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CURRENT LOG *We're thrilled to be publishing a general issue filled with articles on a wide range of marine topics. We were overwhelmed and pleased with the positive response, and numerous articles and activities submitted. Our goal is to continue to publish one general issue per year, so keep your eye out for next year's deadline! I hope you find an article that will be of interest in your classroom whether you're an informal educator, educational researcher, or just want to learn more about the world of water.*

Please also mark your calendar for NMEA's 2003 Call for Papers deadline! All session proposals must be received no later than 5 p.m. on February 1, 2003. If you have any questions about concurrent sessions, please contact Vicki Clark at vclark@vims.edu. To find out more about the 2003 national conference on July 20-24 in Wilmington, North Carolina, please visit our website at www.marine-ed.org/nmea2003!

Cheers,

Lisa Tooker
Editor

CONTENTS

Cover image: Commander John Bomiak, NOAA Corps.

Volume 18 • Number 4 • 2003

THE NEPTUNE PROJECT

BY NANCY PENROSE AND MARK STOERMER

THE NEPTUNE PROJECT *will encircle and cross the Juan de Fuca tectonic plate in the Northeast Pacific ocean with 3,000 km of fiber-optic/power cable and at least 30 heavily instrumented experimental sites. This network will enable regional-scale, long-term, real-time observations and experiments with the ocean, seafloor, and subseafloor. NEPTUNE's real-time connection to the Internet will offer unparalleled opportunities for learners of all ages in a wide variety of settings to participate in the excitement of scientific discovery.*

INTRODUCTION

Beneath the waters of the northeast Pacific lies the Juan de Fuca tectonic plate, one of a dozen or so plates that make up the surface of the Earth. Here, in this one place, all the major Earth and ocean processes are represented. Blue whales are thought to reach the northernmost end of their migration. Deep-sea volcanoes spew forth heat-loving microbes; life forms that were once beyond even our imaginations thrive at hydrothermal vents. Earthquakes are born from the shifting of myriad faults. Salmon pass through these waters following ancient pathways. Bottom currents complete their grand tour, having hugged the seafloor all the way from Antarctica. Sediments once held tamely rockbound in coastal mountains are shot to sea during storms, carving canyons as they go.

This ideal location, just off the west coasts of the U.S. and Canada, has been chosen as the site for NEPTUNE (http://www.neptune.washington.edu and http://www.neptunecanada.ca), a transformational project that is part of a worldwide effort to develop regional, coastal, and global ocean observatories. NEPTUNE's 3,000-km network of fiber-optic/power cables will encircle and cross the seafloor of the Juan de Fuca plate (see Figures 1a and 1b). A series of mini-observatories will be equipped with a variety of instruments to collect data from the tops of the waves to below the seafloor.

EXPLORING THE OCEAN-EARTH ENVIRONMENT VIA THE INTERNET

Hardwired to high-bandwidth telecommunications networks (Canada's CA*net3 and the U.S. Internet 2), NEPTUNE will extend the Internet to the seafloor and ocean; real-time data will flow into land-based laboratories, classrooms, and science exhibits around the world; commands to instruments will flow from shore to ocean. Remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) will reside at depth,

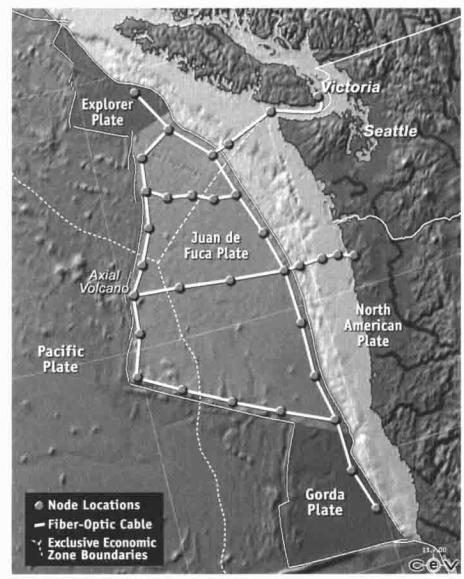

Figure 1a. Cable system map

recharge at nodes on the cable with power carried from shore stations, and offer command-and-control capabilities to shore-based users.

