West Coast Scientists Lead NSF Effort To Prototype Cyberinfrastructure For Research And Education Access To Ocean Observatories

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Oceanographers and computer scientists will design cyberinfrastructure to link research institutions on land with several existing or planned ocean observatories off the west coasts of the United States, Canada and Mexico. That infrastructure will be a prototype for the use and automation of undersea sensor networks-both delivery of data from sensors and the control of sensors and networks from land-and will assist in designing sensor networks for conducting research in other remote and hostile environments.

The National Science Foundation (NSF) today awarded $3.9 million over four years to the University of Washington (UW), the University of California, San Diego (UCSD) and partner institutions to build the Laboratory for the Ocean Observatory Knowledge Integration Grid (LOOKING). It is the largest of nearly 120 awards from the agency's Information Technology Research (ITR) program this year, which total $130 million to be disbursed over the next five years.

Participating institutions will collaborate on experimental wireless, optical networks and grid technology, including development of web services, networking protocols, devices and sensors. The prototype grid will eventually link communities of oceanographers via high-speed wireless and optical networks to observatories off the coasts of Mexico, the United States and Canada. "A number of projects are already underway to deploy ocean observatories and sensors in the Pacific Ocean to permit *in situ* ocean research," said John Delaney, principal investigator and a professor of oceanography at the University of Washington. "This grant will allow us to make that research interactive by providing an essential architecture for the software, hardware and network services that will enable routine ocean access to researchers, educators, students and the general public."

The ITR grant is a collaborative award, with roughly half the work led by Delaney with co-PIs Ronald Johnson and Edward Lazowska of UW and Mark Abbott, Dean of Oregon State University's College of Oceanic & Atmospheric Sciences. Alan Chave of Woods Hole Oceanographic Institution (WHOI) has proposed a web services framework for LOOKING (in close collaboration with Bill St. Arnaud of Canada's CANARIE); WHOI will flesh this out with middleware and test the result using existing ocean observatories and terrestrial IT infrastructure. The other half of the award will be administered by the University of California, San Diego (UCSD), with most of the work to be carried out by Scripps Institution of Oceanography and the California Institute for Telecommunications and Information Technology [Cal-(IT)²]. "Our prototype infrastructure will be a large distributed data grid, driven by a variety of instruments, and we want it to be capable of interactively analyzing and collaboratively visualizing multiple data objects," said John Orcutt, Deputy Director of Scripps and LOOKING's principal investigator at UCSD. "One of our biggest challenges is the design of middleware to facilitate and enable instrument and infrastructure control, data generation and distributed storage, data assimilation and ocean simulation, analysis, visualization, and collaboration."

The LOOKING project is emblematic of a growing focus on global, coastal and regional-scale observatories since the NSF initiated its Ocean Observatories Initiative (OOI) in 2001. That federally-funded initiative is scheduled to be funded in fiscal 2006 with $245 million over five years. Those and existing ocean observatories will be managed and operated by another NSF creation-the Ocean Research Interactive Observatory Networks

(ORION) program. ORION coordinates the science, technology, education and outreach of the emerging network of science-driven ocean observatories.

Working with other NSF-funded organizations, LOOKING will develop cyberinfrastructure to link multiple coastal or regional observatories, including the Southern California Coastal Ocean Observatory (SCCOOS) which will provide real-time data from its existing sensors. New web services, networking and control prototypes will also be tested in conjunction with several new observatories to be constructed over the next five years (all of which, like ORION, derive their acronyms from heavenly bodies):

MARS (Monterey Accelerated Research System), a deep water, proof-of-concept testbed for cabled observatories, to begin construction in 2005, led by the Monterey Bay Aquarium Research Institute (MBARI);
VENUS (Victoria Experimental Network Under the Sea), Canada's shallow-water equivalent of the MARS testbed, to begin construction in late 2004, led by the University of Victoria; and
NEPTUNE (North East Pacific Time-series Undersea Networked Experiments), a joint U.S./Canadian regional cabled observatory planned for the northeast Pacific, led by LOOKING PI Delaney. NEPTUNE itself is the prototype for the first electro-optically linked, multi-node network of interconnected sensor arrays designed to measure and interact with all facets of solid Earth and coastal-to-global ocean-atmosphere processes that span the local to planetary scales. The northern loop of the network, with C$62 million already committed from NEPTUNE Canada in partnership with ORION, is scheduled to be operational in 2007, with full-network operation anticipated in the 2008-2010 time frame.

To manage-on land-the vast amounts of data streaming from these ocean observatories, LOOKING will rely on the emerging capabilities of the NSF-funded OptIPuter project. Dedicated lightpaths, or *lambdas* (individual wavelengths of light on optical fibers), linking UW and UCSD will form LOOKING's optical core, with plans for eventual links to NASA research centers, institutions in Mexico and Canada, as well as other U.S. universities that do ocean research. Researchers at the University of Illinois will provide optical networking and visualization expertise on the project. "OptIPuter will provide real-time software as well as high-performance compute and storage capacity," said OptIPuter and Cal-(IT)² director Larry Smarr, who is co-PI on LOOKING and a professor of computer science and engineering at UCSD's Jacobs School of Engineering. "The dedicated lightpaths will also permit super-fast, interactive control of ocean-going instruments along with real-time access to the data from those instruments."

Given LOOKING's focus on tools for research and education, web services will be a priority at UCSD, UW, OSU, MBARI, and WHOI, as well as CalPoly, the National Center for Supercomputing Applications, University of Illinois at Chicago's Electronic Visualization Laboratory, and the Canadian Network for the Advancement of Research, Industry and Education Inc. (CANARIE). Two other projects based at UCSD-ROADnet and HiSeasNet-will provide data handling software and ocean-to-shore, high-speed wireless and satellite communication systems. International partners include the oceanographic department of Mexico's Center for Scientific Research and Higher Education of Ensenada (CICESE).

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Functional Components of an Ocean Observatory

Satellite & Buoy Data

Other Nodes

sensor | **Inst.** | **Inst. Process**

sensor | **Inst.** | **Inst. Process**

Observatory Node

Node Control Process

Other Nodes

Operations & Dataflow Mngt.
- **Shore Control Process**
- **Data Buffering Process**
- **Data Archive Process**
- **Streaming Data Process**

Internet and Research & Education Networks
- **Science User**
- **Modeling & Simulation**
- **Public User**

Cabled Sensor Networks