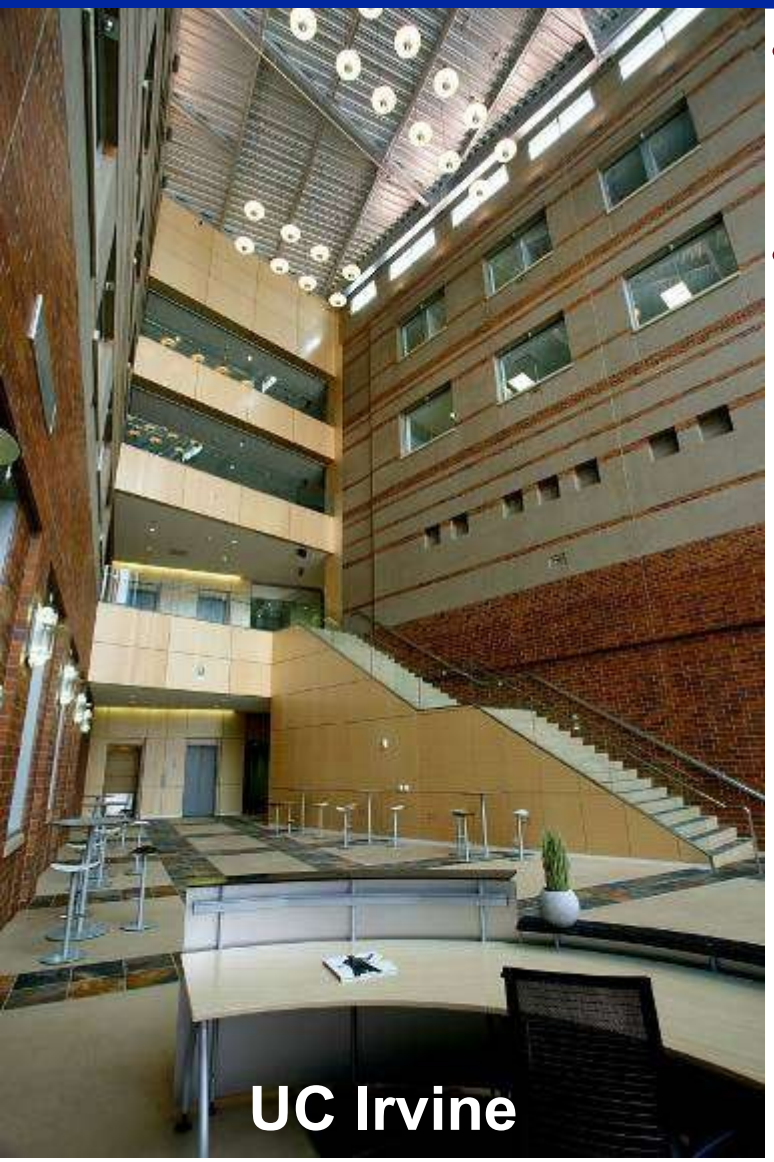
Cyberinfrastructure for Ocean Observing

Invited Talk
Fort Johnson Seminar Series
Charleston, SC
April 4, 2008

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

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

Preparing for a World in Which Distance is Eliminated…

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UCIrvine

Calit2 Brings Computer Scientists and Engineers Together with Biomedical Researchers

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

CAMERA Marine Microbial Ecology

Institute for Genomics and Bioinformatics
University of California, Irvine

NanoTumor Center

JCSG Joint Center for Structural Genomics

NCMIR National Center for Microscopy and Imaging Research at San Diego, an NIH supported resource center

NBCR National Biomedical Computation Resource
an NIH supported resource center

Biomedical Informatics Research Network

Information Theory and Applications

WISARD

lifechips university of california, irvine www.lifechips.org

UCSD UCIrvine Southern California Telemedicine Learning Center (TLC)

it2

Calit2 Facilitated Formation of the Center for Algorithmic and Systems Biology

Tri-Conference at the Center for Algorithmic and Systems Biology

CASB http://casb.ucsd.edu

UCSD, November 30-December 3, 2006, San Diego, CA, USA

algorithmic biology
systems biology
computational proteomics

UC San Diego and the California Institute for Telecommunications and Information Technology (Calit2) will host three conferences devoted to the disciplines of algorithmic biology, systems biology and computational proteomics. In partnership with the International Society for Computational Biology, the RECOMB Satellite Conferences on Systems Biology and Computational Proteomics will provide a forum for new methods that broadly address either or both of these areas. Algorithmic Biology will feature leaders in the field of computational biology who will discuss the emerging challenges at the interface of biology and computer science.

ALGORITHMIC BIOLOGY
NOVEMBER 30, 2006

- PAVEL PEVZNER, UCSD (CHAIR)
- SERAFIM BATZOGLOU, STANFORD
- DAVID HAUSSLER, UC SANTA CRUZ
- MANOLIS KELLIS, MIT
- RON SHAMIR, TEL AVIV UNIV
- MICHAEL WATERMAN, USC



CALIT2 AUDITORIUM
ATKINSON HALL, UCSD
LA JOLLA, CALIFORNIA

SYSTEMS BIOLOGY
DECEMBER 1-2, 2006

- TREY IDEKER, UCSD (CHAIR)
- MARTHA BULYK, HARVARD MEDICAL
- ERIC DAVIDSON, CALTECH
- DAVID EISENBERG, UCLA
- ANNE-CLAUDE GAVIN, EMBL HEIDELBERG
- MARK GERSTEIN, YALE
- DAPHNE KOLLER, STANFORD
- BING REN, UCSD
- RON SHAMIR, TEL AVIV UNIV

Calit2 | the UC Discovery Grant

COMPUTATIONAL PROTEOMICS
DECEMBER 2-3, 2006

- VINEET BAFNA, UCSD (CHAIR)
- MARSHALL BERN, XEROX PARC
- STEVE BRIGGS, UCSD
- NEIL KELLEHER, UNIV OF ILLINOIS
- NEVAN KROGAN, UCSF
- FOREST WHITE, MIT
- RICHARD SMITH, PACIFIC NORTHWEST NATIONAL LAB

UCSD SPONSORS

ISCB | molecular systems biology

CASB







http://casb.ucsd.edu/

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Mass Spectrometers as "Sensors" of the Coastal Desert Ecosystem-the Search for Natural Products

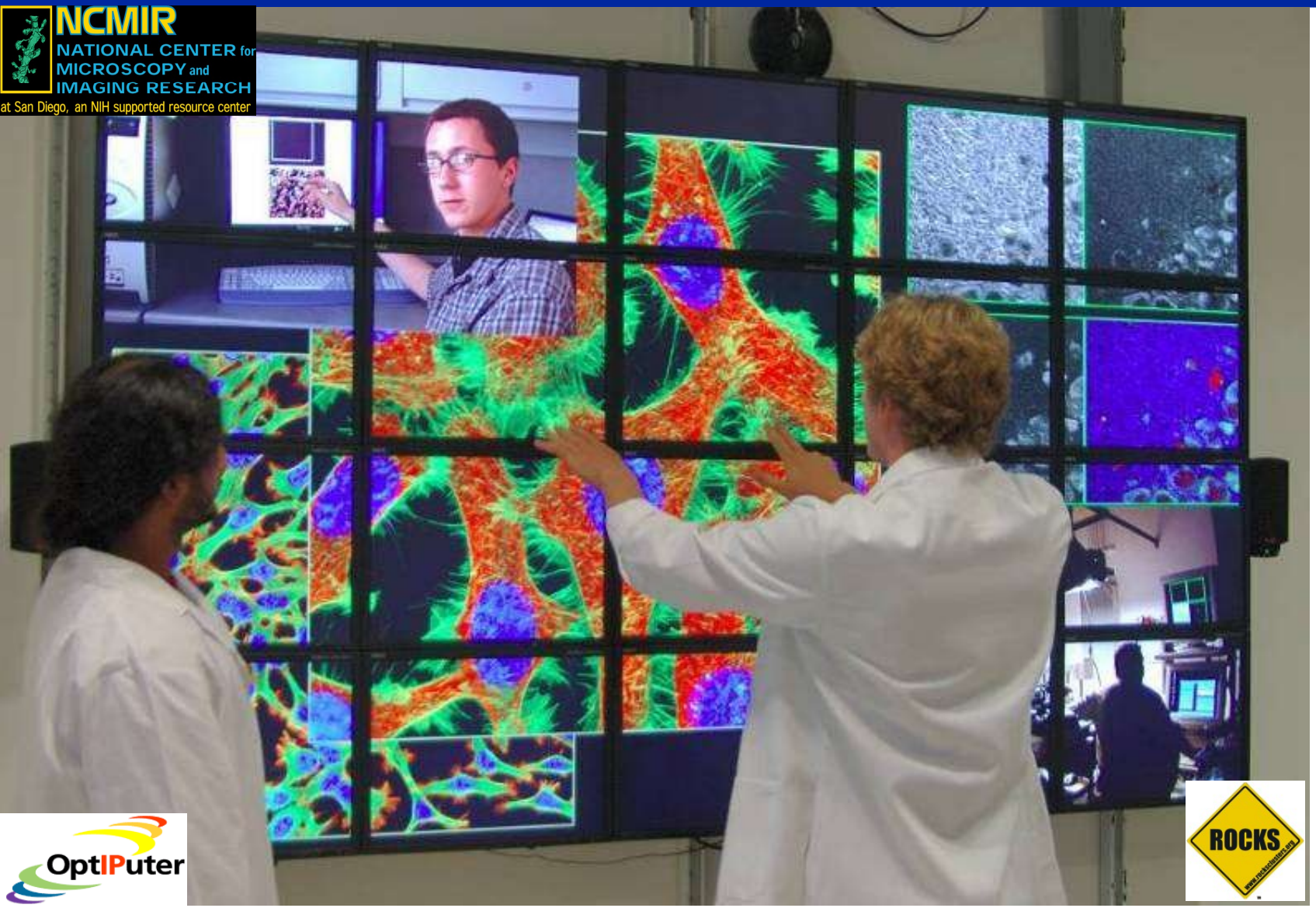
- Each Time the Environment Is "Sensed" Upwards of 1 Million Mass Spectra Will be Recorded
- Test and Refine Theories of Peptide Fragmentation Through Algorithms that Interpret Mass Spectra
- Automate the Integration of Peptide Identification with Genome Maps, Protein Interaction Networks, Pathways, Subcellular Locations, Gene Ontologies, Splice Isoforms, and Post-Translational Modifications
- Develop a Combination of Experimental and Computational Protocols to Characterize by High-Resolution Mass-Spectrometry (FTICR) Non-Ribosomal Peptides and Cognate Non-Ribosomal Peptide (NRP) Synthetases, a Class of Natural Products
  - First Attempt To Sequence NRPs DeNovo Using Mass Spectrometry

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Source: Pavel Pevzner, CASB, UCSD

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



Scalable Adaptive Graphics Environment (SAGE)

evl electronic visualization laboratory

NSF

Now in Sixth and Final Year

Picture Source: Mark Ellisman, David Lee, Jason Leigh

OptIPuter

ROCKS

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

it2

My OptIPortal™ – Affordable Termination Device for the OptIPuter Global Backplane

- 20 Dual CPU Nodes, 20 24” Monitors, ~$50,000
- 1/4 Teraflop, 5 Terabyte Storage, 45 Mega Pixels--Nice PC!
- Scalable Adaptive Graphics Environment (SAGE) Jason Leigh, EVL-UIC

evl electronic visualization laboratory





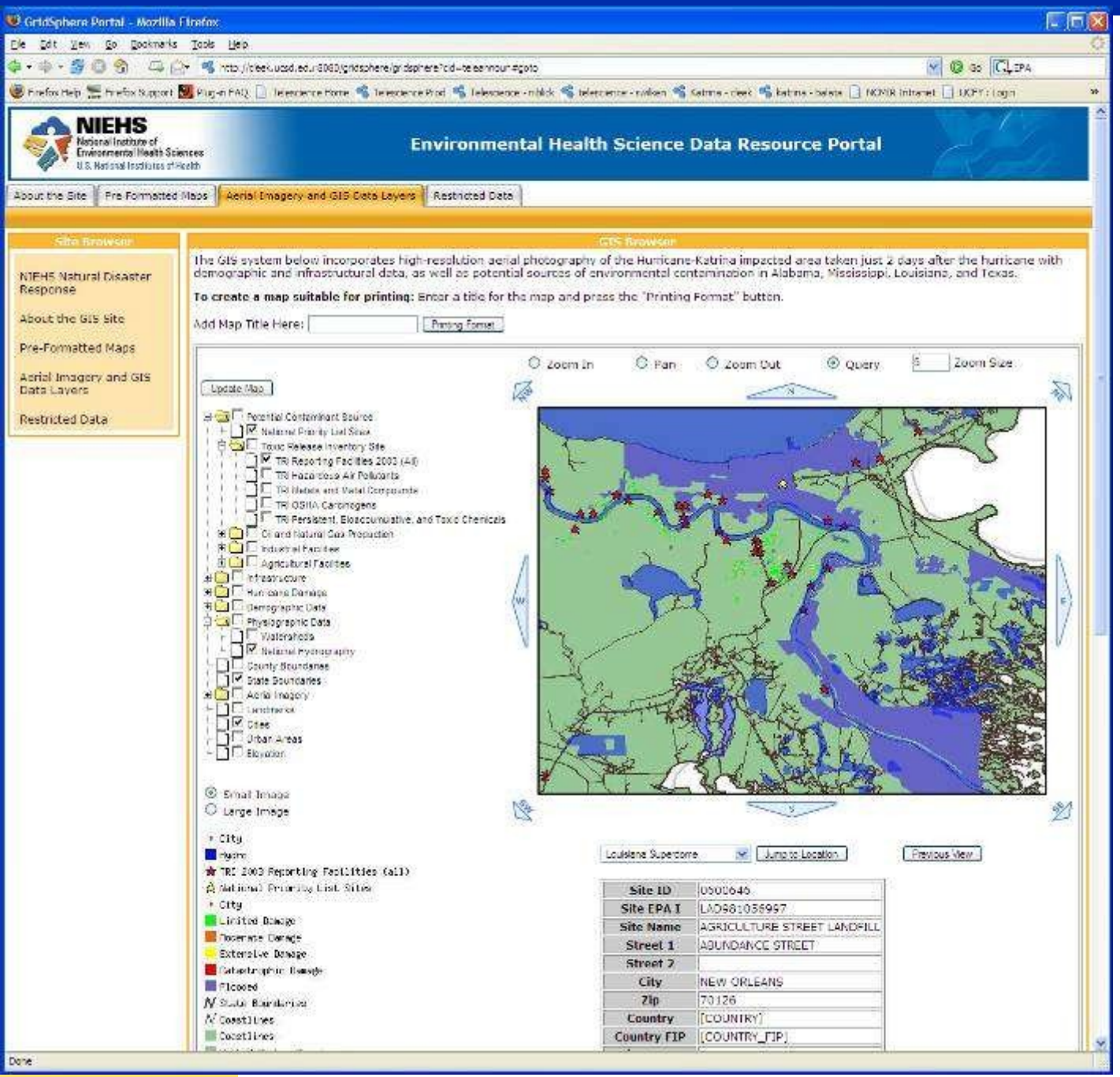
UCSD UCIrvine

Powered by Rocks ROCKS

Source: Phil Papadopoulos SDSC, Calit2

it²

GIS Portal for Analyzing Toxicological Events from the Aftermath of Hurricanes Katrina & Rita



NIEHS
National Institute of Environmental Health Sciences
U.S. National Institutes of Health

