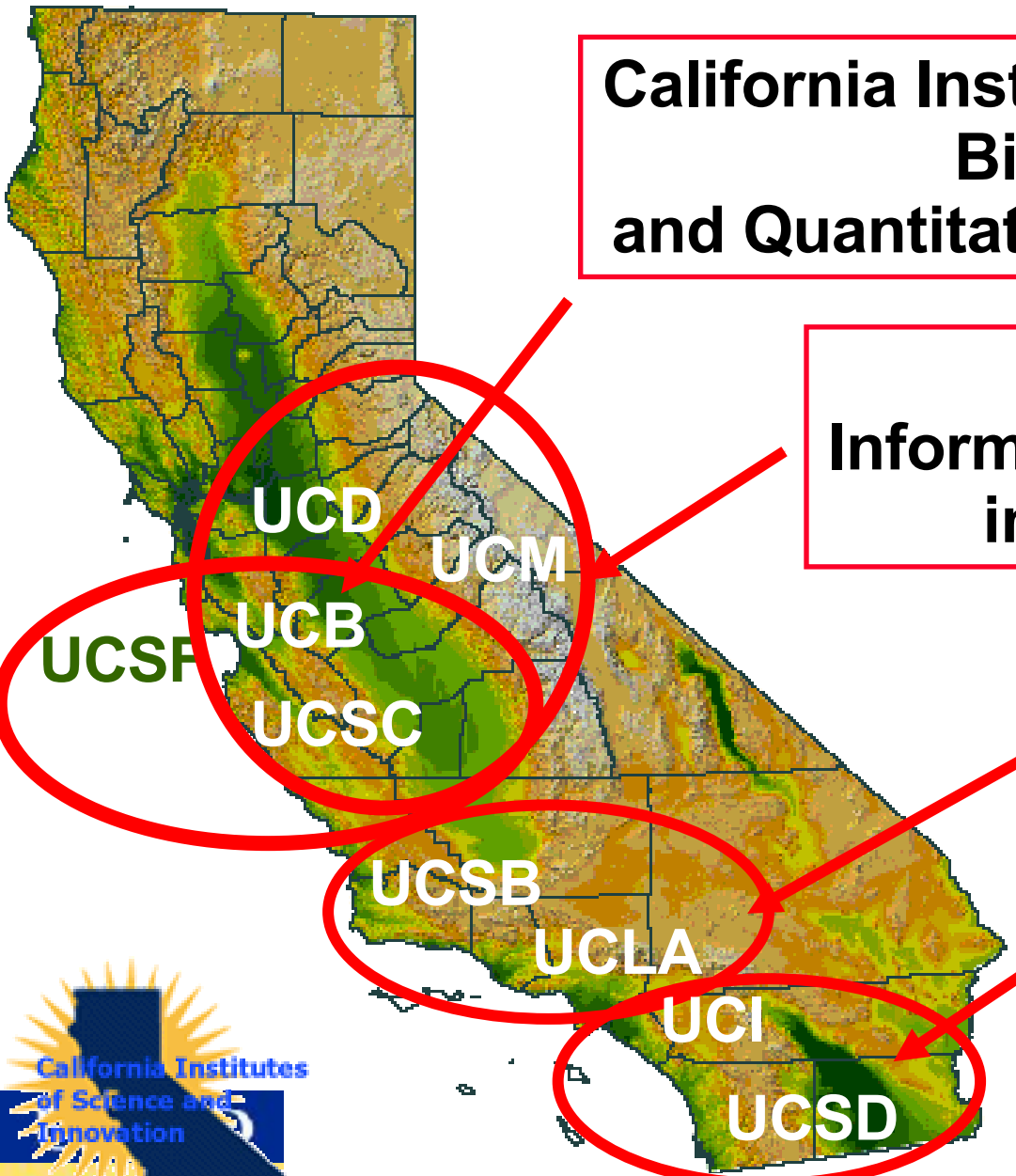
I. K. Schuller, A. Kummel, M. Sailor, W. Trogler, Y-H Lo

A Near Future Metagenomics Fiber Optic-Enabled Data Generator



Source John Delaney, UWash

California's Institutes for Science and Innovation
A Bold Experiment in Collaborative Research



California Institute for Bioengineering, Biotechnology, and Quantitative Biomedical Research

Center for Information Technology Research in the Interest of Society

California NanoSystems Institute

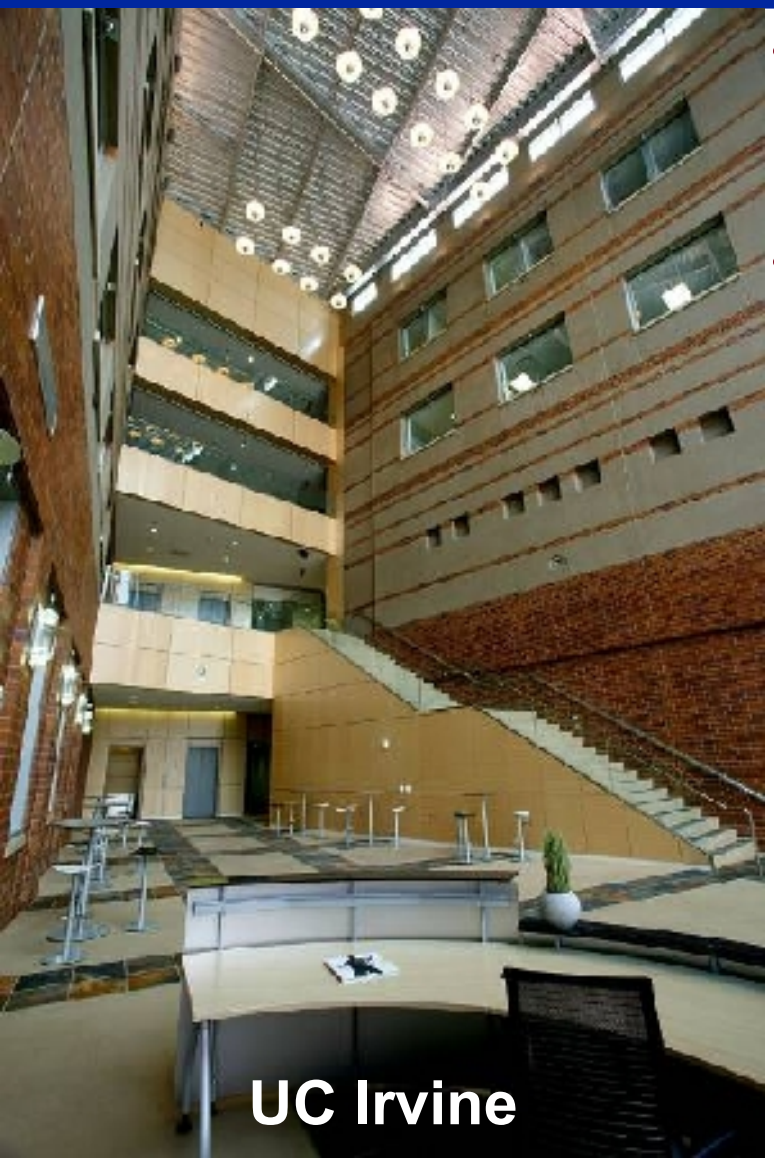
California Institute for Telecommunications and Information Technology

California Institutes of Science and Innovation

UCHV

www.ucop.edu/california-institutes

Two New Calit2 Buildings Provide New Laboratories for "Living in the Future"



- "Convergence" Laboratory Facilities
  - Nanotech, BioMEMS, Chips, Radio, Photonics
  - Virtual Reality, Digital Cinema, HDTV, Gaming
- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks



