A Fiber-Optic Telescope to the Deep Sea

By Nancy Penrose, Communications Coordinator, Regional Scale Nodes Program

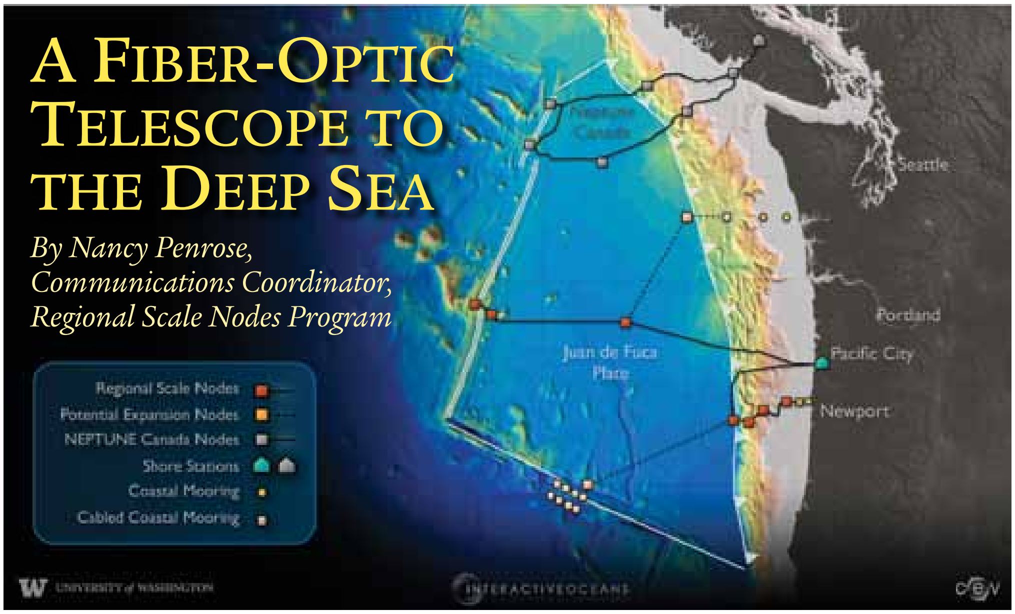

Figure 1. Regional Scale Nodes cable system map; RSN website: www.interactiveoceans.washington.edu; OOI website: www.oceanobservatories.org]. Image credit: RSN and Center for Environmental Visualization, University of Washington

Abstract

Real-time science and education in the North East Pacific Ocean using the Regional Scale Nodes cabled ocean observatory component of the NSF Ocean Observatories Initiative will soon be here. This innovative infrastructure, made up of 500 miles of fiber-optic/power cable and thousands of instruments, is now under construction and is scheduled to begin operations in 2014. By enabling continuous *in situ* studies of ocean phenomena 24/7/365 for decades, cabled ocean observatories are opening a new era of oceanography not only for scientists but also for educators and students.

A mysterious and fascinating deep-sea world hidden under thousands of meters of water is coming to computers in classrooms, laboratories, libraries, and homes around the world. Students, educators, scientists, anyone with an Internet connection will be able to explore the ocean from their desktops, dive to the seafloor without going near the water, chart the activity of an underwater volcano, or track the migration of a blue whale. The idea that the ocean is only what can be seen from the edge of the shore will begin to be replaced with the recognition that the deep ocean is a vitally important part of our planet to explore and understand.

Real-time science and education in the Northeast Pacific using the Regional Scale Nodes (RSN) cabled ocean observatory component of the NSF Ocean Observatories Initiative (OOI) will soon be here.

The OOI, which also includes coastal and global components, will construct a network of instruments, undersea cables, and moorings that will span the Western Hemisphere. A common computer architecture–cyberinfrastructure–will integrate the observatories' thousands of instruments, tens of thousands of users, and terabytes of data.

The OOI, one of the largest-ever ocean science programs, is managed and coordinated by the Consortium for Ocean Leadership. Institutions involved in construction of the infrastructure include the University of Washington, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, Oregon State University, and the University of California, San Diego. The OOI system will be open for use by a wide variety of science and education communities. Construction is expected to take five years, and the observatories are designed to operate for 25 years.

Development and construction of the RSN are led by the University of Washington (UW). Operations are scheduled to begin in 2014. Nearly 500 miles of fiber-optic/

power cable will reach from the subduction zone off the coast of Oregon, where the Juan de Fuca tectonic plate is being pulled beneath the North American plate, all the way to the active underwater volcanoes and hydrothermal fields of the Juan de Ridge spreading center. The cable will provide unprecedented levels of power and two-way high bandwidth communications to instruments and moorings that will cover the ocean from below the seafloor to the tops of the waves. Data types will include stunning imagery from the particularly power and bandwidth hungry high-definition underwater video cameras.

Historically, oceanographers have gone to sea in ships to study the oceans. Limitations of this expeditionary approach include studies within very short time frames and little geographic coverage; battery-powered instruments with limited lifetimes and low-bandwidth communication capabilities; short periods of favorable weather when scientists can use ships to productively conduct research in the North Pacific; brief dives using research submarines and robotic undersea vehicles; and surface-only studies using satellites.