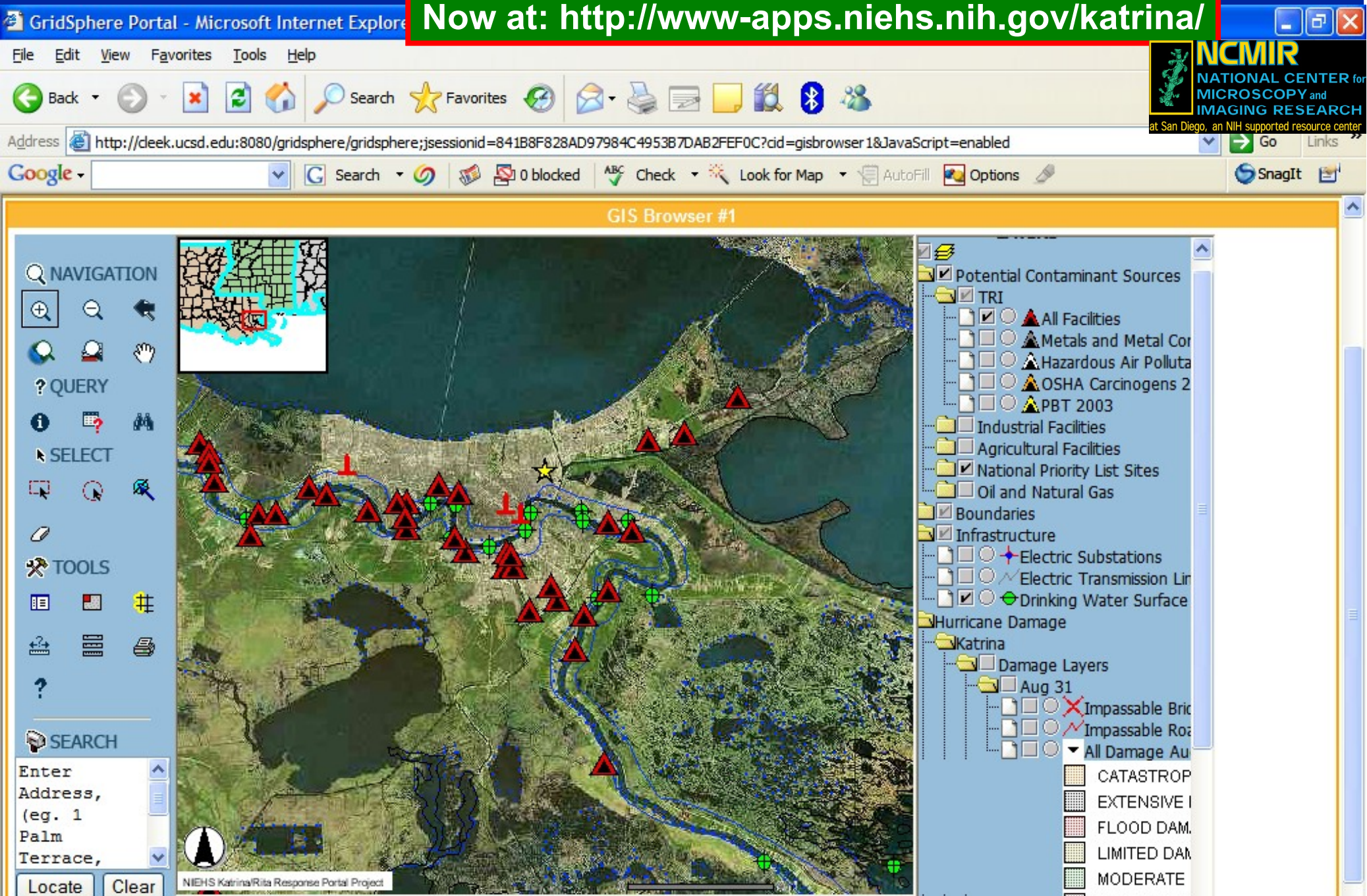
Keith Pezzoli, Robert Tukey, Hiram Sarabia, Ilya Zaslavsky, Marie Lynn Miranda, William A. Suk, Abel Lin, and Mark Ellisman *Environmental Health Perspectives* **115**, 564 (2007)

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

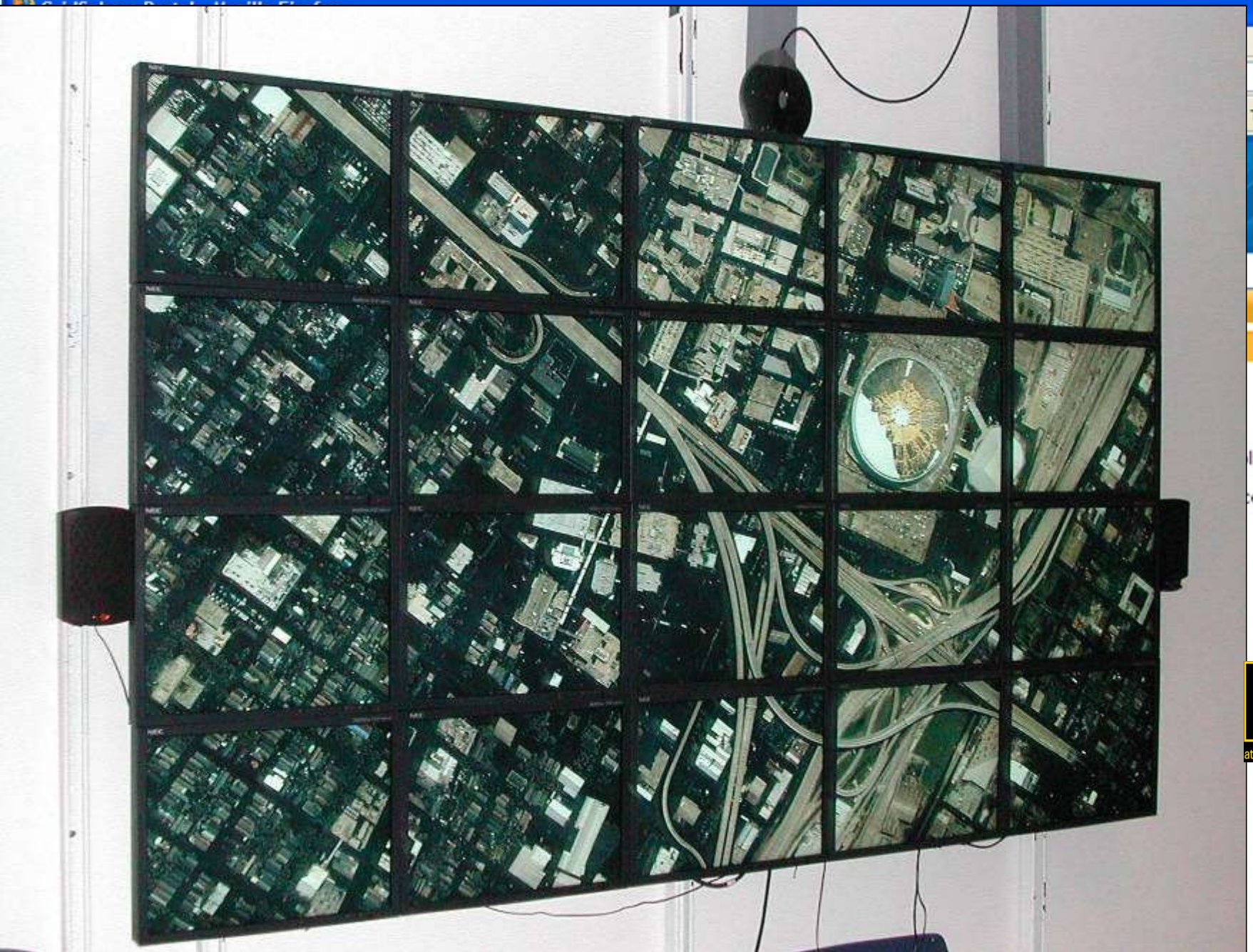
it2

NIEHS Portal Finding Drinking Water Surface Intakes and Toxics Release Inventory (TRI) Facilities

Now at: http://www-apps.niehs.nih.gov/katrina/



Launch Images to OptIPortal from Web Browser Portal Using EVL's LambdaCam



Go

Ticket submission

Logout

Welcome, Guest

lays at any of the NIEHS

ess (outside of the

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

evl electronic visualization laboratory

it2

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

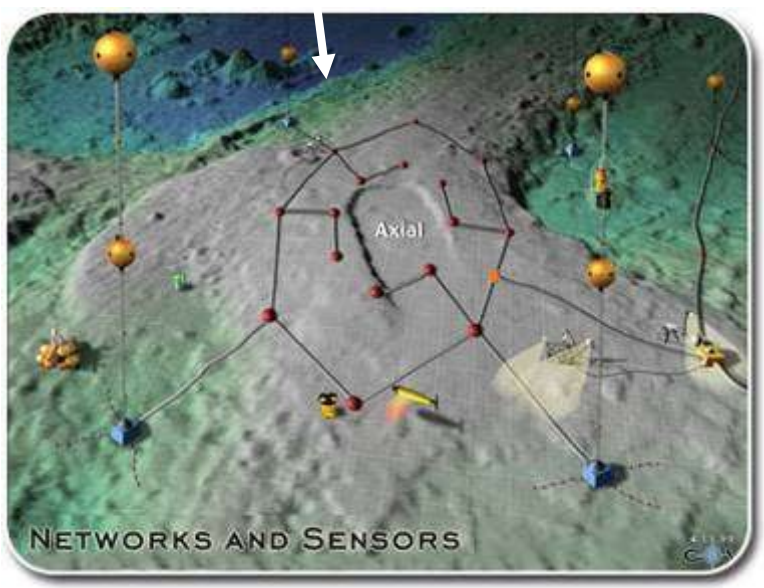
The Ocean Observatories Initiative (OOI) -- a Networked Infrastructure Of Science-Driven Sensor Systems



CONSORTIUM FOR Ocean Leadership
DISCOVERY • UNDERSTANDING • ACTION

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NSF



LEO15 Inset Courtesy of Rutgers University, Institute of Marine and Coastal Sciences

it²

OOI Will Address Science Questions on Coastal, Regional, and Global Scales, Linked by a Common Instrument, Infrastructure, and Information Management System

Source: John Orcutt, Matthew Arrott, SIO/Calit2



OOI CI Team:

- UCSD
  - SIO, Calit2, SDSC
- Rutgers
- WHOI
- Raytheon

A program of JOI Joint Oceanographic Institutions

JOI Awards, Funded by NSF:

- Regional Scale Node
  - ~$150M, UWash
- Global/Coastal Scale Nodes
  - ~$100M, Woods Hole Lead
- Cyberinfrastructure
  - ~$30M, SIO/Calit2 UCSD

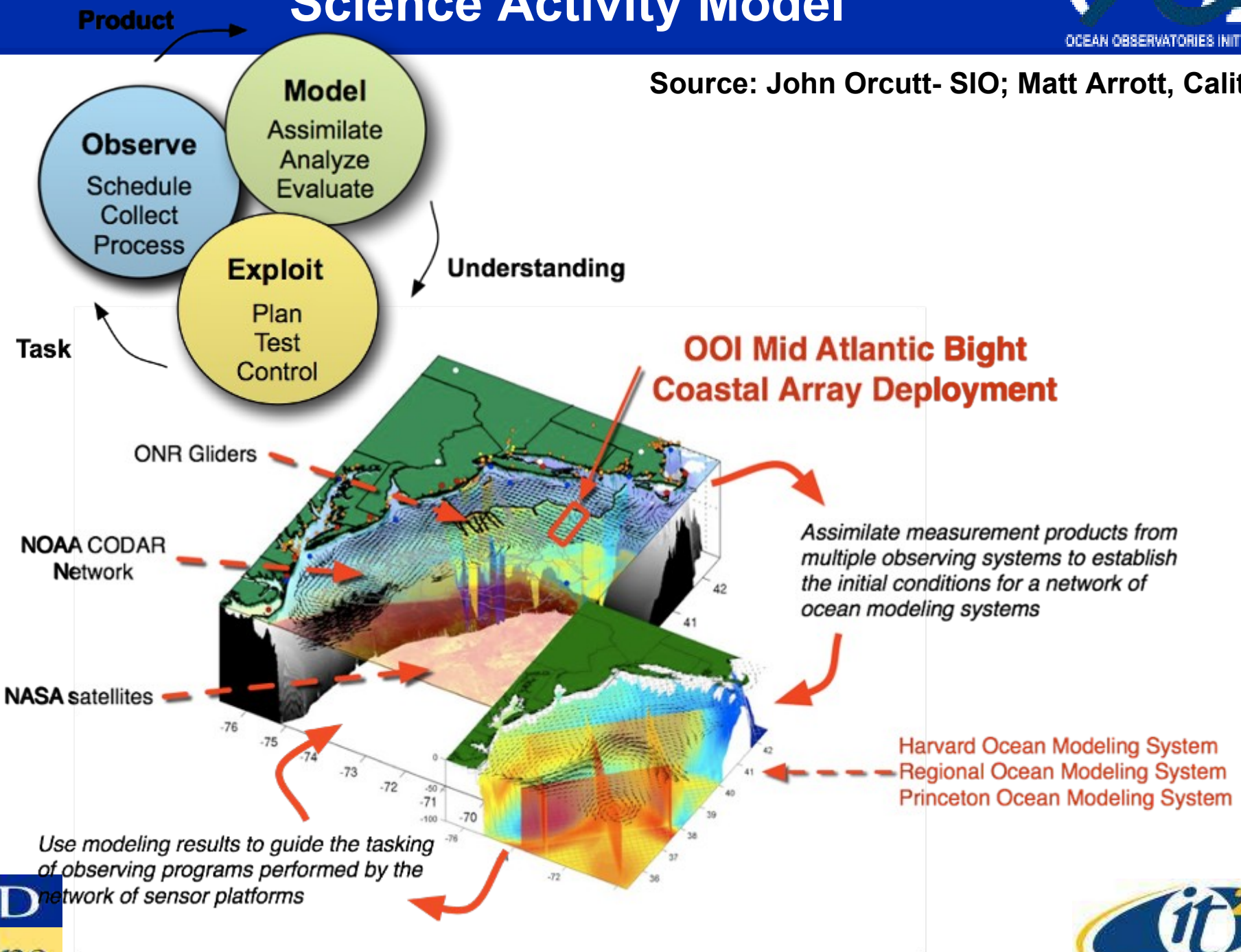
Construction Program
5 Year

UCSD UCIrvine

it2

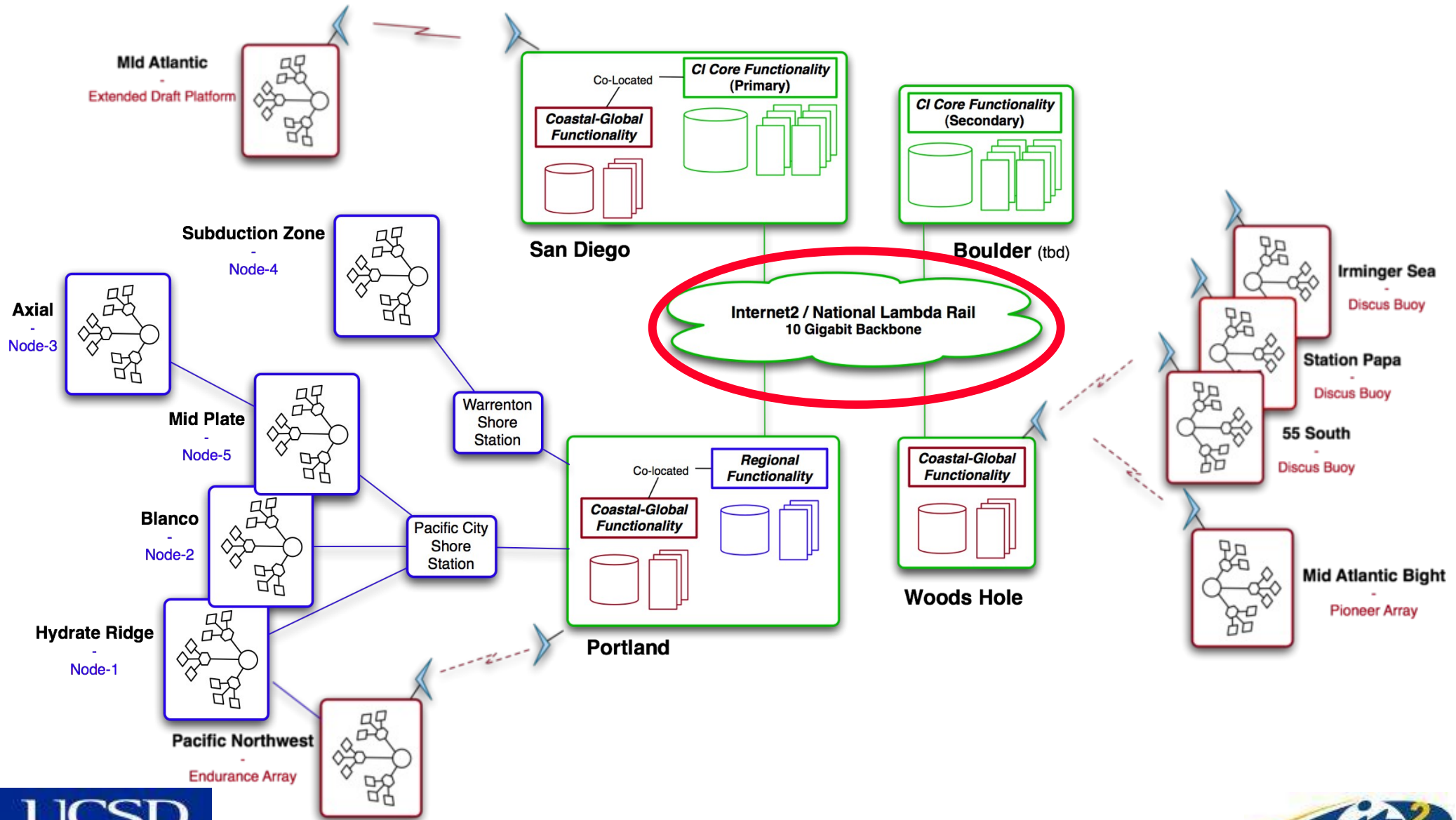
OOI CI
Science Activity Model

Source: John Orcutt- SIO; Matt Arrott, Calit2



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OOI CI
Physical Network Buildout