These innovations will give users the ability to enter, sense, and interact with the total ocean-Earth environment. Via the Internet, students and the general public will be offered unparalleled opportunities to interact with scientists and their data in settings that will range from aquariums, museums, science centers, and schools to living rooms and libraries anywhere on the globe.

With an expected lifetime of 30 years, the NEPTUNE infrastructure will provide unprecedented time series of multidisciplinary measurements, enabling regional-scale,

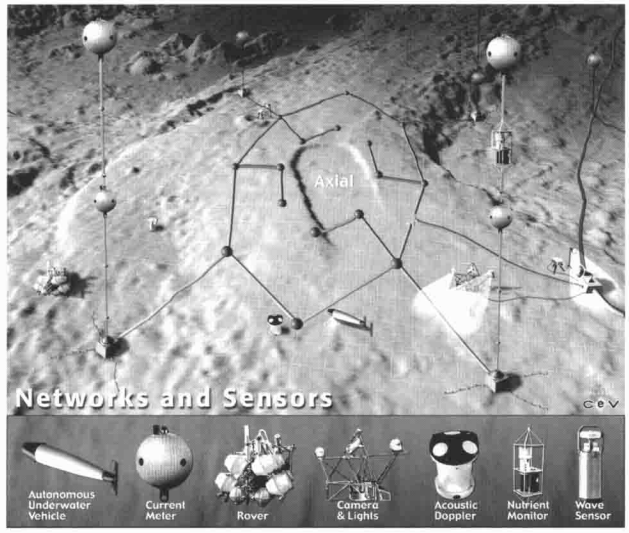

Figure 1b. Closeup of Axial seamount with instruments.

long-term, real-time observations and experiments with the ocean, seafloor, and subseafloor. Its sensor networks will enable exploration of natural processes over the fourth dimension, time, as well as the three spatial dimensions. Large sensor networks established to study land-based natural processes are relatively common, but NEPTUNE will be the first large-scale ocean observatory and is likely to serve as a prototype for others built in the coming decades.

The full NEPTUNE network is expected to be operational by 2007. Test-beds in British Columbia (http://www.venus.uvic.ca/) and California (http://www.mbari.org/mars/) have been funded, and are expected to begin transmitting real-time data via cable and and/or satellite within the next couple of years. NEPTUNE may also serve as a unique test-bed for sensor and robotic systems designed to explore other oceans in the solar system, such as the ice-covered water ocean of Europa, the second moon of Jupiter.

OCEAN OBSERVATORIES: A NEW PARADIGM IN THE OCEAN SCIENCES

For the past century and a half, oceanographers have used ships as their primary platforms for explorations of the oceans. This expeditionary phase has served the sciences well and many significant discoveries have been made. Indeed, the discovery of chemosynthetic life forms at deep-sea hydrothermal vents in the late 1970s, using the ship-based deep-sea submersible, *Alvin*, triggered a revolution in the biological sciences. Knowledge has increased significantly about movements of the Earth's tectonic plates, fluctuations in fish populations, and the origins and processes of life on this planet. Complementing this ship-based approach have been long-term observations made via satellites and ocean buoys that have led to dramatic improvements in, for example, forecasting the El Niño weather phenomenon and an understanding of the oceans' role in global climate change.

Despite these advances, present approaches are limited by the spatial and time dimensions that can be observed. Satellites offer powerful synoptic views of the ocean, but coverage is limited to only a few meters below the sea surface. Ocean buoys can reach great depths, but are constrained by limited battery power and are restricted to one point in the ocean. Ship-based expeditions leave the oceans unsampled for weeks to decades, the very time frames that are most critical for understanding the impacts that humans and the natural environment exert on each other. A single event, such as a submarine earthquake, an eruption, or a violent storm, can trigger changes in a wide range of systems, such as benthic ecosystems, changes that would be difficult to understand without knowledge of the context and timing of the triggering event. Changes taking place at widely separated locations, such as the release of subseafloor-dwelling microbes after an earthquake, may be related in ways that cannot be detected without regional-scale simultaneous observations.