www.calit2.net

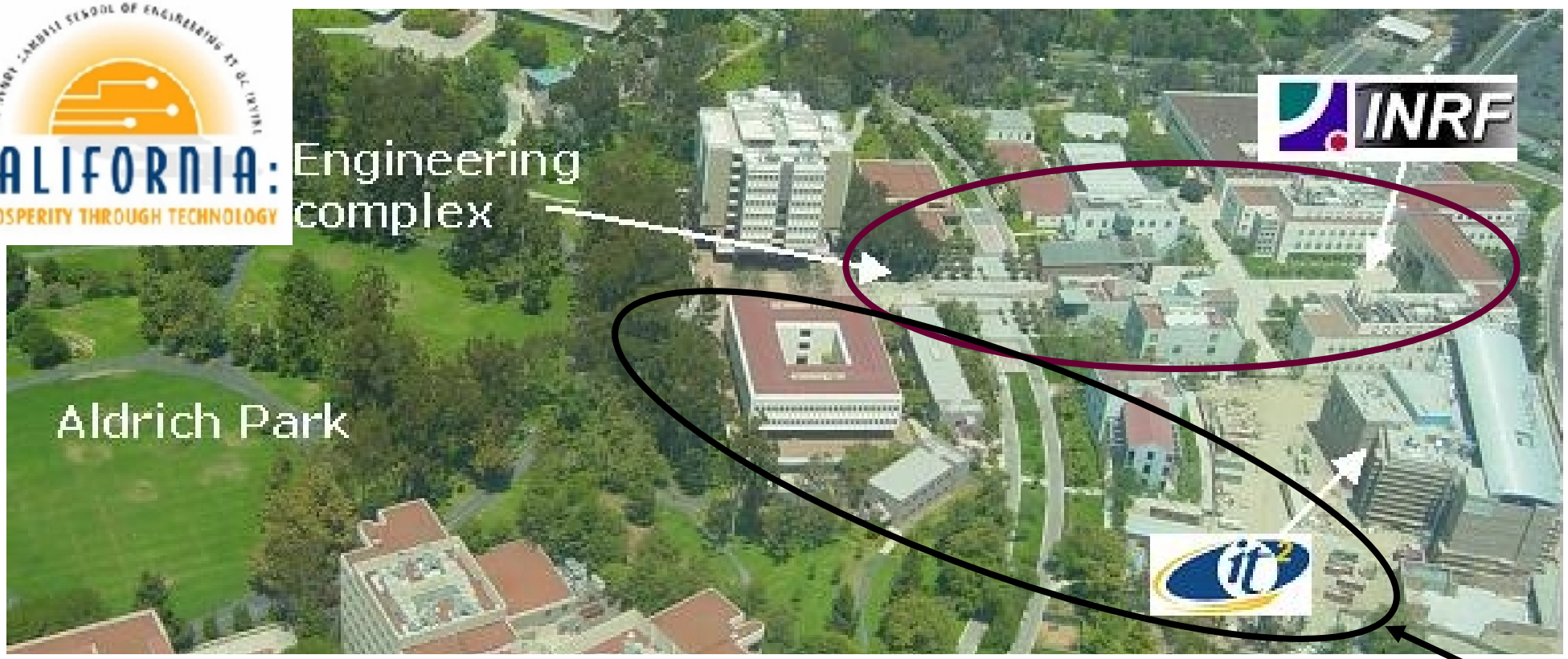
UCSD
UCIrvine

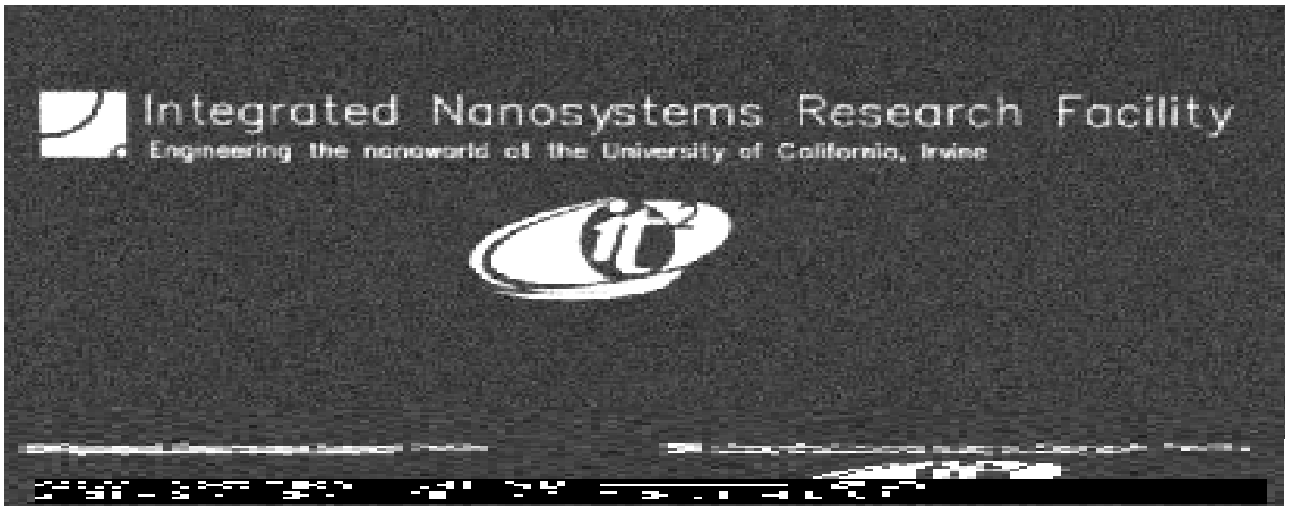
Preparing for a World in Which Distance is Eliminated…