Towards a Total Knowledge Integration System for the Coastal Zone—SensorNets Linked to Fiber Cable

- Moorings
- Ships
- Autonomous Vehicles
- Satellite Remote Sensing
- Drifters
- Long Range HF Radar
- Near-Shore Waves/Currents
- COAMPS Wind Model
- Nested ROMS Models
- Data Assimilation and Modeling
- Data Systems



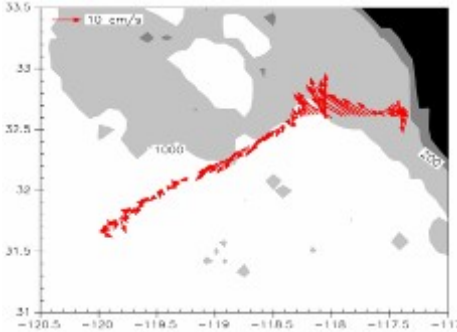
Yellow—Proposed Initial OptIPuter Backbone

NOAA

NSF

ROADNet

COCMP
Coastal Ocean Currents Monitoring Program





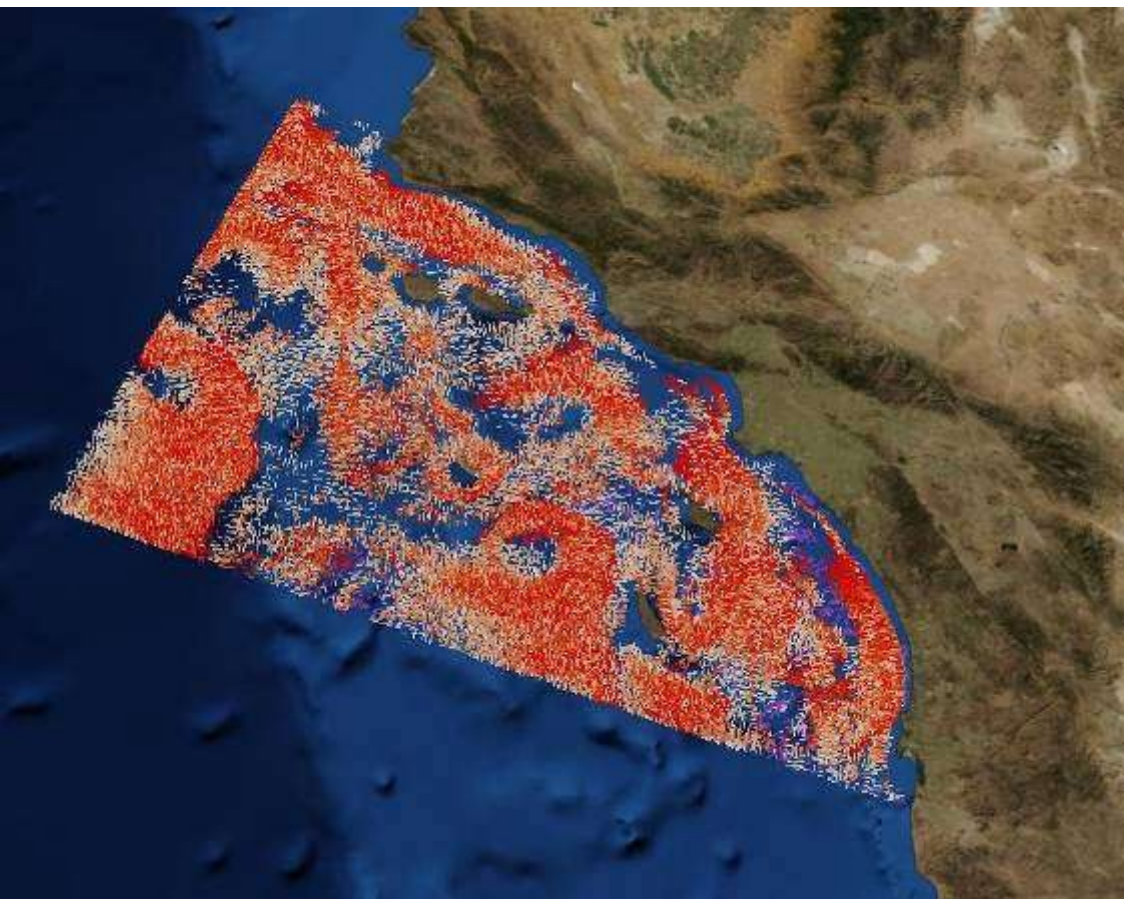
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www.sccoos.org/

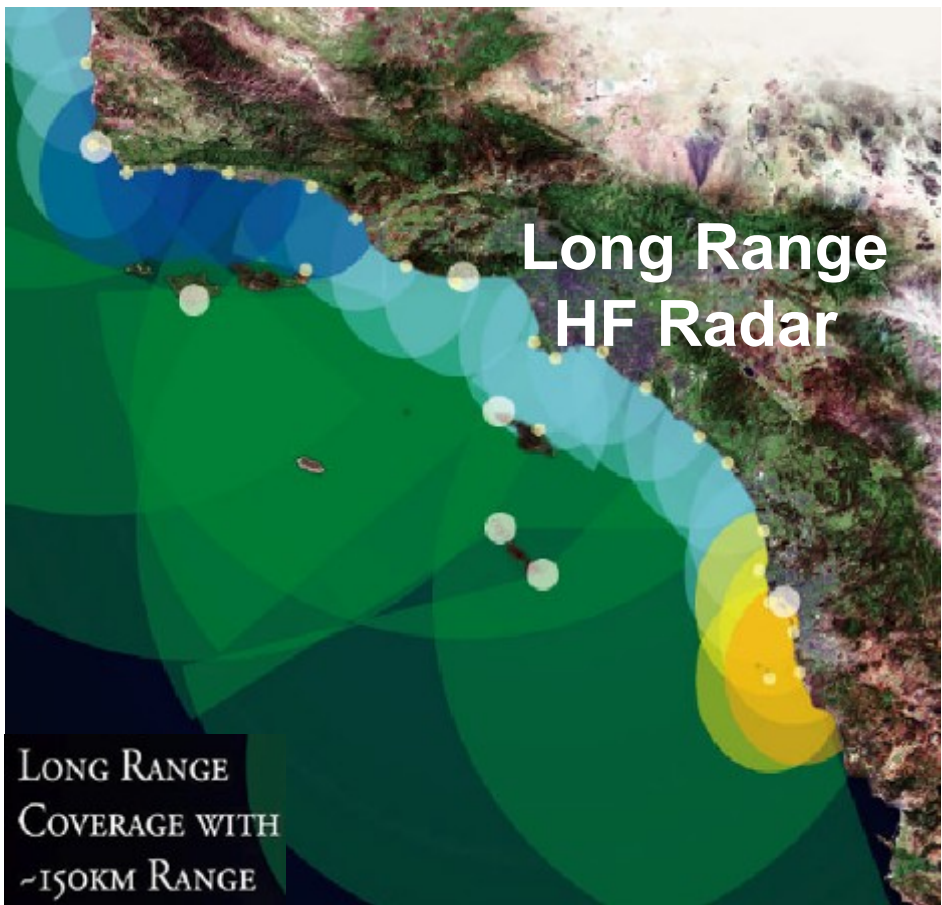
it2

Use OptIPuter to Couple Data Assimilation Models to Remote Data Sources and Analysis in Near Real Time

Visualization: Philip Weber, Matthew Arrott, Calit2



Source: SCCOOS



JPL ONR MBARI California Institute of Technology

OOI Ocean Observatories Initiative

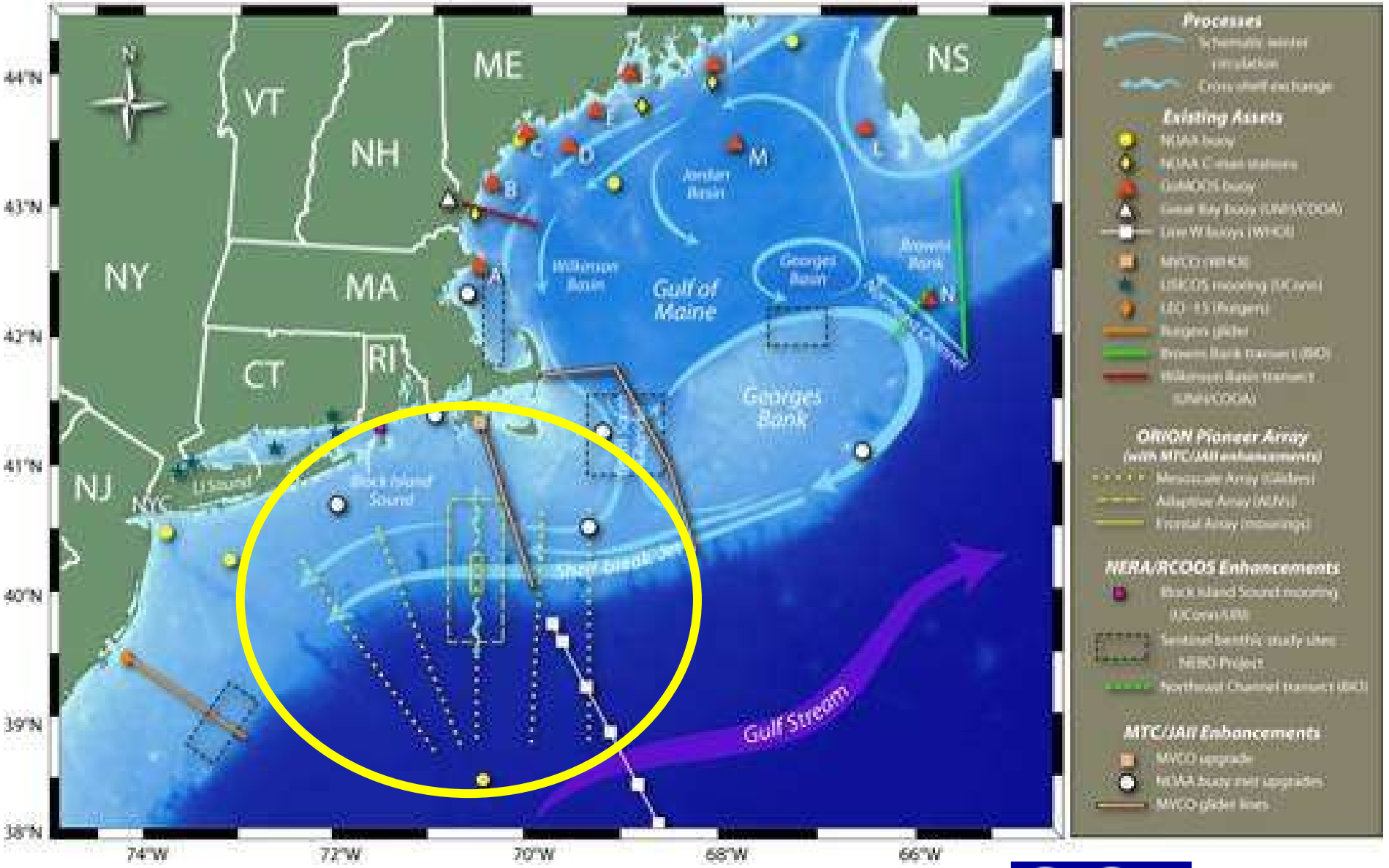
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Regional Ocean Modeling System (ROMS)