Cabled ocean observatories such as NEPTUNE will be free from the limitations of battery life, ship schedules, shipboard accommodations, bad weather, and delayed access to data. Such observatories will offer scientists and educators anywhere in the world the opportunity to observe and/or participate in ocean experiments; scientists will be able to routinely command their instruments to respond to storms, plankton blooms, earthquakes, eruptions, slope slides, and other events. Continued improvements in climate prediction that combine data from cabled observatories, ocean buoys, and satellites, will improve planning and promise greater reduction in losses to fishing and agricultural communities, governments, and consumers around the world.

Recognizing the important role of ocean observatories, the U.S. National Science Foundation has developed the Ocean Observatories Initiative (http://www.geo-prose.com/projects/ooi.html) to provide Federal funding for ocean observatories at three different scales: coastal, regional, and global. NEPTUNE anticipates proposing to become the regional-scale component of this Initiative. In addition, the Canada Foundation for Innovation (http://www.innovation.ca) has awarded funds, subject to conditions, toward building the approximately 30 percent of the NEPTUNE network that will be located in Canadian waters.

NEPTUNE'S EDUCATIONAL POTENTIAL

From A Teacher's Viewpoint: Although full implementation of NEPTUNE is a few years in the future, excitement about its education and outreach potential, as well as scientific uses, is growing. As Ruth Cruz, a teacher at Tolt Middle School in

Carnation, Washington, explains, "I teach all the sciences in a multi-age classroom. To me, NEPTUNE is gift-wrapped for educators because the whole tectonic plate will be studied with all its natural processes. I will be able to hook the project into a wide variety of points within a curriculum.

"Teachers and schools are getting a lot of pressure to raise student scores in science and math. I believe there is no better teaching than getting kids involved in a present-day situation, something that is happening right now. NEPTUNE is not just a curriculum or a textbook or a set of rules—it is the full spectrum of real science and a teacher can work it all in to the math and science standards."

Cruz has participated in three oceanographic cruises, twice as a REVEL (http://oceanweb.ocean.washington.edu/outreach/revel) participant (see *REVELing in Seafloor Exploration* on page 13), and knows well the excitement that comes from working side by side with scientists as new discoveries are made. "The fact that NEPTUNE will put out the raw data is scary, but also an incredible opportunity. It will be a matter of finding ways to help students and teachers use it."

The Project Commitment: The six institutions that are building NEPTUNE—the University of Washington, the University of Victoria, the Monterey Bay Aquarium Research Institute, the Woods Hole Oceanographic Institution, Caltech's Jet Propulsion Laboratory, and Canada's Institute for Pacific Ocean Science and Technology—are strongly committed to maximizing NEPTUNE's contributions to formal and informal science education.

According to the Project's Chair, Professor John Delaney of the University of Washington's School of Oceanography, one of NEPTUNE's most important goals is to create opportunities for students, teachers, and the general public to travel along on the scientific journey, and to participate in the voyage of discovery that defines the scientific investigative process.

Figure 2. Kids exploring the wonders of whales and technology.

"I have always considered it a great privilege to be an oceanographic researcher," he explains. "The opportunities and the challenges are vast. The potential for making a difference is profound. Yet much of our work is foreign to the daily lives of the public, the people who pay for our work, the people who benefit from it, and for those who study it in classrooms.

"We often wonder how to share the excitement and significance of our work with students, taxpayers, and decision makers. How can we convey the essence of our enthusiasm? How can we inspire their interest?" He asks.