it²

Calit2 is Creating a Nano-Bio-Info Innovation Laboratory

CALIFORNIA: PROSPERITY THROUGH TECHNOLOGY





Donald Bren School of Information and Computer Science

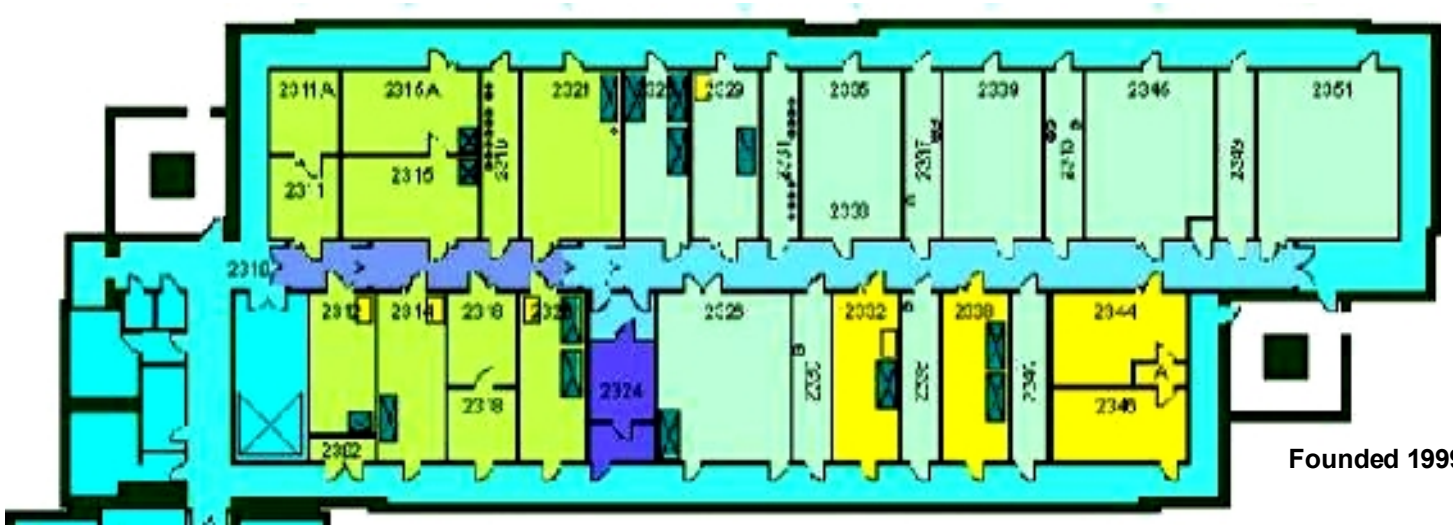
UCSD
UCIrvine

it²

Start with Fabrication Facilities for Micro & Nanosystems

8600 SQ FT clean room space with class 100/1000/10000 areas

www.inrf.uci.edu



Founded 1999



SEM/EDX with 3 nm resolution on 100 mm wafers



Deep Reactive Ion Etcher for bulk micromachining



Double-sided mask aligner for 150 mm wafers



Low-temp PECVD



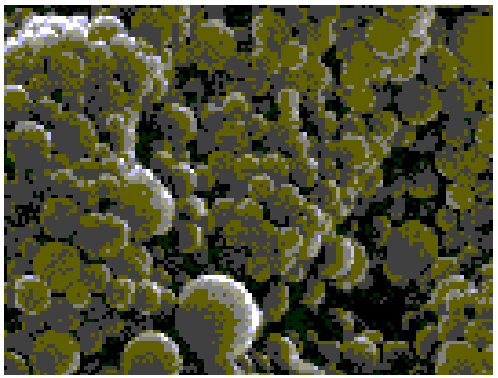
E-beam Lithography

UCSD
UCIrvine

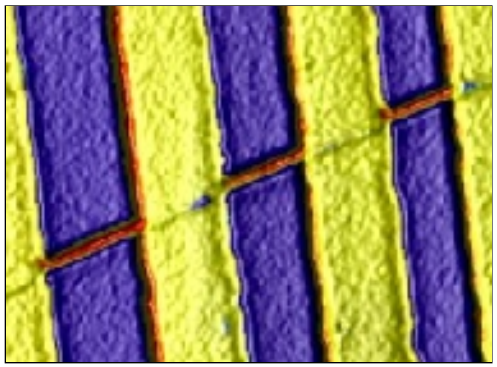
it²

INRF Supports Researchers in Nano and BioMEMS

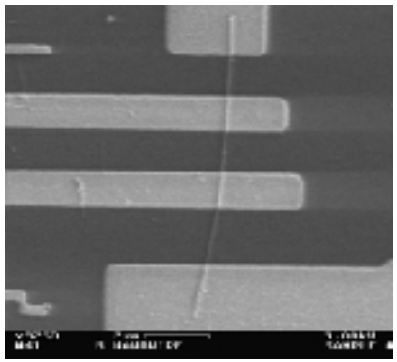
Nanotechnology / Nanofabrication



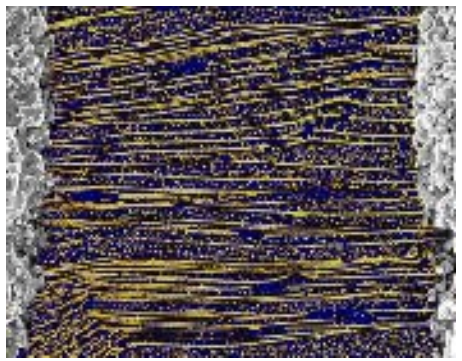
Spray atomization of nano powders



Carbon nanotubes for sensor and electronic applications

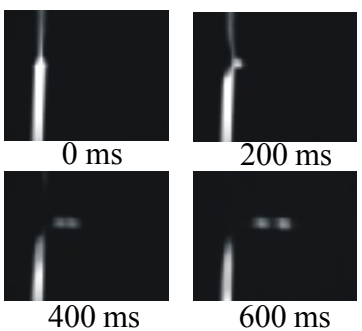


Boron-based nanowires for novel circuits

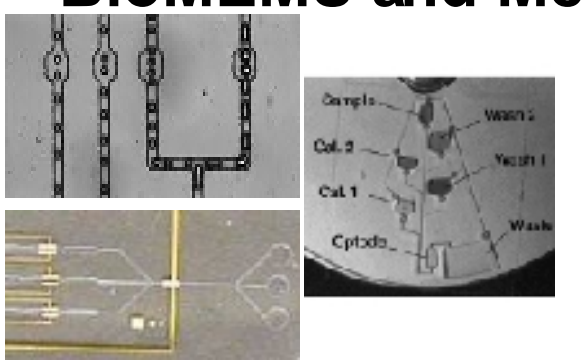


New methods of making arrays of nanowires

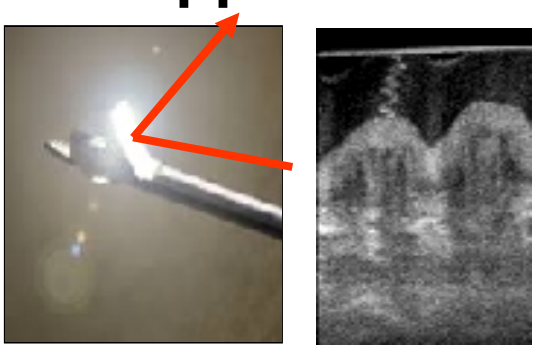
BioMEMS and Medical Applications



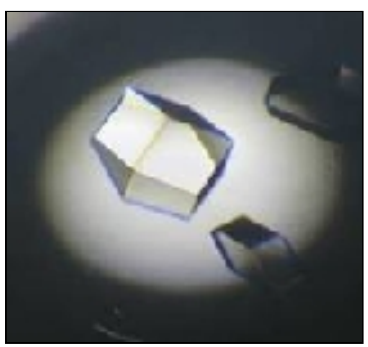
Microfluidic devices for electrophoretic separations



Microfluidic devices using droplets, CD microfluidics and magnetohydrodynamics



Micromirror on a catheter for optical biopsy using coherence tomography



Protein crystallization in nanovolumes

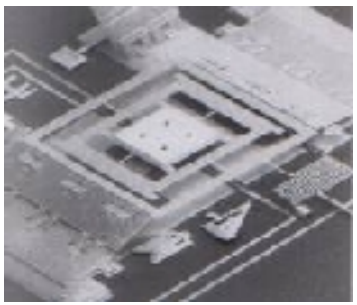
UCSD
UCIrvine

INRF

it²

INRF Also Supports Development of Novel Photonics and RF Devices

Fiberoptic Communications



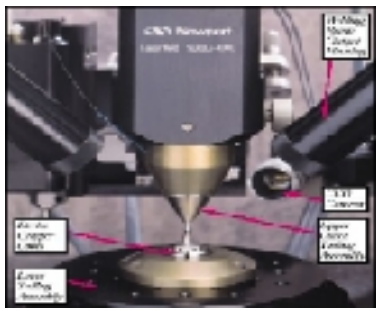
Micro mirrors and tunable Fabry-Perot Interferometers



Polymer waveguides, polarization controllers and other electro-optical devices



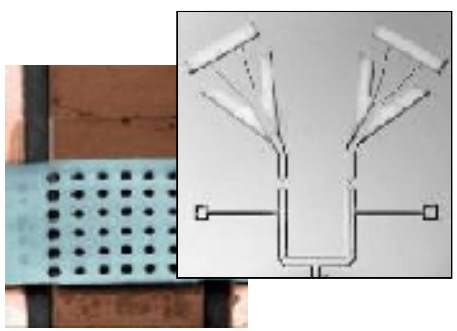
All-fiber tunable devices including acousto-optic tunable filters



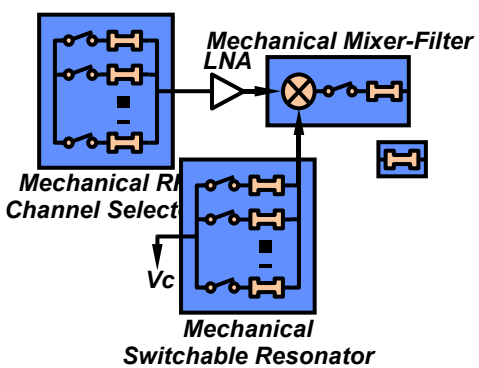
Intelligent fiber-optic alignment algorithms

INRF

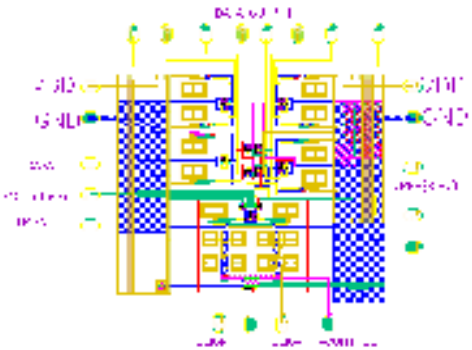
RF and Wireless Communications



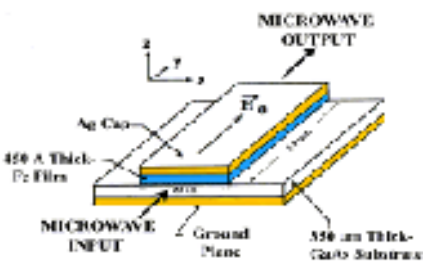
Reconfigurable antennas with integrated RF MEMS switches



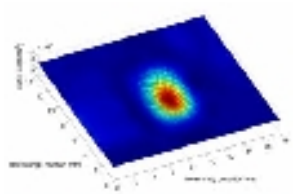
MEMS-based ultra-low-power RF receivers



High-speed RF mixed-signal circuit design



Fe-GaAs integrated wideband microwave devices



Microwave imaging for damage assessment of structures

UCSD
UCIrvine

it²

INRF Partners Companies with University Researchers: 70 Past and Current Collaborating Companies

INRF

40 UCI Faculty from a Dozen Departments

- Advanced Customs Sensors Inc.
- Agilient
- Alpha Industry/Network Device Inc.
- AXT/Alpha Photonics Incorporated
- Alpine Microsystems Incorporated
- Auxora, Inc.
- Bethel Material Research
- Broadcom
- Broadley-James Corp.
- Cito Optronics, Inc.
- Coherent, Inc.
- Conexant
- Coventor
- DRS Sensors
- Endevco
- Friends USA
- General Monitors
- Global Communication Semiconductor
- Hewlett Packard
- Hitachi Chemical Research
- IJ Research
- Impco Technology
- Intelligent Epitaxy Incorporated
- International Technology Works
- IOS
- Irvine Sensors
- Jazz Semiconductor
- Linfinity Microelectronics
- Maxwell Sensors
- Metrolaser Incorporated
- Microtek Lab Incorporated
- MicroWave Technology
- Moog, Inc.
- Network Device
- Newport Opticom
- NexGen Research Corporation
- Northrop Grumman Corporation
- Numerical Technologies
- Ormet Corp.
- Oplink Communications
- Optical Crossing
- Optinetrics
- Optiswitch Technology
- Physical Optics Corp.
- Printronix
- ProComm Enterprises
- Rainbow Communications
- Raytheon Systems
- Rockwell
- RF Integrated Corp.
- Sabeus Photonics
- Saddleback Aerospace
- SAIC
- Second Sight, LLC
- Semco Laser Technology
- Sequenom
- Silicon Storage Technology, Inc.
- Simax
- Skyworks Solutions
- SVT Associates
- Tamarack Scientific, Inc.
- Tanner Research, Inc.
- Texas Instruments, Inc.
- TRW
- U Machines
- Versa Technology
- VSK Photonics
- WIN Semiconductors
- Xtal Technologies
- Y Media Corporation