http://ourocean.jpl.nasa.gov/

it2

Northeastern Regional Coastal Ocean Observing System Will Add Pioneer Array



Source: WHOI

Ocean Sensing Systems – Paradigm Shift

OCEAN OBSERVATORIES INITIATIVE

Platform-centric Sensing Systems

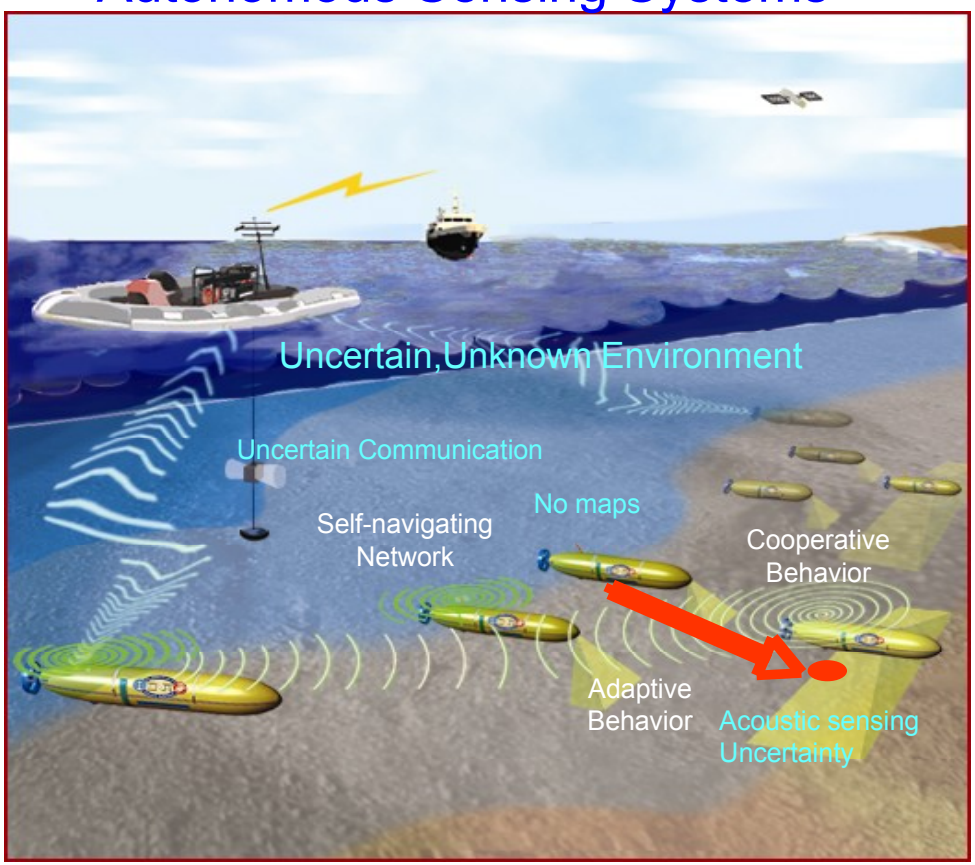








Net-centric, Distributed Autonomous Sensing Systems

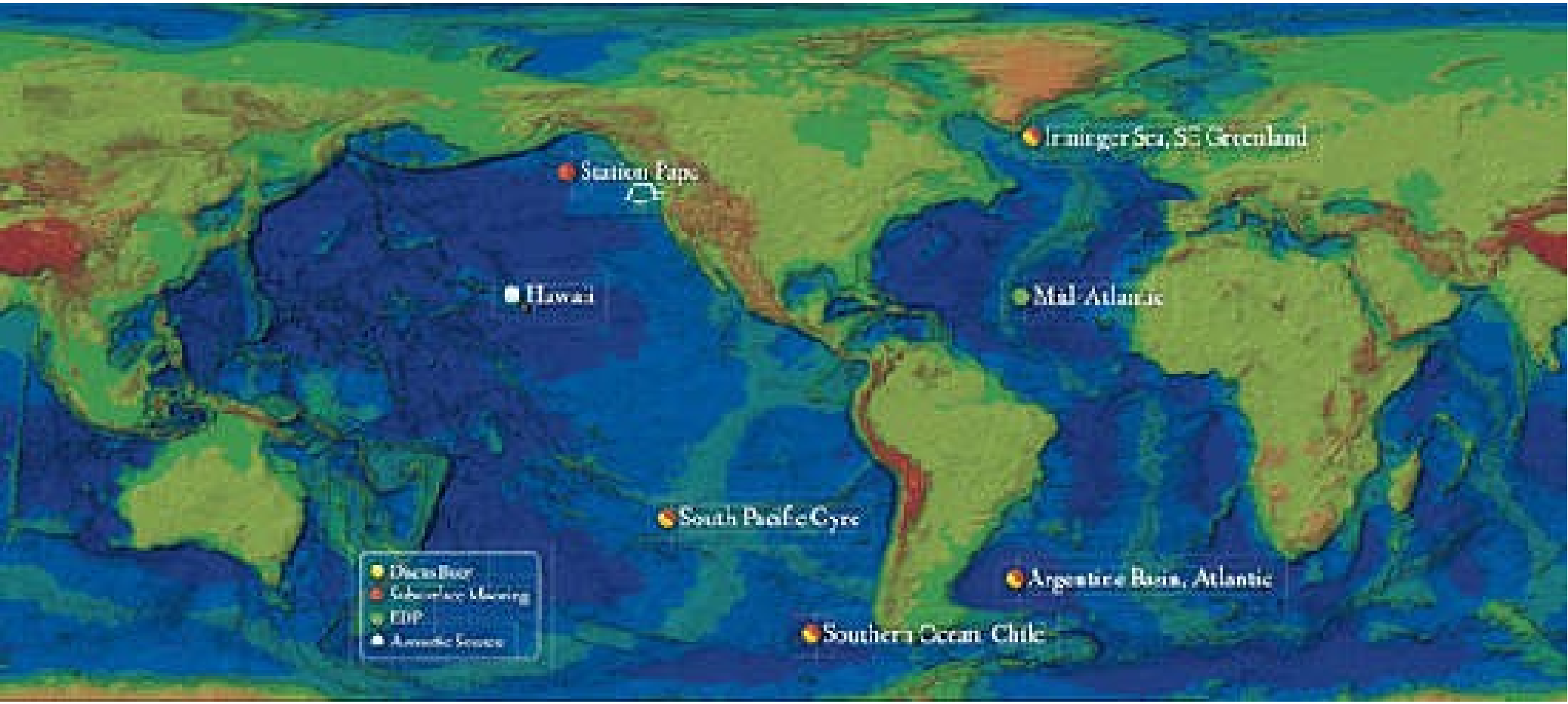


Similar in Shift to Net-centric Warfighting

UCSD
UCIrvine

it²

Location of Global Moorings--Part of the Coastal/Global Network of Ocean Observatories



OCEAN OBSERVATORIES INITIATIVE

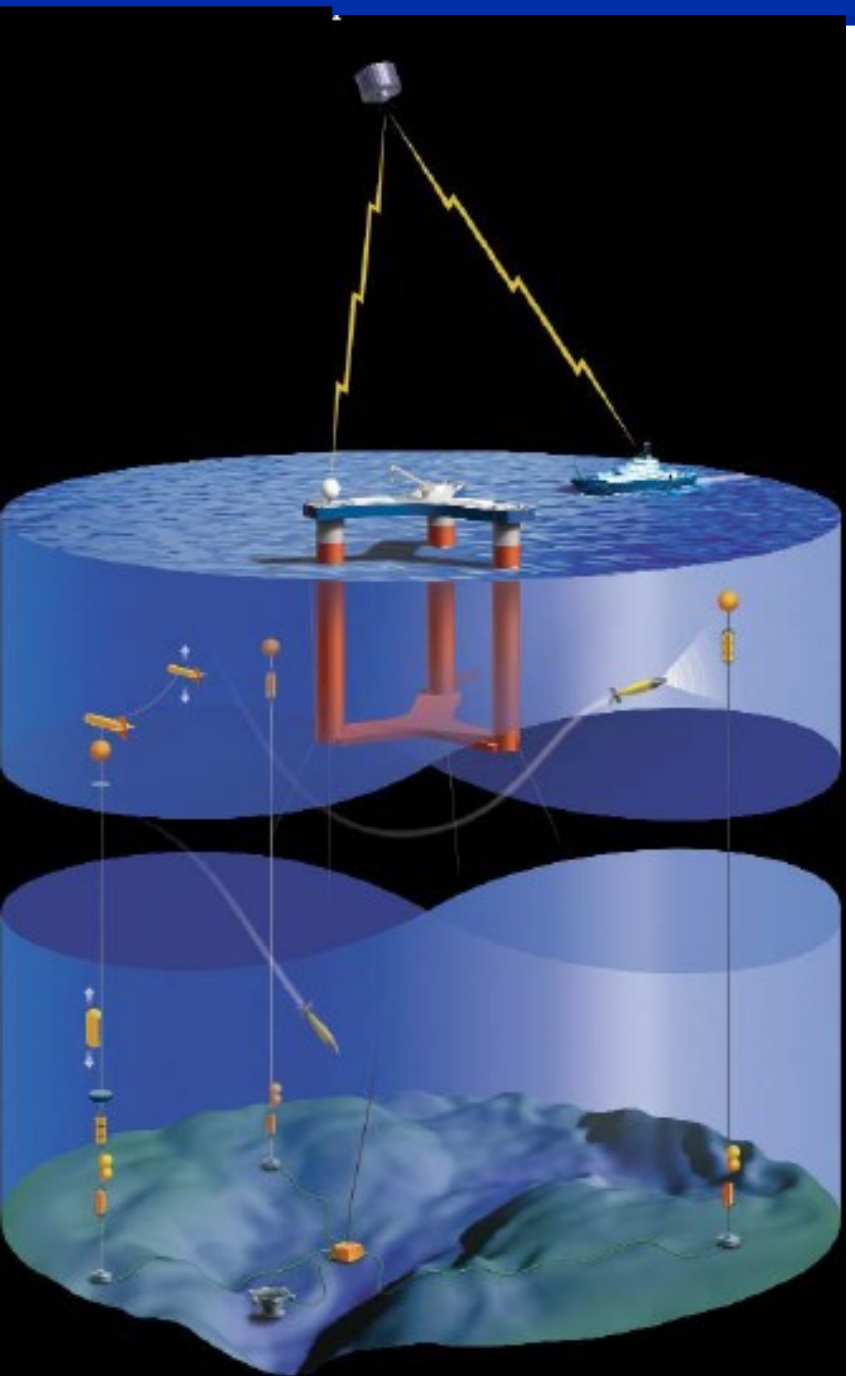
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Source: SIO, UCSD

it2

Extended Draft Platform
Proposed Deployment Mid- Atlantic

OCEAN OBSERVATORIES INITIATIVE





Berger, J., UCSD/SIO O'Sullivan, J., TECHNIP
Halkyard, J., Offshore Engineering Consultants,
Orcutt, J., UCSD/SIO

Gigabit Fibers on the Ocean Floor
-- Controlling Sensors and HDTV Cameras Remotely



LOOKING is Driven By NEPTUNE CI Requirements

LOOKING:
(Laboratory for the Ocean Observatory Knowledge Integration Grid)

http://lookingtosea.ucsd.edu/

- **Goal:**
  - **Prototype Cyberinfrastructure for NSF's Ocean Research Interactive Observatory Networks (ORION) Building on OptIPuter**
- **LOOKING NSF ITR with PIs:**
  - **John Orcutt & Larry Smarr - UCSD**
  - **John Delaney & Ed Lazowska –UW**
  - **Mark Abbott – OSU**
- **Collaborators at:**
  - **MBARI, WHOI, NCSA, UIC, CalPoly, UVic, CANARIE, Microsoft, NEPTUNE-Canarie**

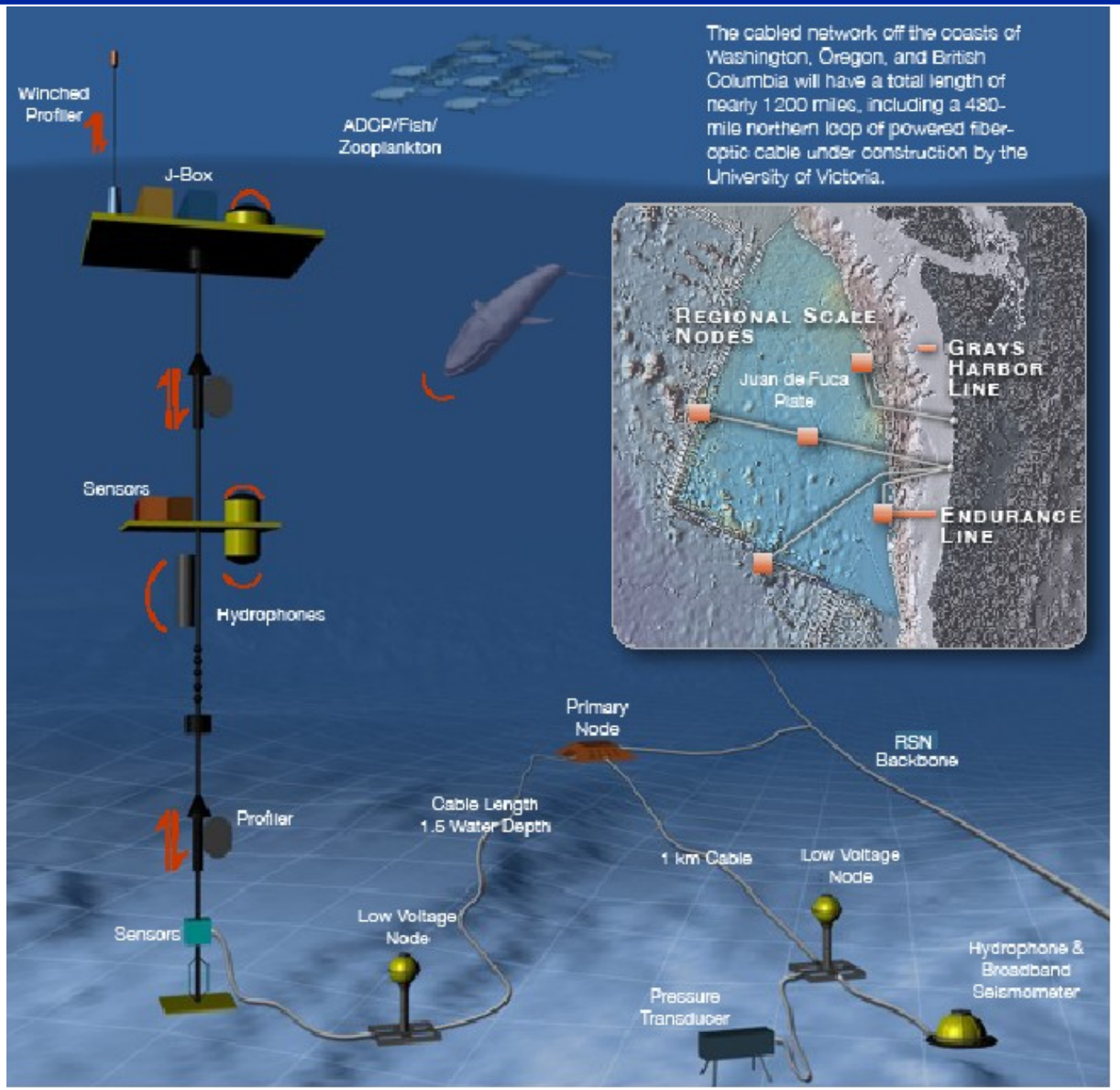
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NSF LOOKING Laboratory for the ocean observatory knowledge integration grid

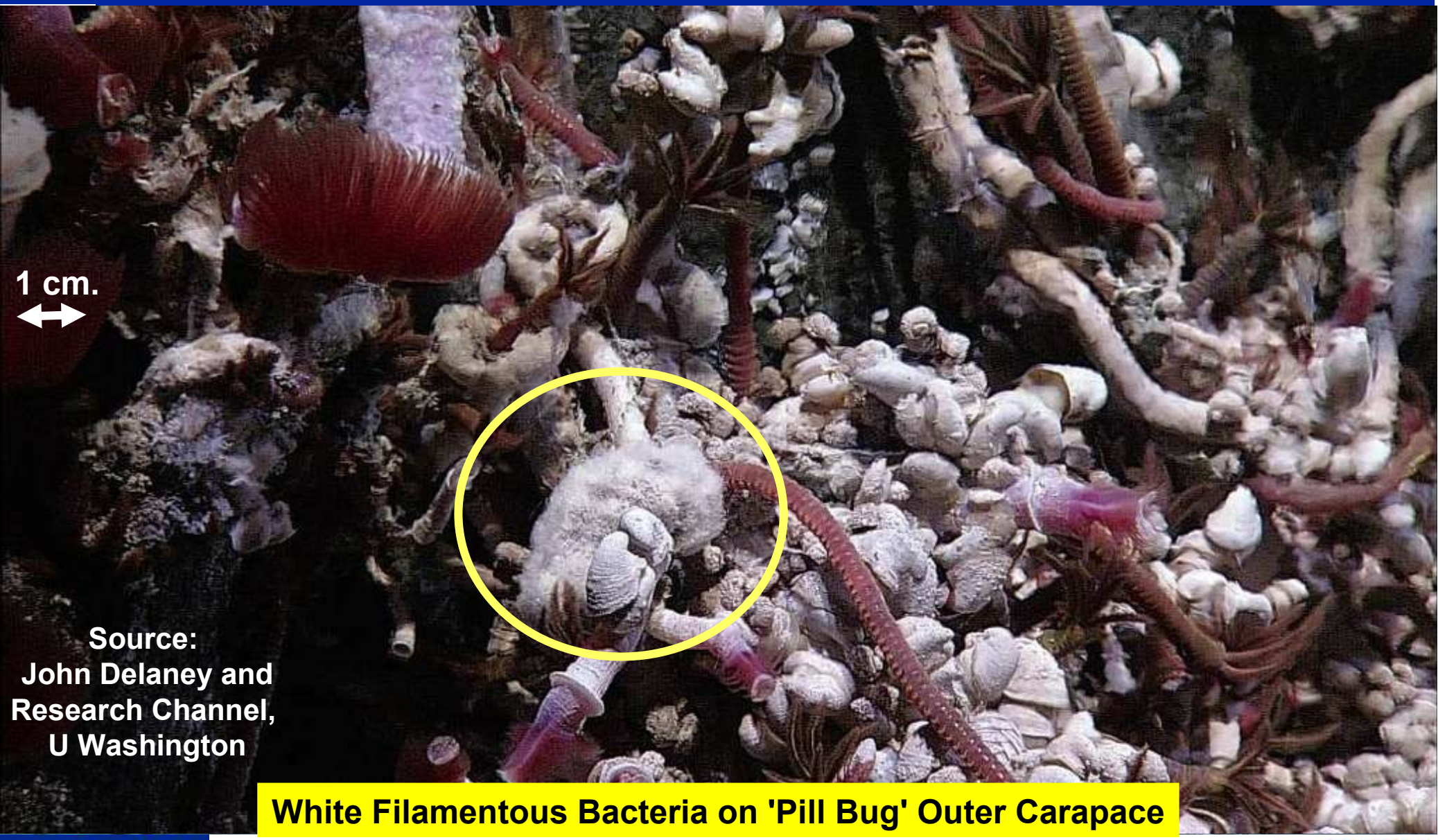
Making Management of Gigabit Flows Routine

it²

Mooring and Instrument for the Regional Cabled Node



Electro/Fiber Optic Cable Enables Remote Interactive HD Imaging of Deep Sea Vent



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High Definition Still Frame of Hydrothermal Vent Ecology 2.3 Km Deep