Despite the constraints, many exciting and beneficial discoveries have been made using these traditional methods: new life forms at hydrothermal undersea vents; changes in ocean temperatures that lead to El Niño climate patterns; the propagation of earthquakes across a tectonic plate, the motions of tsunamis across an ocean basin.

Each new discovery has triggered thousands of other questions, many of which cannot be answered without using new approaches. By enabling continuous *in situ* studies of ocean phenomena 24/7/365 for decades, cabled ocean observatories are opening a new era of oceanography, not only for scientists in many disciplines, but also for educators and students. Within the OOI, education-user needs are being integrated into all components of network design so that science educators will have the tools to derive products and programs from OOI data and other resources.

As part of the OOI effort, the UW brings many years of experience in conducting seagoing science-education programs. The UW has taken a phased approach to addressing the challenges of moving into the era of cabled observatories: 1) learning how to transmit high-bandwidth data live from sea; 2) distributing these data in real time to audiences around the globe; and 3) including students and educators in seagoing operations and observatory planning.

In 2005, the VISIONS '05 expedition, led by RSN Program Director and UW Professor of Oceanography, John Delaney, and UW Professor of Oceanography Deborah Kelley, broadcast live high-definition video imagery from the seafloor for the first time. Three educational programs were produced from sea. (Figure 2) Two-way dialogues

Figure 2. Deborah Kelley, on the far left, Professor of Oceanography at the University of Washington and Project Scientist with the Regional Scale Nodes Program, inside the control van for the Jason II tethered robotic vehicle, onboard the research vessel Thomas G. Thompson, during the VISIONS '05 expedition in September 2005. Also shown are Jason operators. Jason II carried the high-definition underwater video camera that was used to broadcast live high-definition video imagery from the seafloor for the first time.
Image credit: University of Washington.

between researchers and teachers at sea onboard the UW Research Vessel *Thomas G. Thompson* and K-12 science educators and students in a UW studio in Seattle were commingled with the seafloor video. The broadcasts were streamed over Internet2 via The ResearchChannel, which reaches 20 million households around the world. The broadcasts are available on the ResearchChannel website (http://www.researchchannel.org/prog/display-series.aspx?fID=1704).

Delaney has a long history of engaging students and teachers in the ocean sciences. He is co-founder of the Research and Education, Volcanoes, Exploration, and Life (REVEL) program, which took more than 80 teachers to sea on expeditions studying the underwater volcanoes of the Juan de Fuca Ridge. REVEL involved science teachers from around the country in authentic, oceanographic research experiences as part of their professional development, and helped develop an extensive and collaborative community of lifelong learners, passionate about understanding the Earth system. (Figure 3)

Many other countries have recognized the value of putting high levels of power and bandwidth into the oceans, and several have begun planning and/or implementing cabled observatories. One such observatory is complementary to the RSN and has already been launched: NEPTUNE (NorthEast Pacific Time-Series Undersea Networked Experiments) Canada, installed on the northern third of the Juan de Fuca tectonic plate and run by the University of Victoria, began operations in December 2009. Data streams from instruments are available at www.neptunecanada.ca. Two other scientific cabled systems have been installed in shallow water: one in Monterey Bay (the Monterey Bay Accelerated Research System, MARS, www.mbari.org/mars) and one off Vancouver Island, Canada (the Victoria Experimental Network Under the Sea, VENUS, www.venus.ca). The University of Victoria, manager of the NEPTUNE Canada and VENUS systems, has partnered with the Shaw Ocean Discovery Center in Victoria (http://www.oceandiscovery.ca/) in outreach and education efforts. In conjunction with the MARS operations, the Monterey Bay Aquarium Institute (MBARI) has developed a program called Education and Research: Testing Hypotheses (EARTH), which uses near-real-time data from ocean observatories to design and test outreach with the Internet as an interface to scientists, teachers, students, and the public (http://www.mbari.org/earth/). EARTH workshops for educators are held each summer.

This image is a conceptual representation of a future seafloor laboratory on the Regional Scale Nodes of the Ocean Observatories Initiative network in the Northeast Pacific ocean.

Robotic systems will be the next-generation extensions of a human telepresence in the oceans as the ocean sciences benefit from a host of powerful emergent technologies driven by numerous disciplines that are entirely external to the world of ocean research. These technologies include, but are not limited to, nanotechnology, biotechnology, information and imaging technologies, and robotics.

Converging with the ability to place high levels of power and bandwidth into the oceans are enabling and adaptive capabilities that will allow sophisticated remote marine operations to be conducted on the seafloor and throughout the water column in ways never before imagined. Future laboratories on the seafloor could use robotic technologies to conduct adaptive sampling exercises from shore, *in situ* DNA analyses of microbes emerging from hydrothermal vents, and chemical probing of gas hydrates to understand their response to seismic events. High-definition video and other data will be transmitted via fiber-optic cable in real and near-real time to land-based laboratories, classrooms, and science centers. Because these images and data will be available via the Internet, learners of all ages will be able to participate in this journey of exploration and discovery.

Source/Credit: Regional Scale Nodes Program and Center for Environmental Visualization at the University of Washington

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