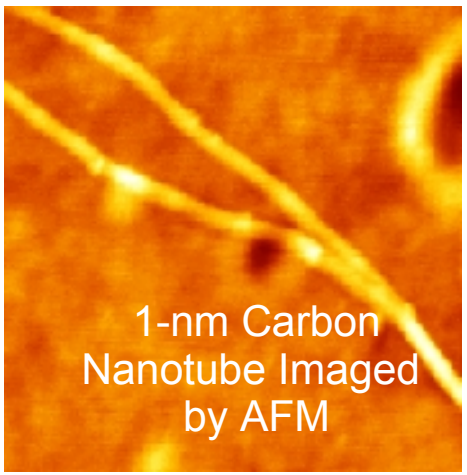
UCSD

UCIrvine

it²

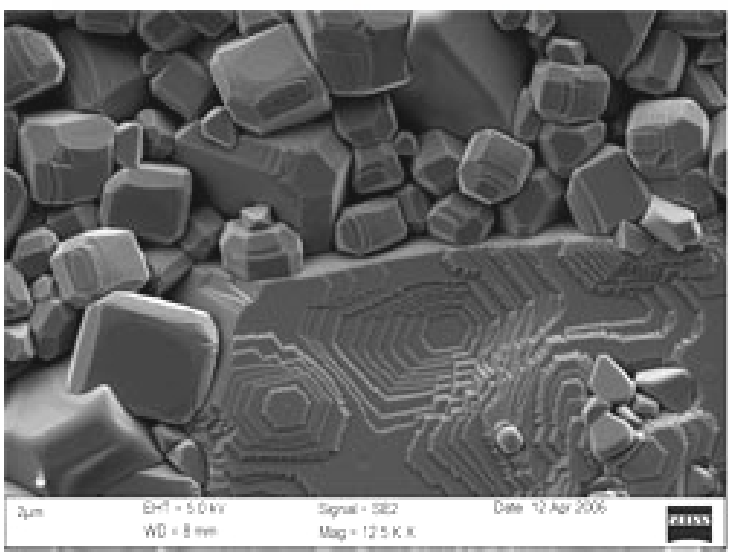
Add in New Nanofabrication and Material Characterization Labs at Calit2@UCI

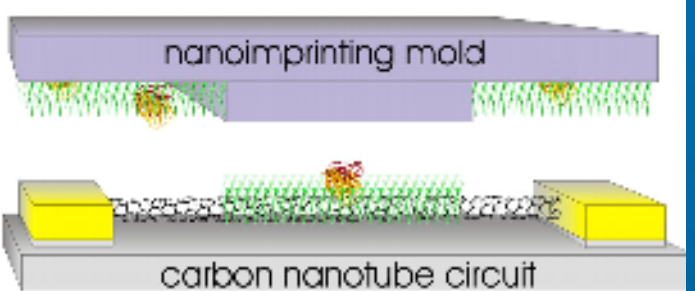
- **Zeiss Microscopy Center**
  - **Focused Ion Beam**
  - **FEG-SEM**
  - **Environmental SEM**
- **Thermal Analysis Lab and Atomic Force Microscope**
- **Nanoimprinting Facility**



Zeiss FIB



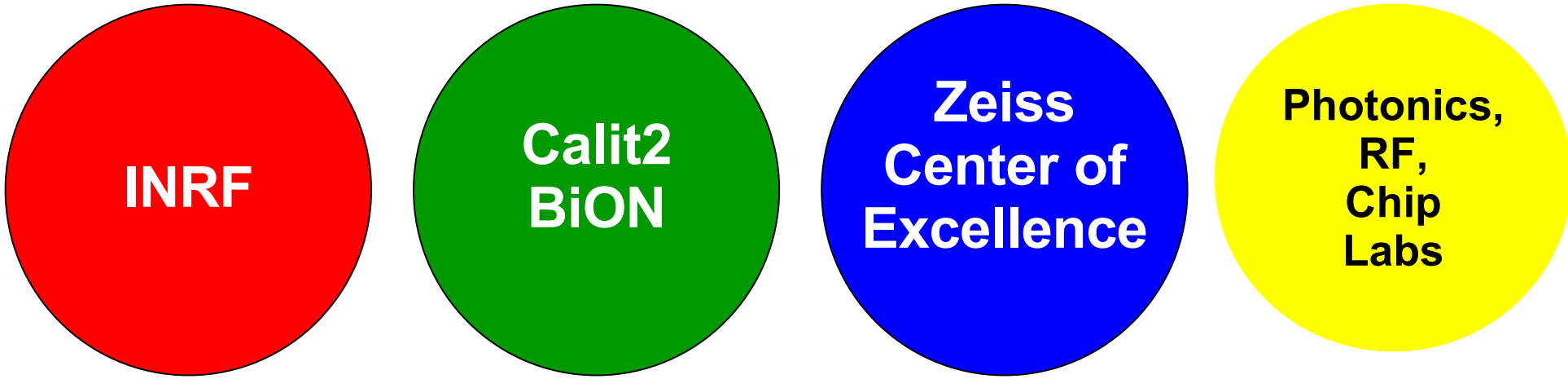






UCSD
UCIrvine

Calit2@UCI Nanobioinfotechnology "Innovation Pipeline"