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Global Access to SensorNets via Internet Creates Environmental Observatories

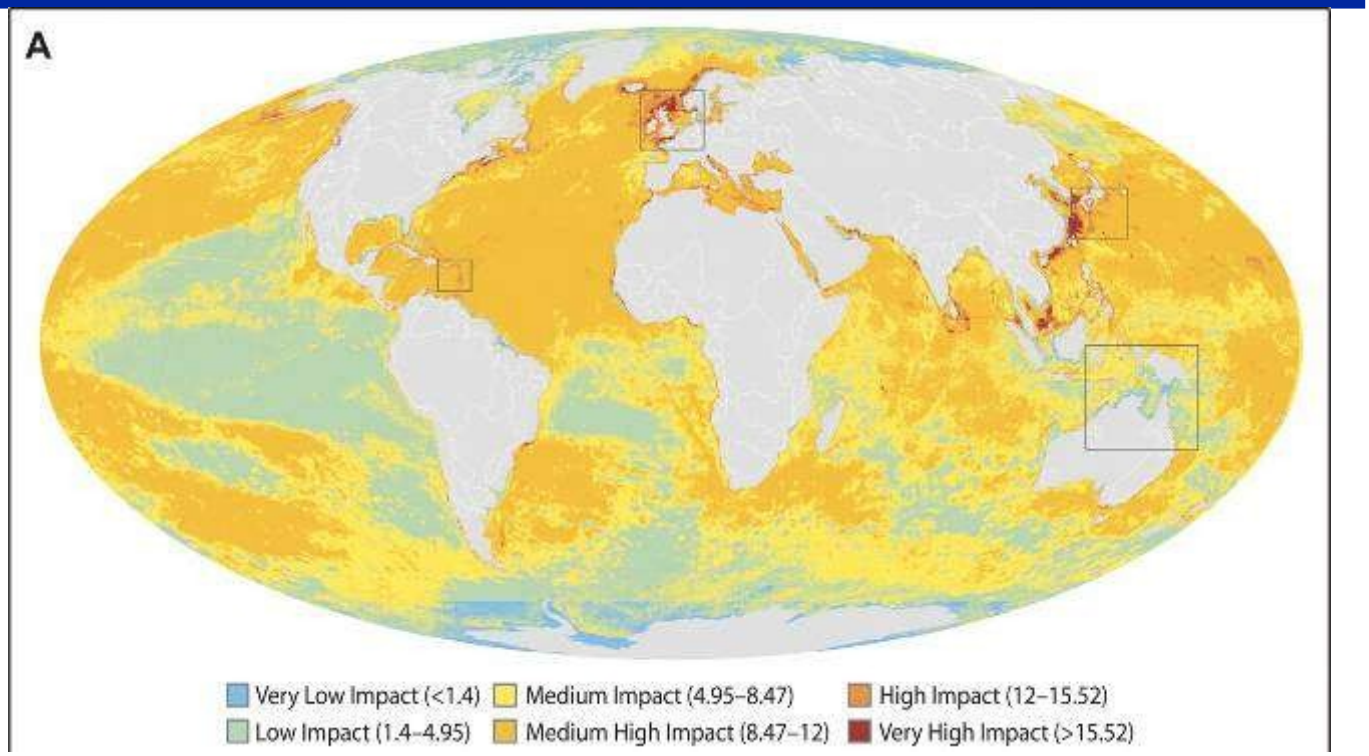


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International Threats to Coral Reefs and Ocean Biology -- Urgent Need for SensorNets



Science December 14, 2007



A Global Map of Human Impact on Marine Ecosystems
Science February 15, 2008



Science May 14, 2007

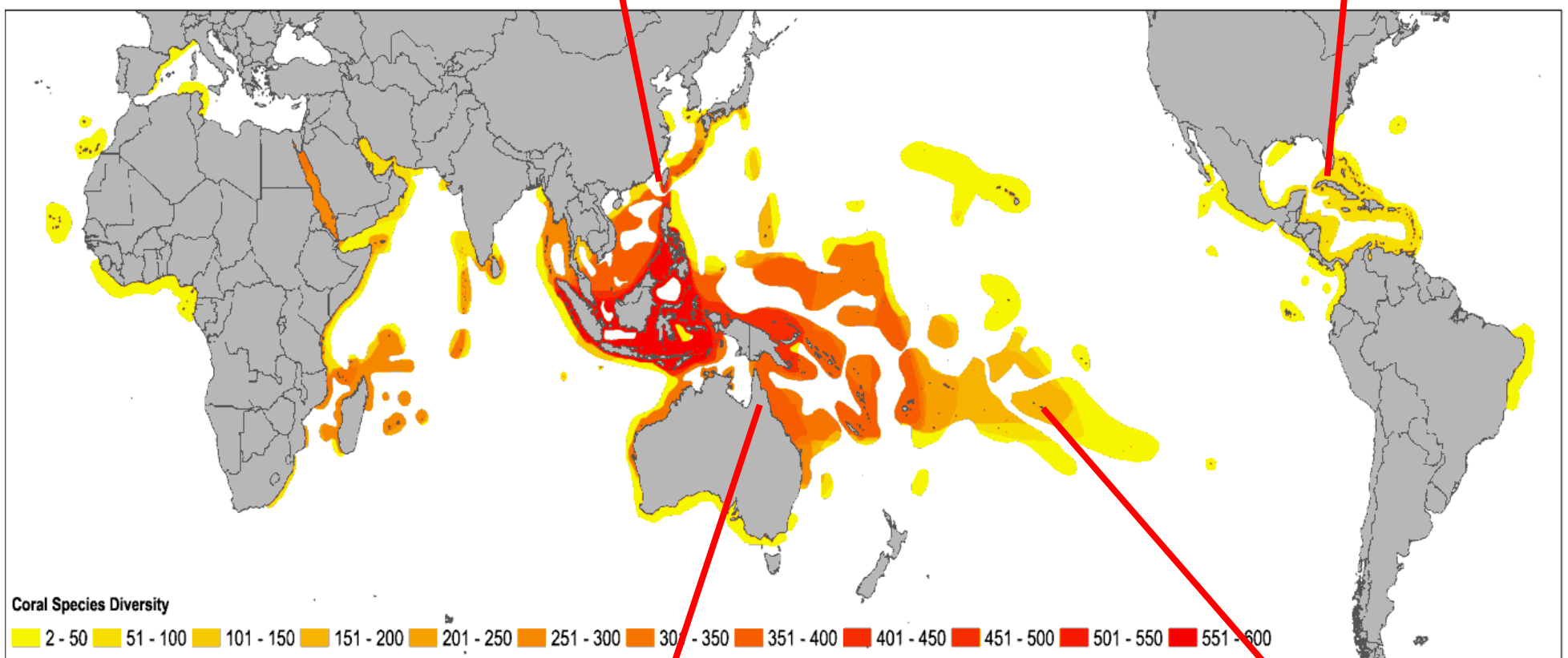
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Coral Reef Environmental Observatory Network (CREON)

www.coralreefeon.org/

Taiwan

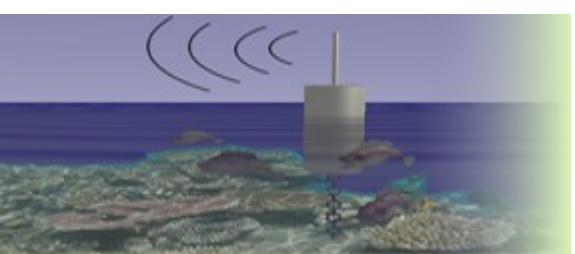
NOAA



NSF Collaboration:
UCSB and AS/NMMBA

GBR

UCSB



Source: Stuart Kininmonth, AIMS

Source : Fang-Pang Lin, NCHC

Taiwan's Kenting's Underwater Observatory

- **Deployed off Southern Taiwan 2004**
  - **Features 10 Underwater Cameras**
    - **Setup To Monitor Different Habitats on The Coral Reef**
  - **Currently Used by Taiwan's Academia Sinica and NMMBA**
- **On-Shore Video Servers are Used to Convert Analog Signals to Digital MJPEG Video Streams**
  - **Remote Observatory, Low Bandwidth (~1 Mbps)**
  - **Video Resolution: 320x240 Pixels**
  - **Effective Transfer Rate: 1 Frame/sec**

OPEN SOURCE DATA TURBINE INITIATIVE
Empowering the Scientific Community with Streaming Data Middleware



CREON



UCSD
UCIrvine

Source: Ebbe Strandell, NCHC

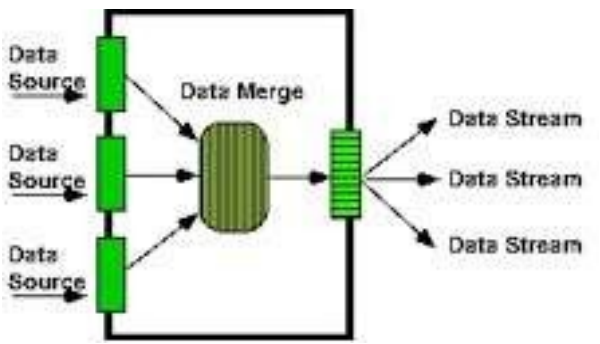
it²

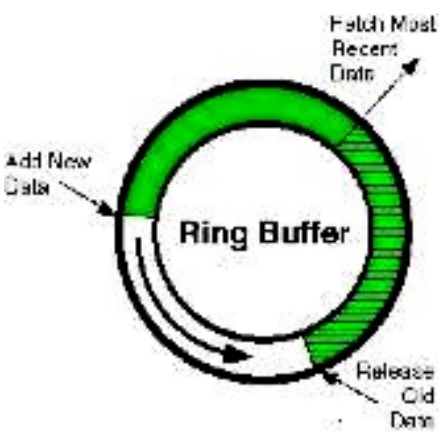
Open Source DataTurbine Initiative
www.dataturbine.org

RBNB
Data Turbine



- In-Network Buffered Data Management and Archiving for Streaming Data
  - Scalable Support for In-Network Intelligent Routing, Data Processing, Filtering, and Topology Management
  - Robust Bridge Environment Between Diverse Data Sources and Distributed Data Destinations
  - Optimized for High-speed Streaming Data
- All-Software Solution (Java)
  - OPEN SOURCE SOFTWARE - Apache 2.0 License
- Used In NSF, NASA, NOAA, DOE Projects
  - Developed by Creare Inc., (www.creare.com)
  - NSF support from SDCI program (Sept 07)



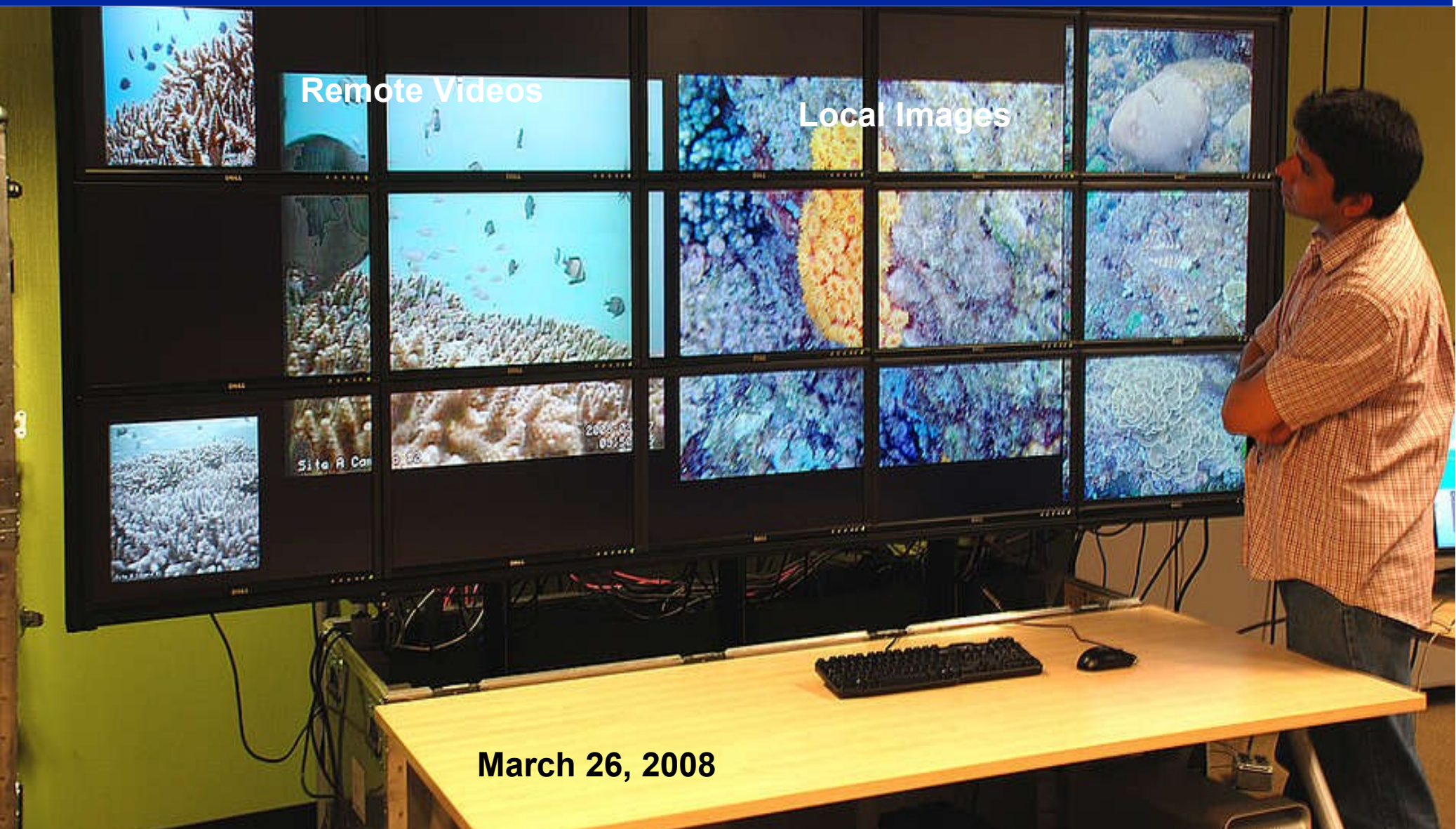


Source: Tony Fountain, Sameer Tilak

OPEN SOURCE DATA TURBINE INITIATIVE
Empowering the Scientific Community with Streaming Data Middleware

UCSD UCIrvine | Gordon and Betty MOORE FOUNDATION | CREON | GLEON global lake ecological observatory network | PRAGMA | it²

New Year's Challenge: Streaming Underwater Video From Taiwan's Kenting Reef to Calit2's OptIPortal



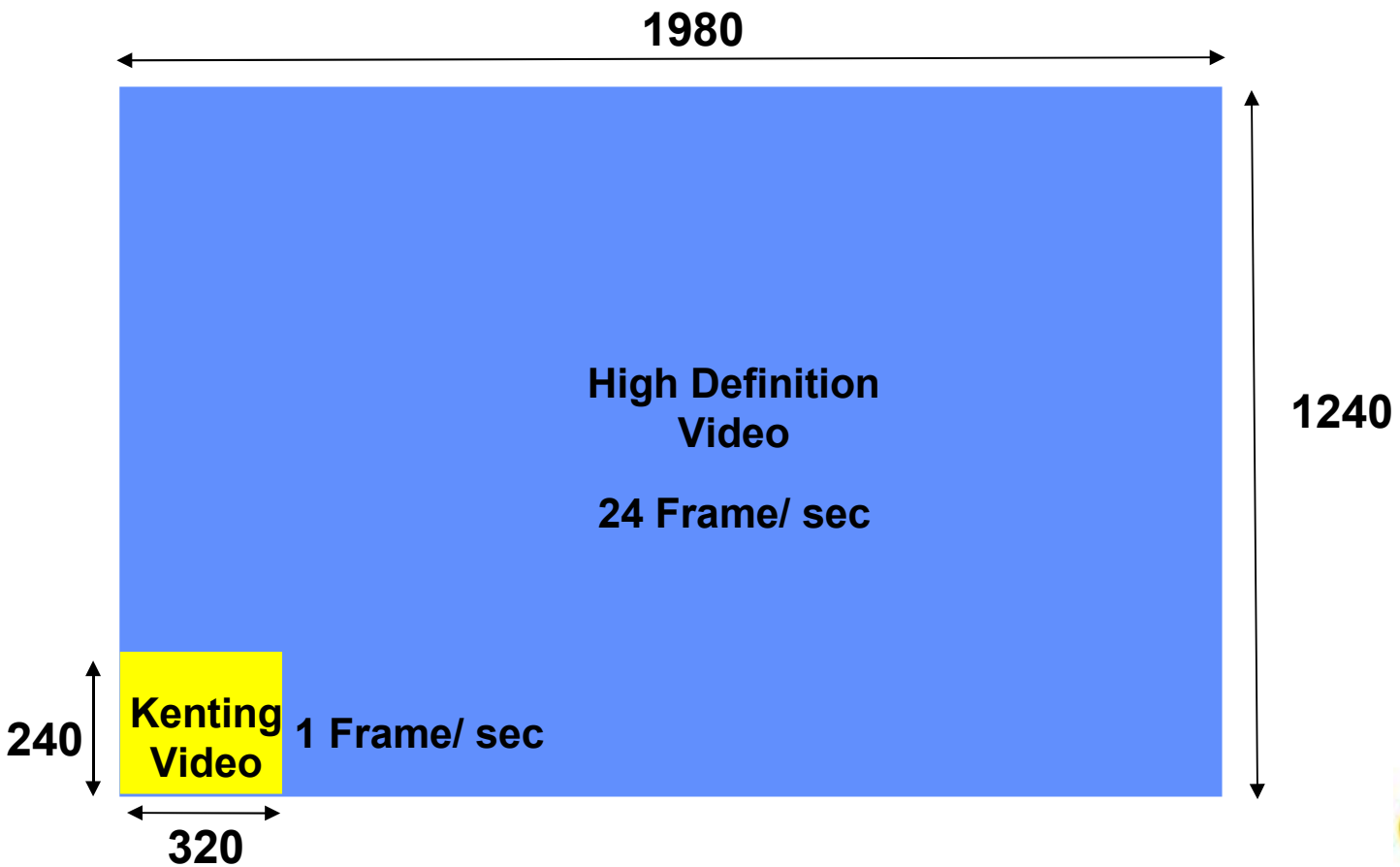
OPEN SOURCE DATA TURBINE INITIATIVE

Empowering the Scientific Community with Streaming Data Middleware

UCSD: Rajvikram Singh, Sameer Tilak, Jurgen Schulze, Tony Fountain, Peter Arzberger
NCHC : Ebbe Strandell, Sun-In Lin, Yao-Tsung Wang, Fang-Pang Lin

The Kenting "Bandwidth Bottleneck"

- Currently Limited Bandwidth Access to Underwater Cameras
  - Two ADSL Cables
- Bandwidth Less Than a Megabit/ Sec
  - Severely Limits Video Resolution and Frame Rate
- Kenting Would Benefit From Much Higher Bandwidth



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Embed Stream Analysis into Network
HD Video Will Increase Accuracy

Source: MBARI and Dr. Laurent Itti of USC's iLab



Video Collected by ROV or Cabled Camera

SDI over Fiber Interlaced

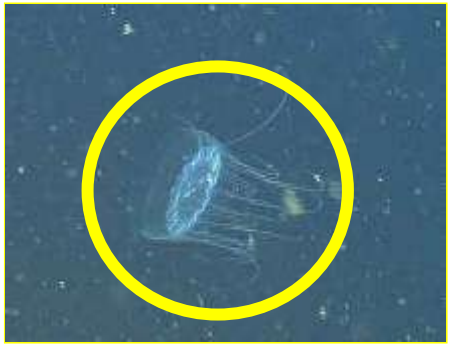


Sony Digital BetaCAM Recorder

SDI over fiber



Capture Control



Detection & Classification

Processing on Beowulf Cluster GB Ethernet Between Nodes



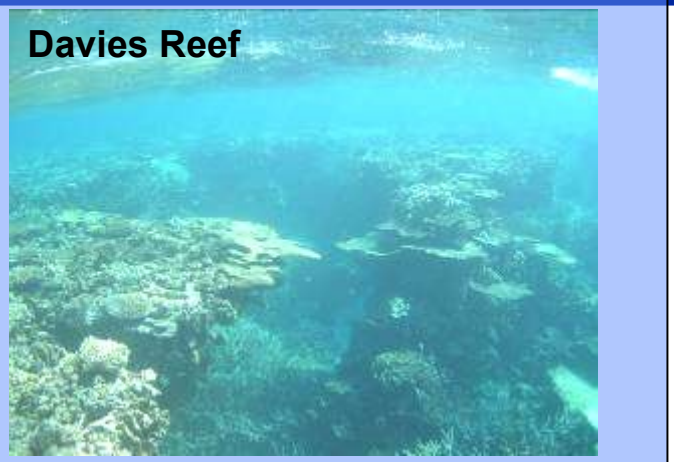
UCSD UCIrvine

LOOKING
Laboratory for the ocean observatory knowledge integration grid

it2

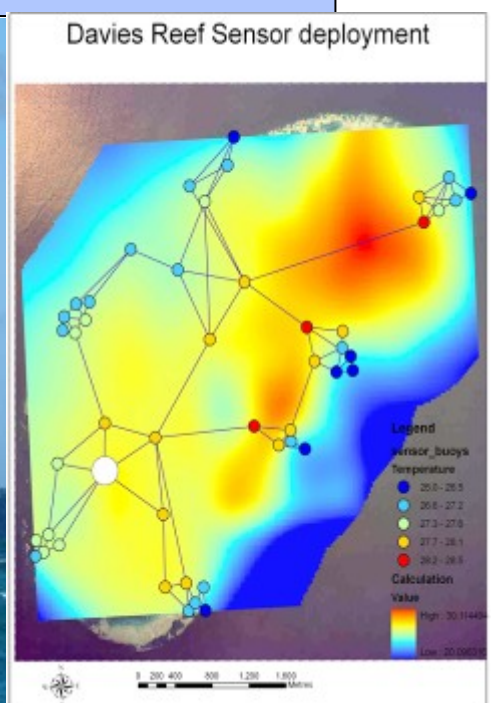
Realtime Sensornets on the Davis Reef Australia With High Speed Wireless Link





The Challenges
- **Tropics**
- **Distance; Power**





10^7bps on 10.5 GHz Carrier
~ 70km over Water

Source: Stuart Kininmonth, Scott Bainbridge, AIMS Australia.

UCSD
UCIrvine

CREON

it²

Moorea Coral Reef LTER Site
Current Bandwidth ~ 100kbps, But Fiber Optic Cable by 2010

- **LTER Established Sept. 2004**
  - **PIs: Russ Schmitt, Sally Holbrook, Pete Edmunds, Bob Carpenter**
  - **Deputy Director: Andy Brooks**
- **20 Investigators**
  - **UC Santa Barbara**
  - **CSU Northridge**
  - **UC San Diego / Scripps**
  - **UC Santa Cruz**
  - **UC Davis / Bodega Marine Lab**
  - **University of Hawaii**
- **Field Operations Based from UC Berkeley Gump Research Station**







NSF

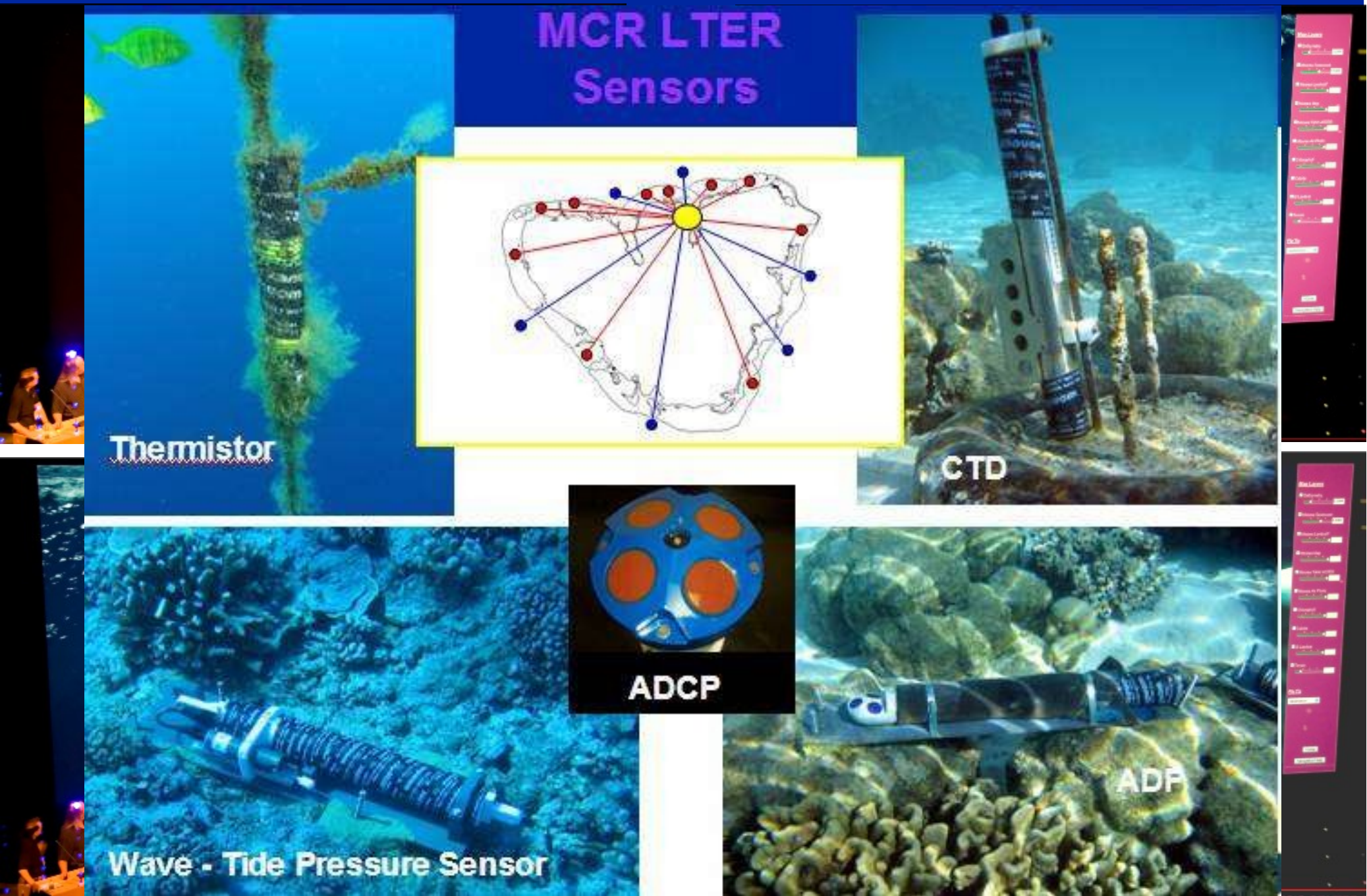
LTER

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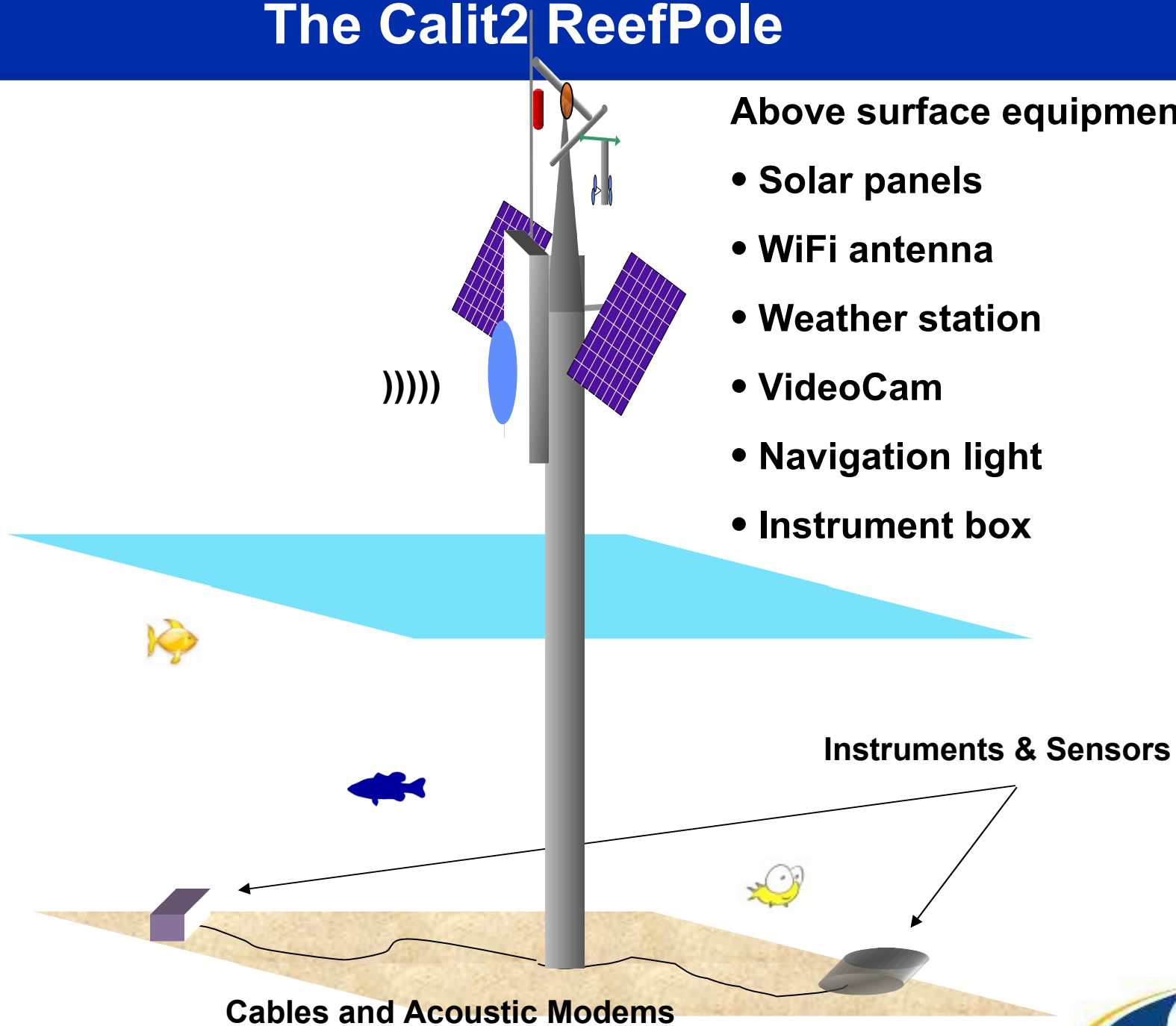
CREON

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Creating a Digital Moorea
Calit2 Collaboration at UC Gump Station (UCB, UCSB)