Micro/Nano Materials and Devices

Bio-Organic Nano Lab

SEM, Advanced Characterization

Integrate with Chips, Telecom

Three centers share a common infrastructure

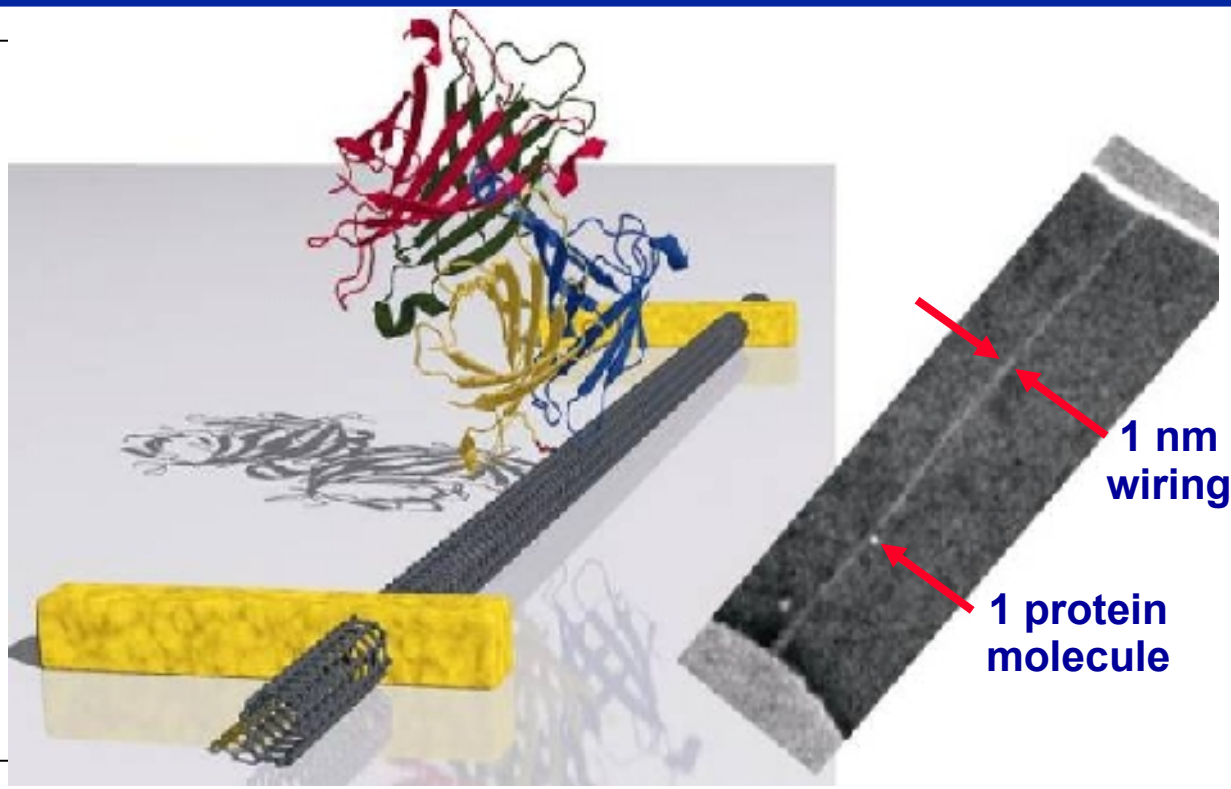
UCSD
UCIrvine

Source: GP Li, Calit2

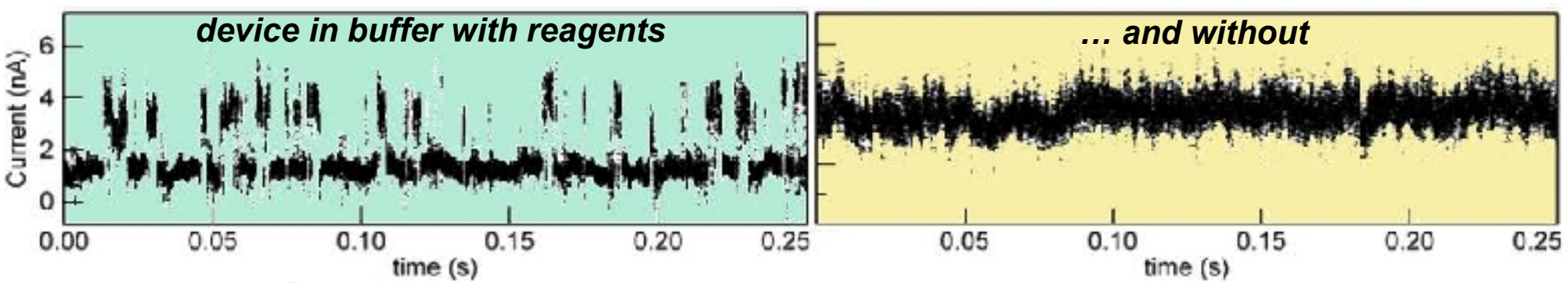
it²

Example: Real-Time Electronic Readout from Single Biomolecule Sensors

- Carbon Nanotube Circuits Provide Nanoscale Connectivity
- New Techniques Integrate Single-Molecule Attachments
- Dynamics and Interactions With the Environment Can be Directly Measured
- Electronic Readout Compatible With Hand-held, Low-power Devices



Schematic & SEM Image of Carbon Nanotube-based Device



UCSD UCIrvine

NSF

Source: Phil Collins & Greg Weiss, Calit2@UCI

it²

Calit2@UCSD Building Anchors
"Bio-Nano-IT Convergence Quad"



UCSD
UCIrvine

Calit2 Materials and Devices Laboratory: "Nano3" – Science, Engineering, Medicine



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



nano3
SCIENCE ENGINEERING MEDICINE

Source: Bernd Fruhberger, Calit2

The First Shared Clean Room Facilities on the UCSD Campus



Class 100/1000

Nearly 50 Academic Projects

Treatment, Understanding, and Monitoring of Cancer
(UCSD, Burnham Institute, UCSB, UCR, UCI --PI: Sadik Esener)

OBJECTIVE: Use of nanotechnology towards eliminating suffering and death due to cancer

- Detect cancerous tumors at the earliest stage
- Treat cancerous cells selectively and effectively
- Understand their progression
- Monitor and destroy residual cancer cells

APPROACH: Delivery via stealth porous mother ships with multi functional payloads

- smart nano sensors and
- tumor activated nano platforms for therapeutics and imaging



Porous mother ship In vasculature



Targeting early tumor formations

Release of payload

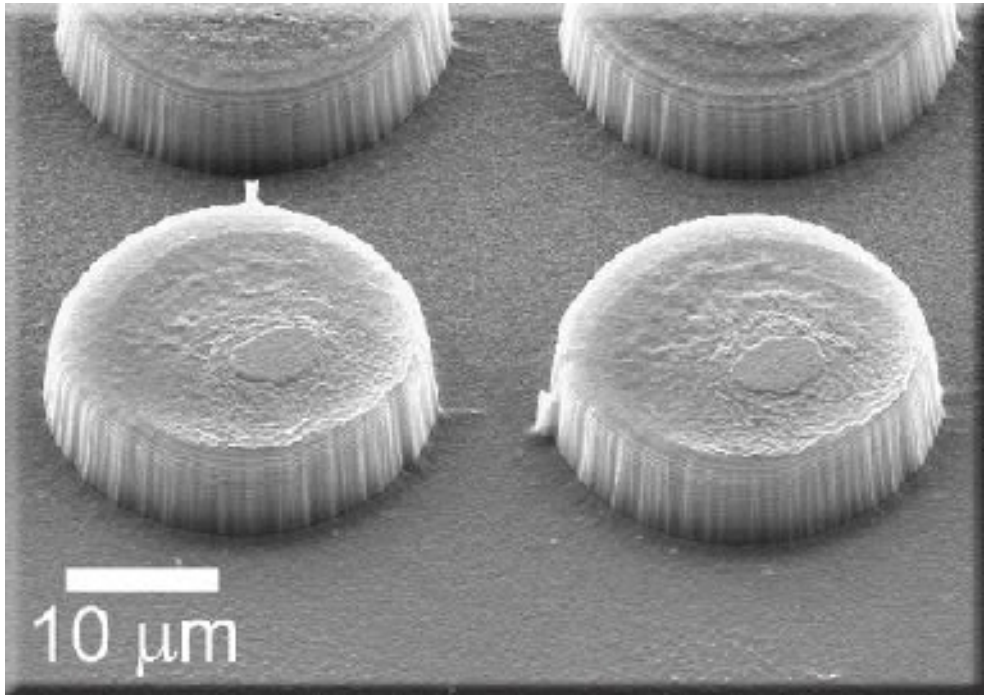


Impact of treatment

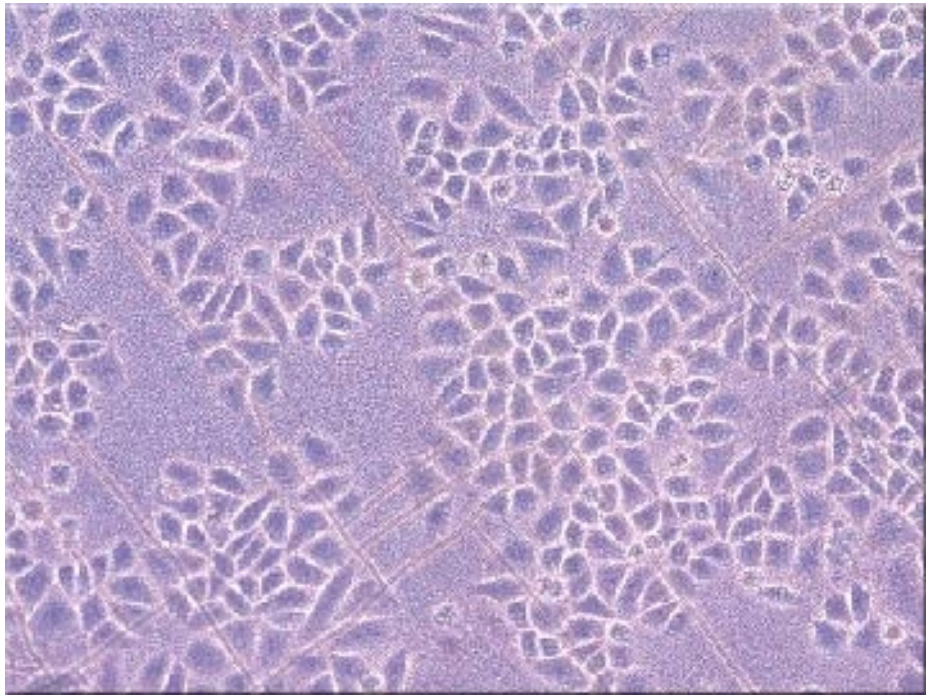
Nano-Structured Porous Silicon Applied to Cancer Treatment

Nanodevices for In-vivo Detection & Treatment of Cancerous Tumors

Porous Photonic Crystals for Cell-based Biosensor



Nanostructured “Mother Ships” for delivery of cancer therapeutics.



Human epithelial (HeLa) cells on a photonic crystal. The colors observed can be used to monitor the physiological status of the cells.