From Flipper Net to High Speed Wireless: The Calit2 ReefPole



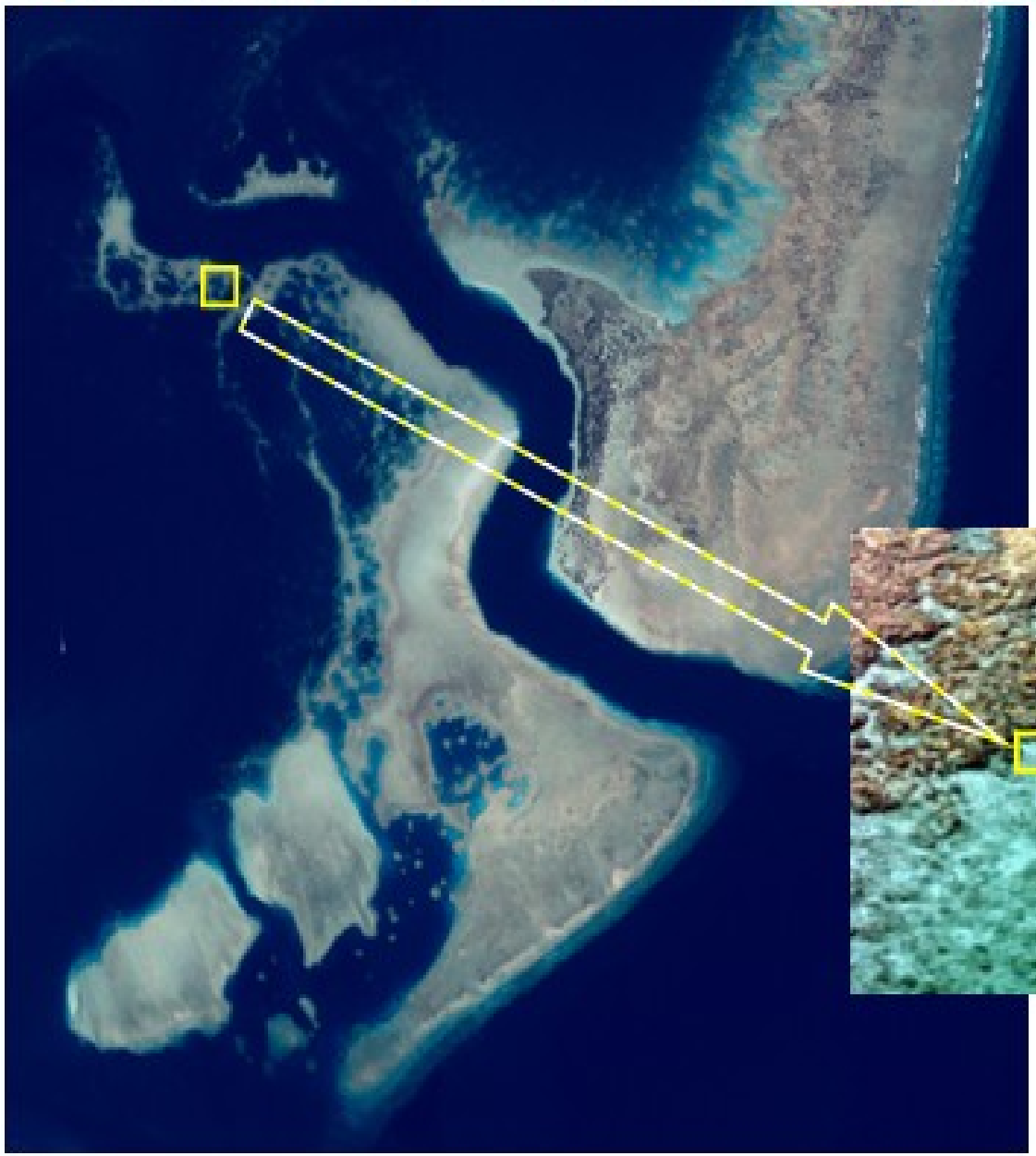
Above surface equipment:

- Solar panels
- WiFi antenna
- Weather station
- VideoCam
- Navigation light
- Instrument box

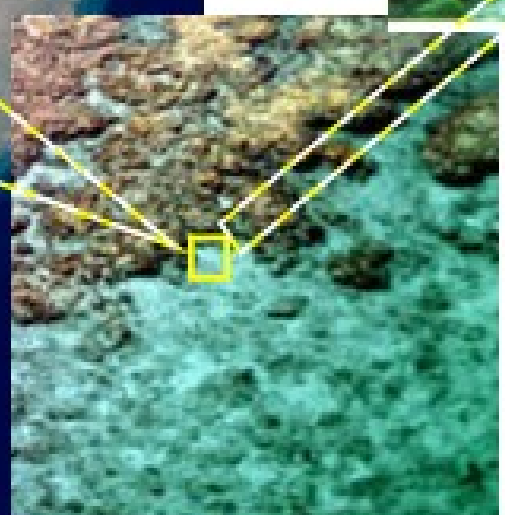
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Calit2 ReefBot Design for Digital Reef Mapping

Explore Every Square Meter of the Moorea Coral Reef from a Remote Desktop







Use The Reef GIS
to Zoom Into
Any Portion
of the Shallow Reef
to View Details Down
to ~ Centimeter

ReefBot Is a Mobile Networked Sensor platform

- **Potential Reef Sensor Suite**
  - Water sampling
  - Computed currents
  - Temperature, turbidity
  - Digital photographic mapping
  - Wave/surf conditions
  - Accurate bathymetry
  - Acoustic monitoring
- **Collected data can be used for multiple studies**
  - Population studies (fish, corals etc)
  - Bleaching, crown of thorns monitoring
  - Growth/destruction profiling
  - Post event assessment
  - Profiling for current/turbidity/siltatation

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



Paul Gilna Ex. Dir.

National LambdaRail
Direct Connect
Computation and Storage Complex

PI Larry Smarr

Funded by: Gordon and Betty Moore Foundation

Joint Partnership of:

UCSD
UCIrvine

Announced January 17, 2006--$24.5M Over Seven Years

Marine Genome Sequencing Project – Measuring the Genetic Diversity of Ocean Microbes



MARINE MICROBIOLOGY INITIATIVE

Gordon and Betty MOORE FOUNDATION

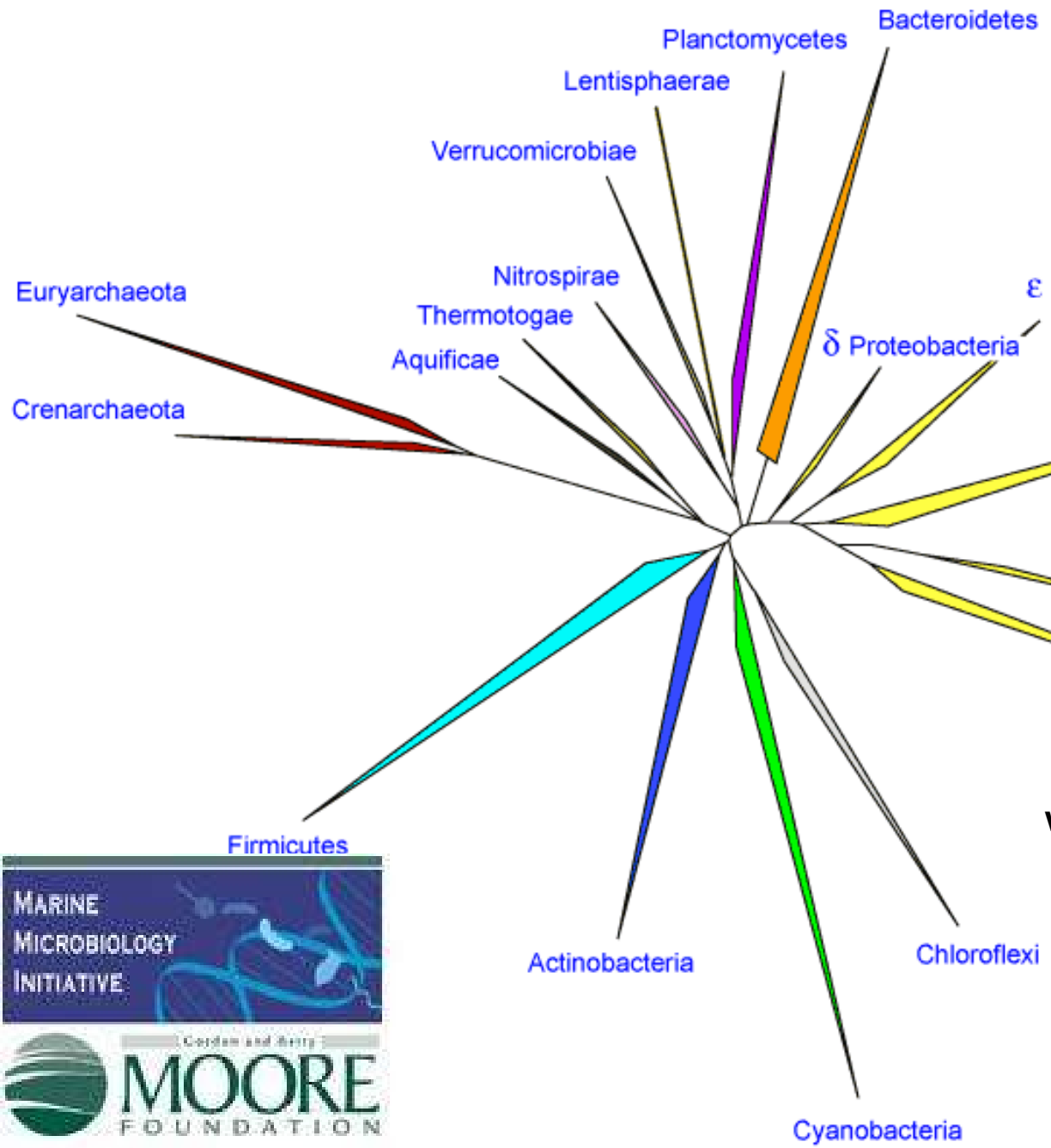
Sorcerer II Data Will Double Number of Proteins in GenBank!

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Moore Foundation Funded the Venter Institute to Provide the Full Genome Sequence of 155+ Marine Microbes



Phylogenetic Trees Created by Uli Stingl, Oregon State

Blue Means Contains One of the Moore 155 Genomes

www.moore.org/microgenome/trees.aspx

MARINE MICROBIOLOGY INITIATIVE

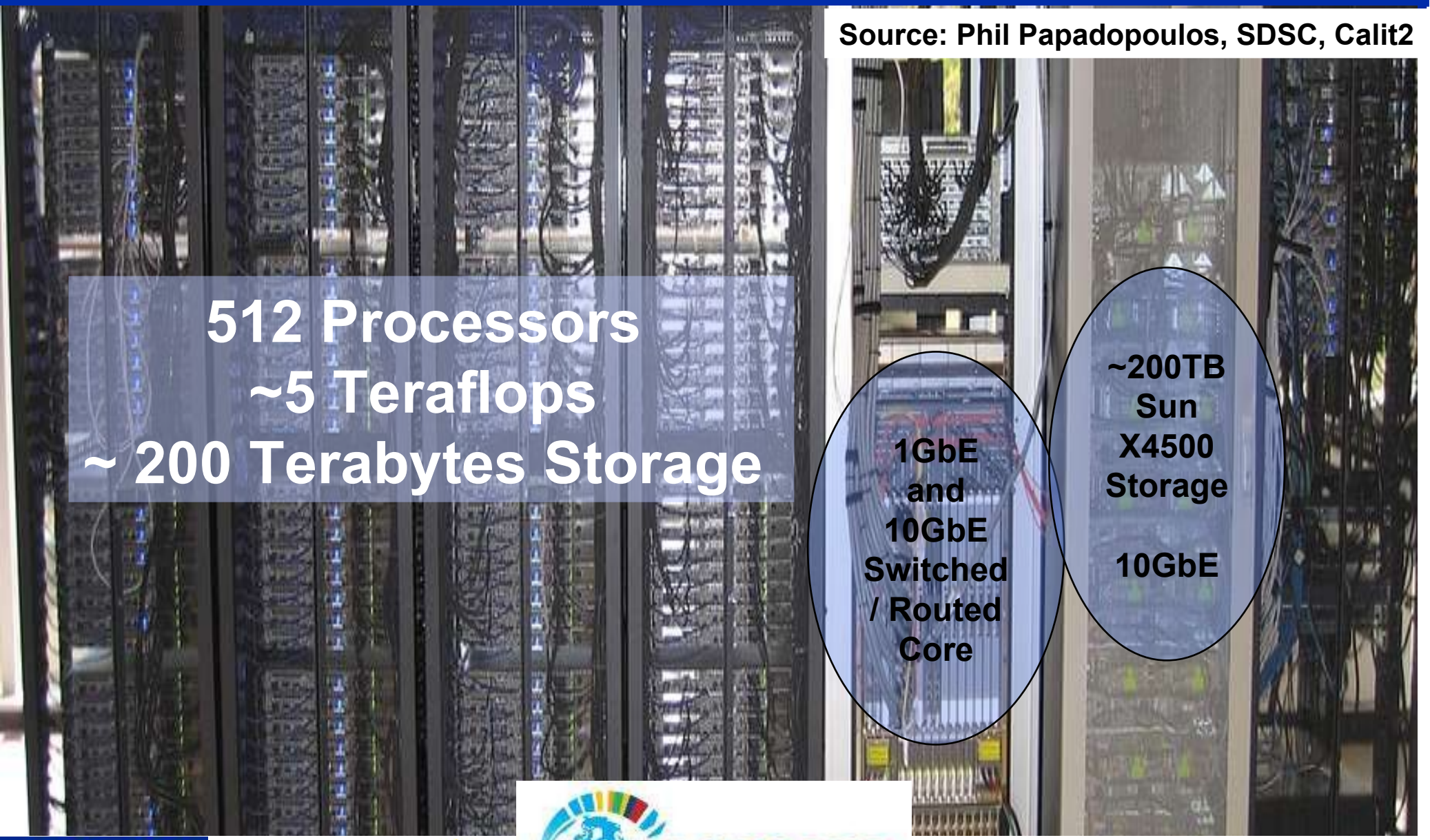
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Calit2 Microbial Metagenomics Cluster Production System

Source: Phil Papadopoulos, SDSC, Calit2



UCSD UCIrvine SDSC ROCKS camera Marine Microbial Ecology J. Craig Venter INSTITUTE it²

Calit2's Direct Access Core Architecture Has Created Next Generation Metagenomics Server

Gordon and Betty MOORE FOUNDATION

Sargasso Sea Data

Sorcerer II Expedition (GOS)

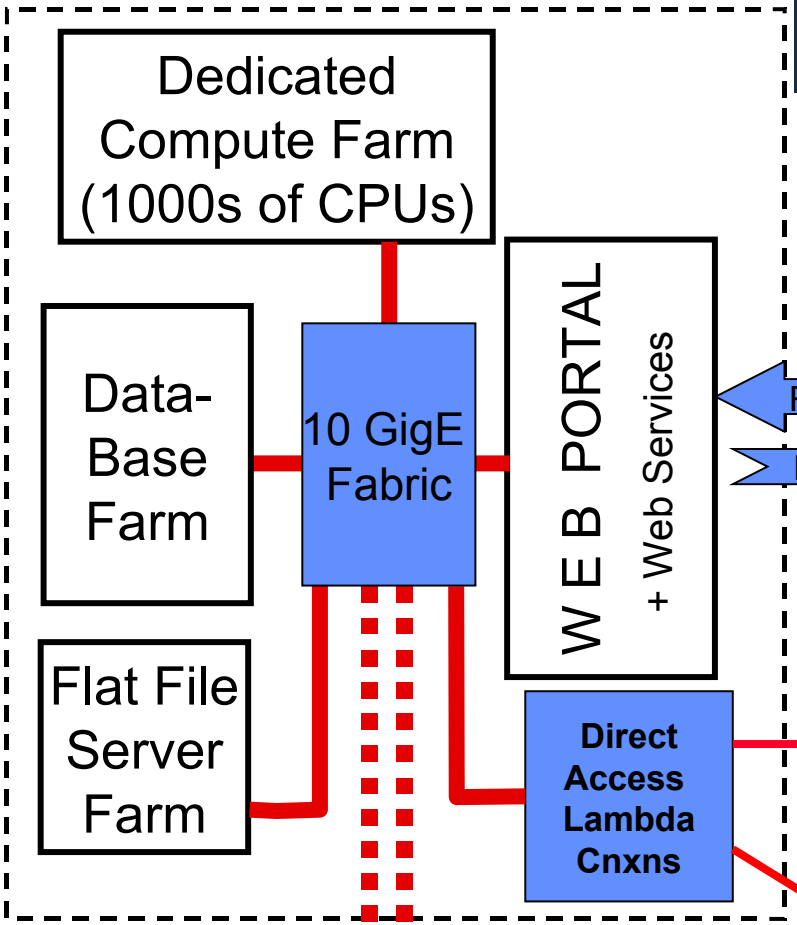
JGI Community Sequencing Project

Moore Marine Microbial Project

NASA and NOAA Satellite Data

Community Microbial Metagenomics Data

Powered by Rocks



Source: Phil Papadopoulos, SDSC, Calit2

CENTER FOR EARTH OBSERVATIONS & APPLICATIONS

SCRIPPS INSTITUTION OF OCEANOGRAPHY

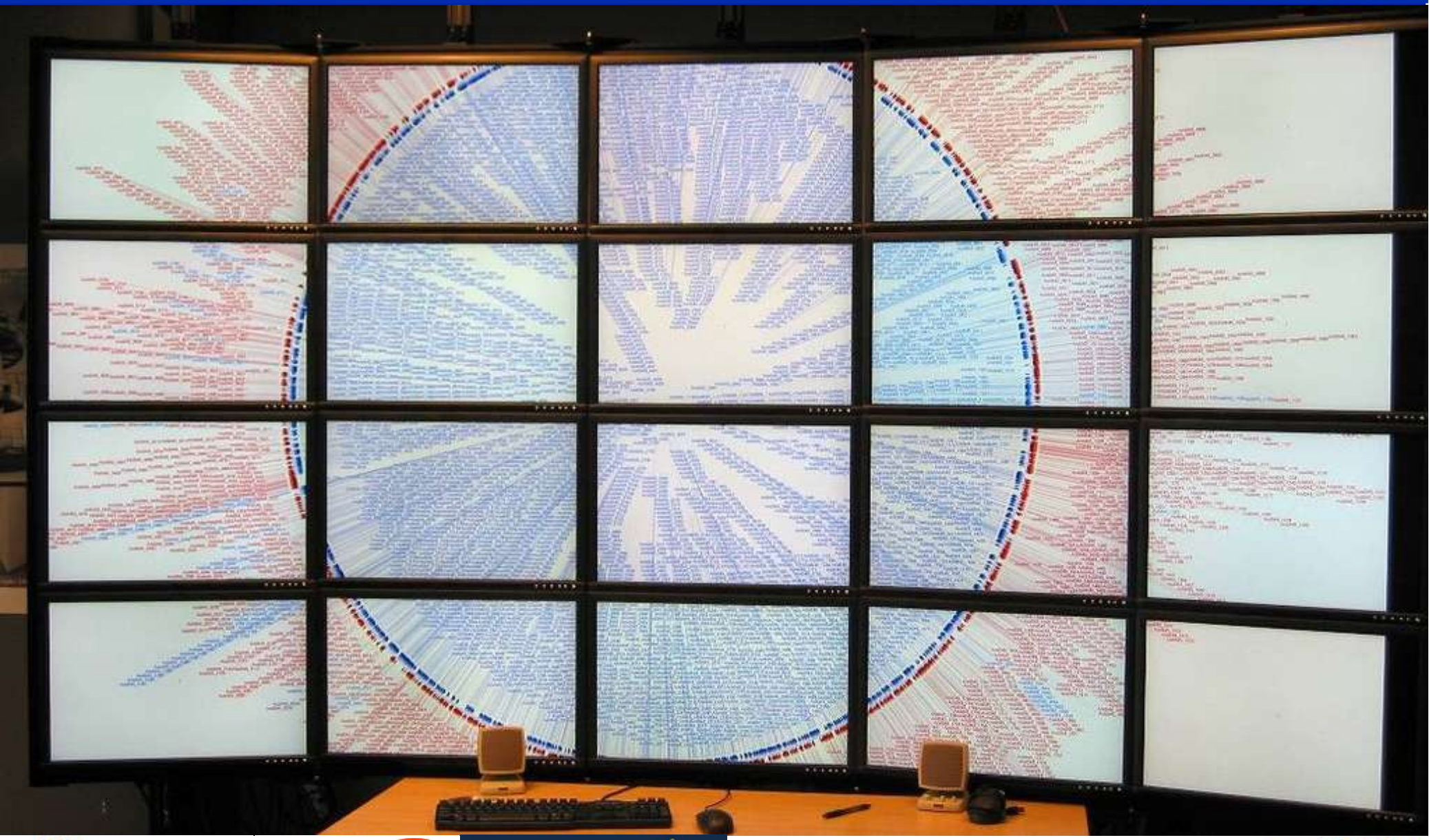
SDSC SAN DIEGO SUPERCOMPUTER CENTER

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Use of Tiled Display Wall OptIPortal to Interactively View Microbial Genome



camera Marine Microbial Ecology

OptIPuter

Powered by Rocks ROCKS

Acidobacteria bacterium Ellin345
Soil Bacterium 5.6 Mb
Source: Raj Singh, UCSD

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Use of Tiled Display Wall OptIPortal to Interactively View Microbial Genome



camera Marine Microbial Ecology

OptIPuter

Powered by Rocks ROCKS

Source: Raj Singh, UCSD

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Use of Tiled Display Wall OptIPortal to Interactively View Microbial Genome



camera Marine Microbial Ecology

OptIPuter

Powered by Rocks ROCKS

Source: Raj Singh, UCSD

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OptIPlanet Collaboratory Persistent Infrastructure Between Calit2 and U Washington



OptIPuter

Ginger Armbrust's Diatoms: Micrographs, Chromosomes, Genetic Assembly

ROCKS







UW's Research Channel Michael Wellings

it2

Comparative Analysis of Coral Reefs to Infer Human Impact



ECOLOGY

Life on the Mean Reefs

The short, nasty existence for reef-dwelling fish at two primeval atolls suggests that intensive fishing elsewhere has skewed predator-prey dynamics

Sandin SA, Smith JE, DeMartini EE, Dinsdale EA, Donner SD, et al. (2008) Baselines and Degradation of Coral Reefs in the Northern Line Islands. PLoS ONE 3(2): e1548

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Ecology of Four Coral Atolls in the Northern Line Islands



Northern Line Islands Expedition

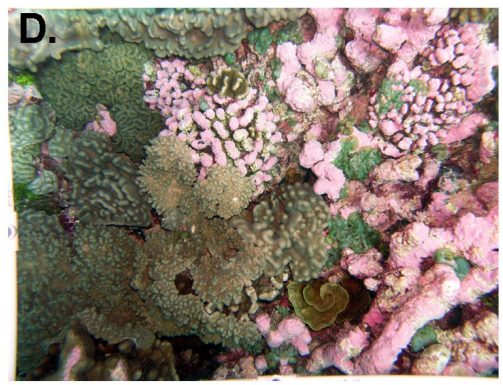
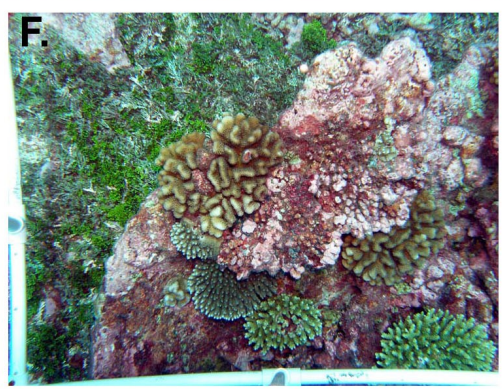
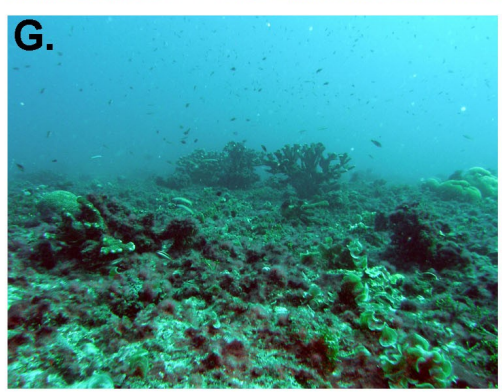
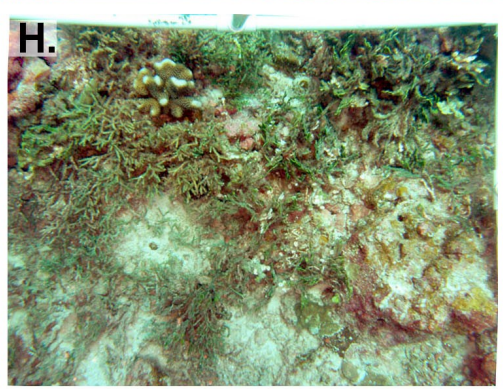
Stuart Sandin & Enric Sala, SIO UCSD



Sandin SA, Smith JE, DeMartini EE, Dinsdale EA, Donner SD, et al. (2008) Baselines and Degradation of Coral Reefs in the Northern Line Islands. PLoS ONE 3(2): e1548

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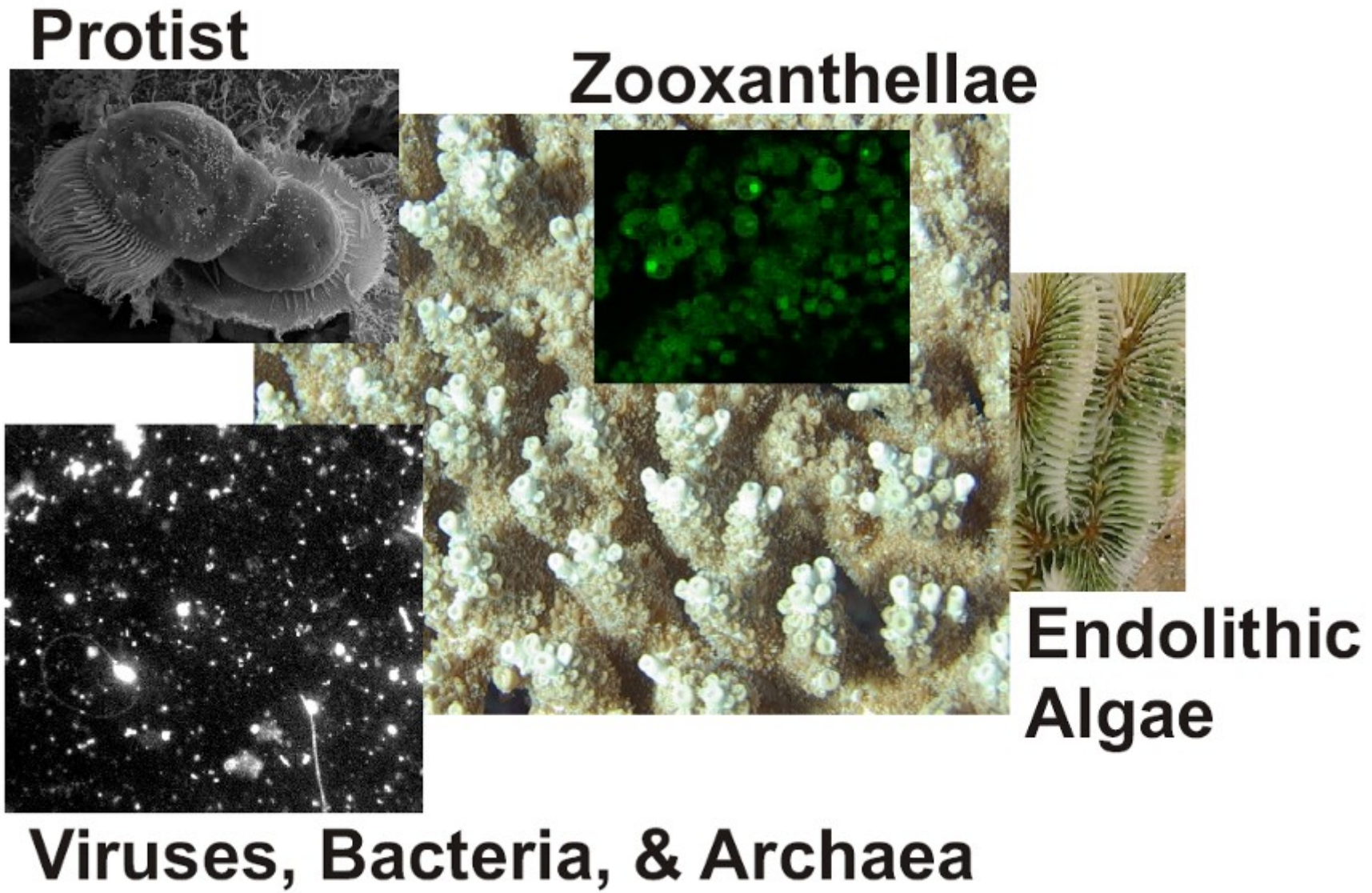
Sandin SA, Smith JE, DeMartini EE, Dinsdale EA, Donner SD, et al. (2008) Baselines and Degradation of Coral Reefs in the Northern Line Islands. PLoS ONE 3(2): e1548

		# of people
Kingman	 	0
Palmyra	 	~15
Fanning Tabuaeran	 	~1,000
Xmas Kiritimati	 	~5,000

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Coral-Microbe-Viral Associations Change with Environment and Stress

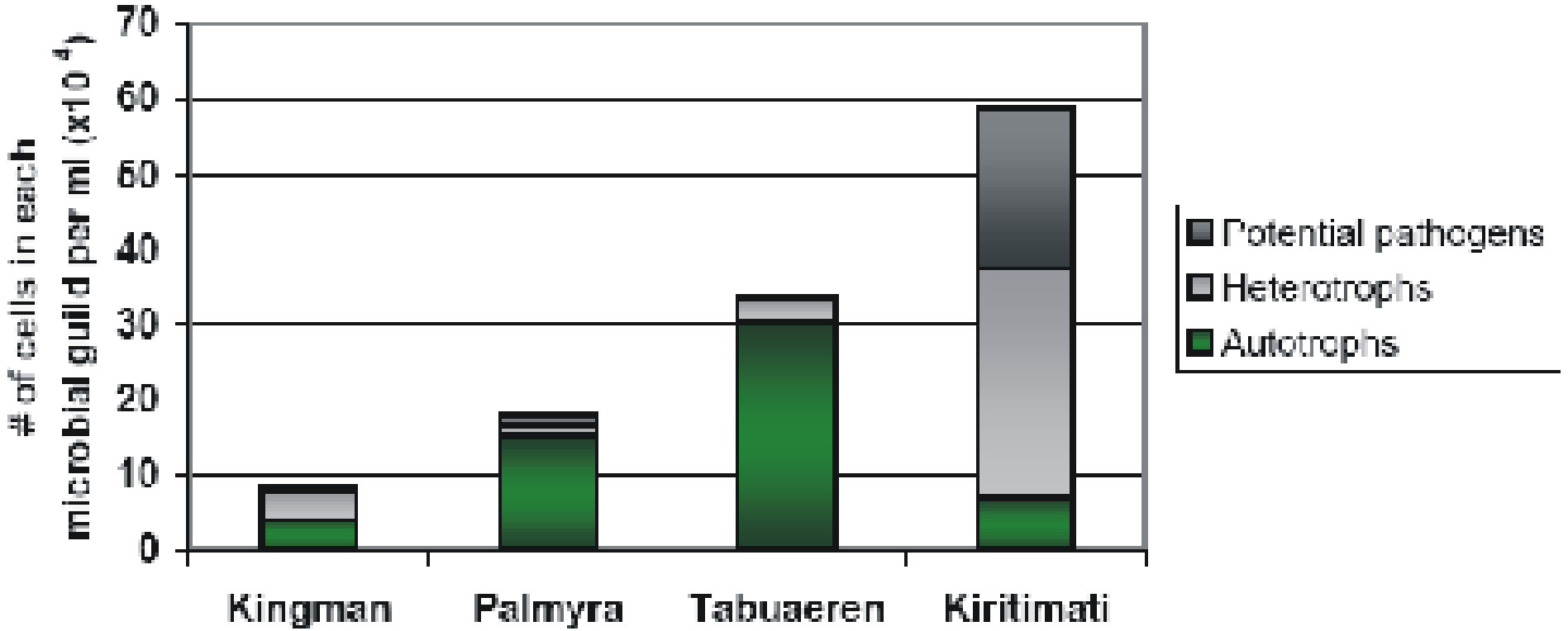


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Source: Eugene Rosenberg, Christina Kellogg, Forest Rohwer, Oceanography v120, 146 (2007)

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Coral Reef Microbial Ecology– More Potential Pathogens With People



Potential pathogens = *Enterobacteria, Staphylococcus, Streptococcus, E. coli, Vibrios*, some plant pathogens

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Dinsdale EA, Pantos O, Smriga S, Edwards RA, Angly F, et al (2008) Microbial Ecology of Four Coral Atolls in the Northern Line Islands. PLoS ONE 3(2): e1584. doi:10.1371/journal.pone.0001584