Michael J. Sailor Research Group
Chemistry and Biochemistry

UCSD
UCIrvine

NanoTumor Center

nano3
SCIENCE ENGINEERING MEDICINE

it²

Calit2 Brings Computer Scientists and Engineers Together with Biomedical Researchers

- **Some Areas of Concentration:**
  - Algorithmic and System Biology
  - Metagenomics
  - Cancer Genomics
  - Human Genomic Variation and Disease
  - Proteomics
  - Mitochondrial Evolution
  - Computational Biology
  - Multi-Scale Cellular Imaging
  - Information Theory and Biological Systems
  - Telemedicine

CASB

camera
Marine Microbial Ecology

INSTITUTE FOR GENOMICS AND BIOINFORMATICS
University of California, Irvine

BIOMEDICAL INFORMATICS RESEARCH NETWORK

NCMIR
NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH
at San Diego, an NIH supported resource center

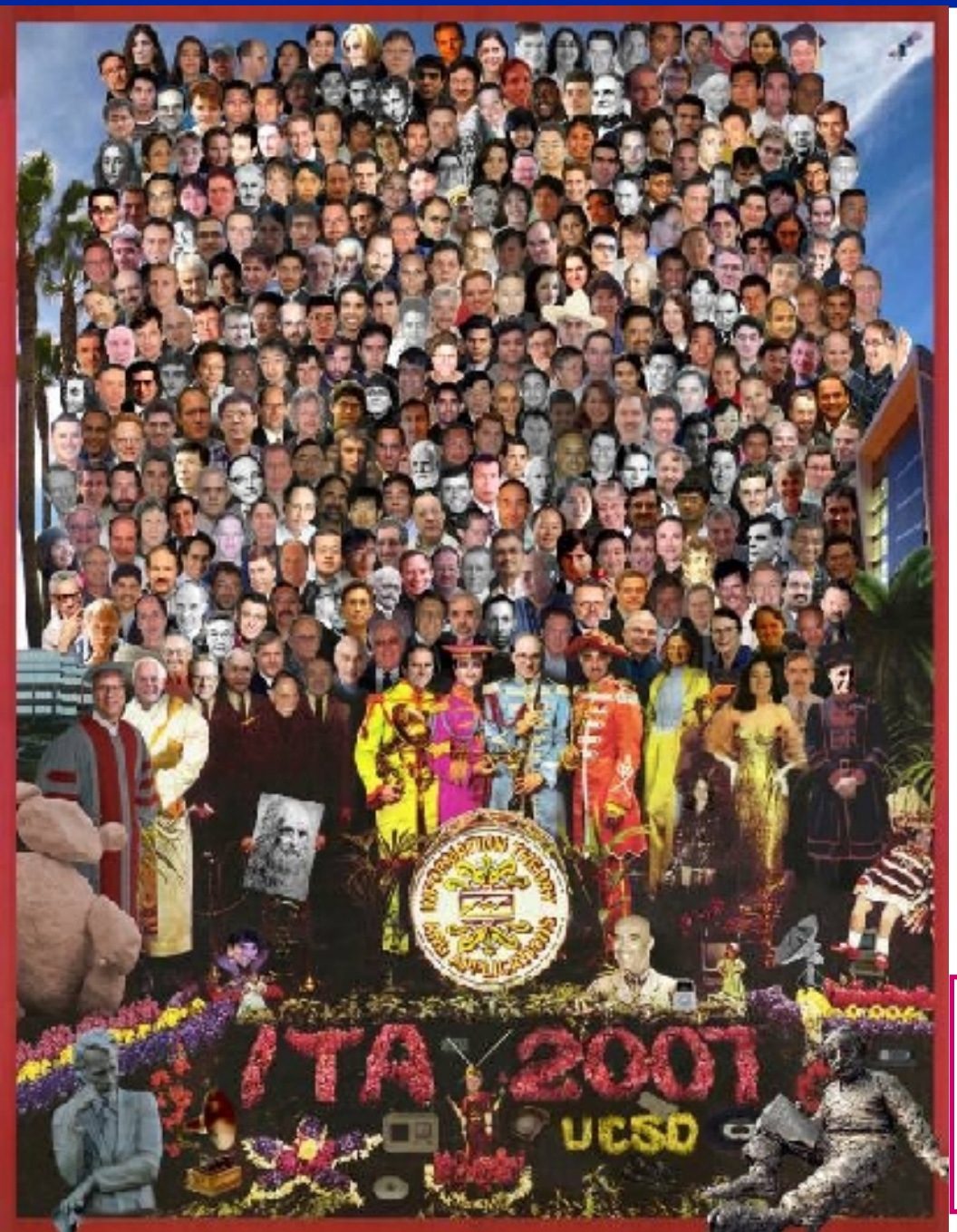
Information Theory and Applications

UCSD
UCIrvine

Southern California Telemedicine Learning Center (TLC)

it2

Information Theorists Working with Bio, IT, and Nano Researchers Will Radically Transform Our View of Living Systems



"Through the strong loupe of information theory, we will be able to watch how such [living] beings do what nonliving systems cannot do: extract information from their surrounds, store it in a stable molecular form, and eventually parcel it out for their creative endeavors. ... So viewed, the information circle becomes the unit of life."
--Werner Loewenstein
The Touchstone of Life (1999)

Calit2's
Information Theory and Applications Center
http://ita.ucsd.edu

With Nanobioinfo Devices Everywhere, How Can We Handle the Data Flows?









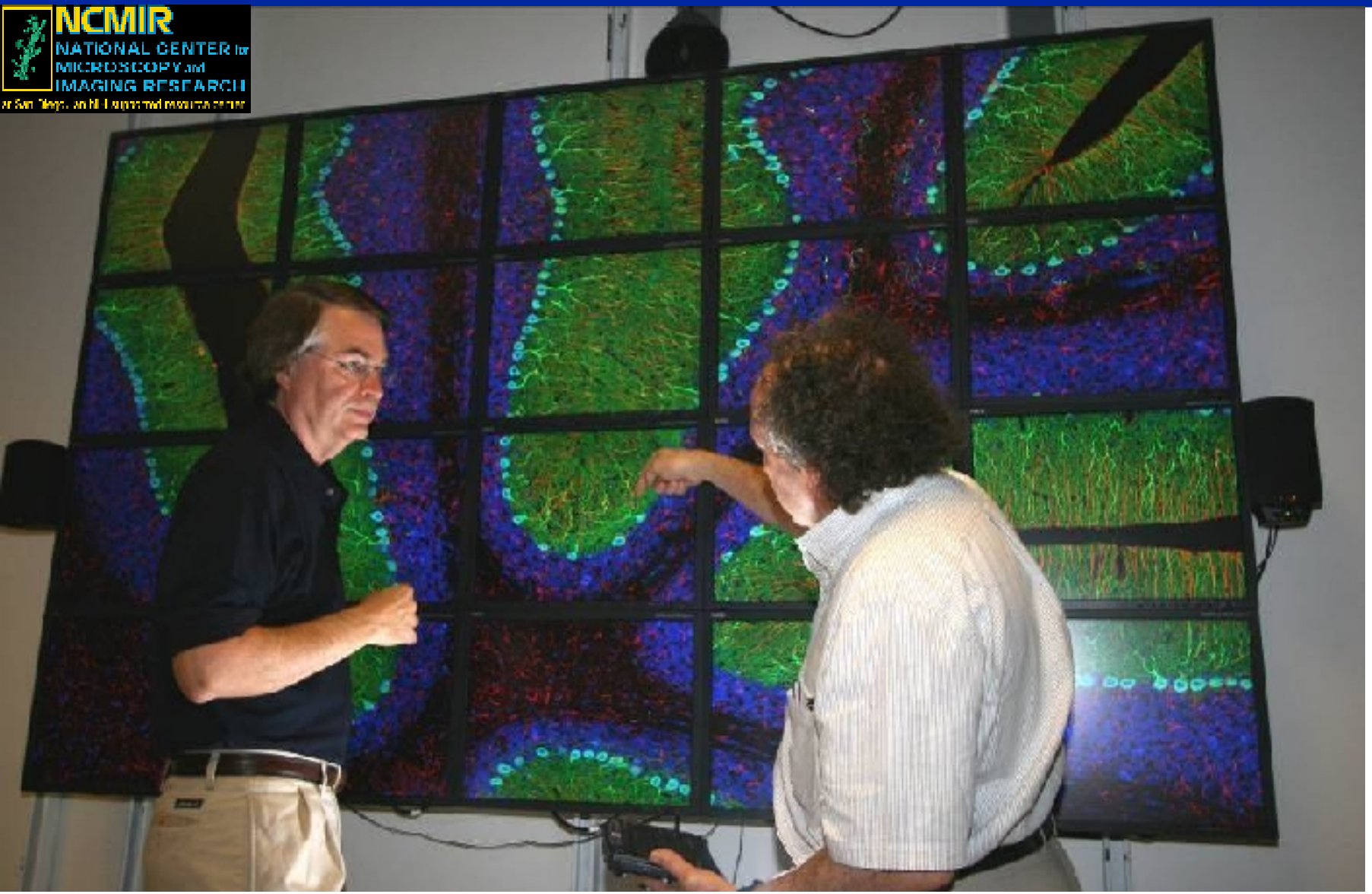
- **Mobile Broadband**
  - 0.1-0.5 Mbps
- **Home Broadband**
  - 1-5 Mbps

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

- **University Dorm Room Broadband**
  - 10-100 Mbps
- **Calit2 Global Broadband**
  - 1,000-10,000 Mbps

100,000 Fold Range
All Here Today!

The OptIPuter Project: Creating High Resolution Portals Over Dedicated Optical Channels to Global Science Data



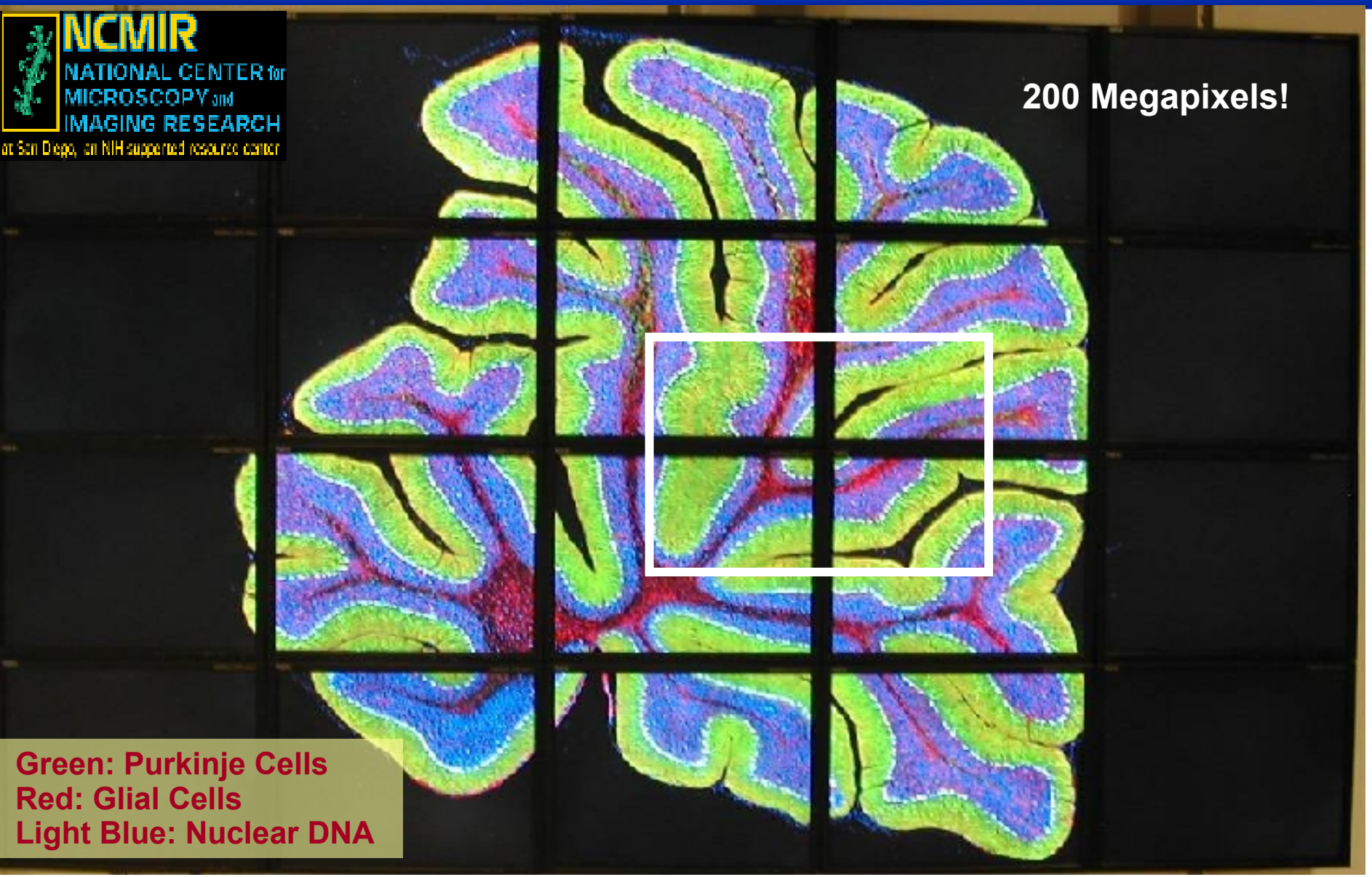
$13.5M Over Five Years

Picture Source: Mark Ellisman, David Lee, Jason Leigh

UCSD
UCIrvine

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

OptIPuter Scalable Displays Are Used for Multi-Scale Biomedical Imaging



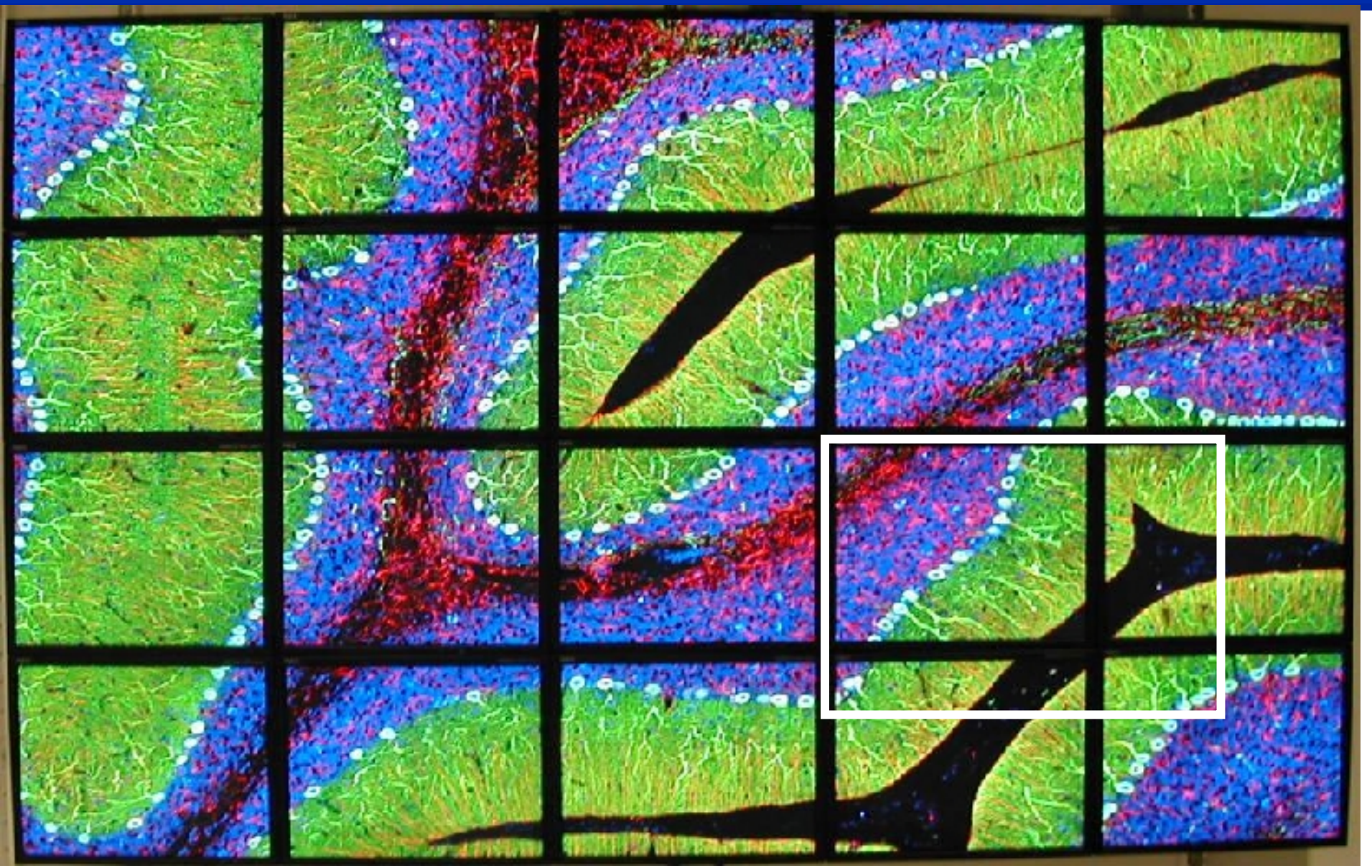
Source: Mark Ellisman, David Lee, Jason Leigh

UCSD
UCIrvine

Two-Photon Laser Confocal Microscope Montage of 40x36=1440 Images in 3 Channels of a Mid-Sagittal Section of Rat Cerebellum Acquired Over an 8-hour Period

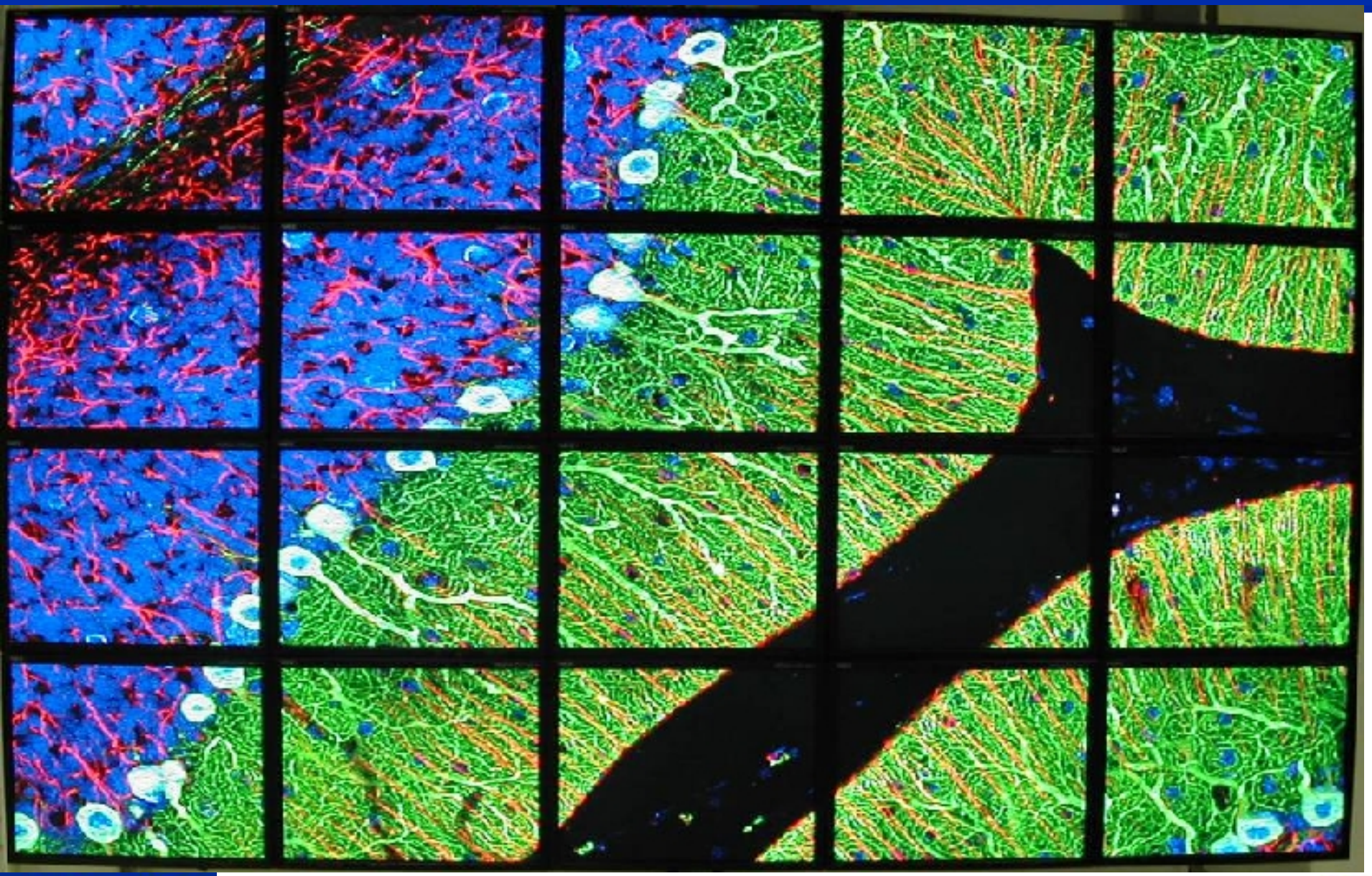
it²

Scalable Displays Allow Both Global Content and Fine Detail



UCSD
UCIrvine

Allows for Interactive Zooming from Cerebellum to Individual Neurons



UCSD
UCIrvine

Calit2 is Now OptIPuter Connecting Remote Moore-Funded Microbial Researchers



Calit2@UCSD Is Connected to the World 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



50 Demonstrations, 20 Counties, 10 Gbps/Demo

President Kalam of India Believes Nanobioinfotech is the Future for 600,000 Villages

- Interactive Knowledge System
- Convergence of Info- Nano - Bio
- Make the Bandwidth Available with No Limits
- PURA--Societal Grid With Electronic Connection of a Billion People

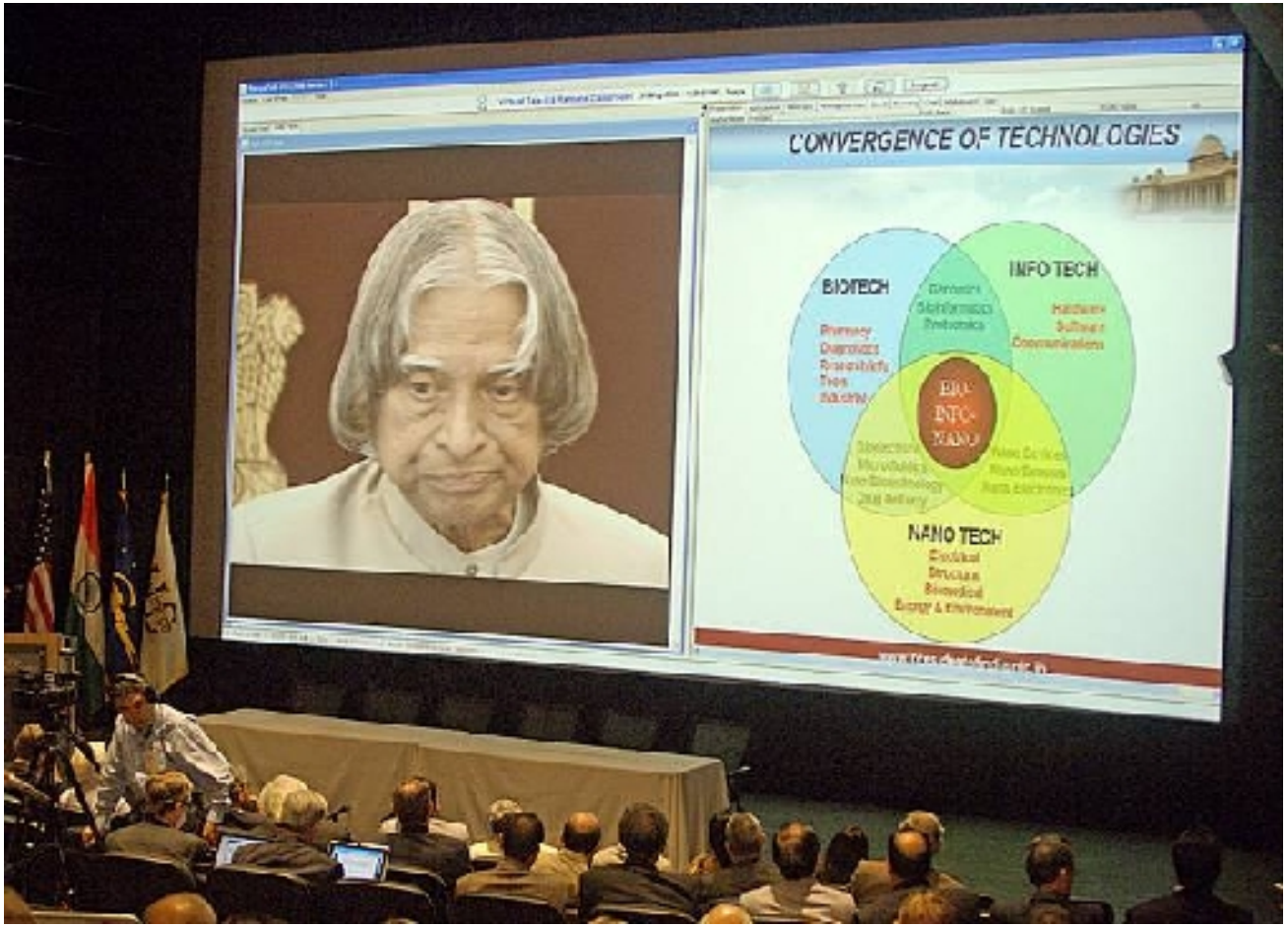


Photo: Alan Decker, UCSD

UCSD
UCIrvine