Professor Delaney believes that NEPTUNE is an ideal tool for increasing ocean literacy: the Project's real-time connection to the Internet will carry the oceans to the heartlands, far from an ocean shore, and will foster the understanding that the natural processes occurring in the oceans affect inhabitants around the globe.

Virtual Exploration: NEPTUNE's high-bandwidth communications technology offers a wide range of new educational opportunities to explore and investigate the dynamics of the marine world by coupling the real-time data stream with cutting-edge visualization techniques. Due to recent advances in technology, live video images from the seafloor and ocean can be streamed into a classroom or exhibit space, and turned into a 3-D virtual-reality world of the seafloor and the ocean space above it. Teachers will be able to take students on a virtual "field trip" to spaces they could never have explored before. NEPTUNE's suites of instruments will include remotely operated video cameras with "eyes" to observe the underwater environment, thermometers to "feel" the temperature of the water, and robot samplers to collect and analyze extremophiles—the heat—and chemical-loving microbes that live at undersea volcanic vents. What about swimming with the whales, virtually, viewing the ocean through the eyes of a marine mammal? (see Figure 2) A "scientist in residence" would be available via the Internet to guide the observations and experiments without ever leaving the laboratory. Students will be able to move through time as well as space by calling upon NEPTUNE's data archives, which will serve as a rich and lasting resource for exploration of the oceans for many types of users and communities.

The Internet2 K20 Initiative: NEPTUNE is an Internet2 K20 Initiative Project. (http://k20.internet2.edu/index.shtml) Internet2 is a collaborative effort by over 170 U.S. universities to develop advanced Internet technology and applications vital to research and education. This Initiative brings together Internet2 member institutions, primary and secondary

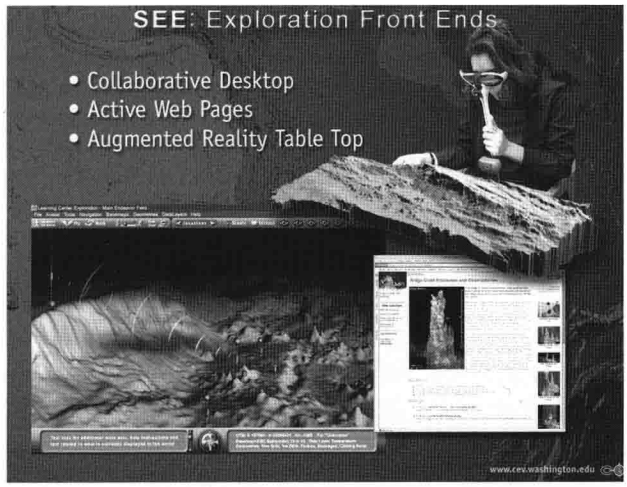

Figure 3: Example of technology used to show virtual marine environments and data.

schools, colleges and universities, libraries, and museums to get new technologies into the hands of innovators, across all educational sectors in the United States, as quickly and as "connectedly" as possible.

Other ocean-science oriented Internet 2 K20 Initiative Projects include the JASON Project, Earthwatch Global Classroom, and the Virtual Marine World Exploration. The latter is a project of the Center for Environmental Visualization (CEV) [(http://www.cev.washington.edu/)] at the University of Washington. Plans for the type of technology to be used in NEPTUNE are under development by CEV. For example, CEV is developing the System for Environmental Exploration (SEE) to create collaborative, 4-D virtual marine worlds (see Figure 3) by integrating visual representations and animated 3-D models of geo-referenced data sets and real-time data from marine sensors and platforms, such as ocean observatories. Visitors to a SEE exhibit will be able to virtually explore and discover a variety of marine environments that they could not physically visit. The visitors will interact and collaborate with participants at other exhibit spaces, either within the museum or in a classroom or science center across town, across the country, or across the globe. Participants will navigate over an experimental site, plan fieldwork, probe data sets, and share messages, as well as view 360-degree computer-generated panoramas, remotely collected imagery, and animated time-series data.

SEE will use a combination of real-time and archived data to develop 3-D geometric models that can be integrated into virtual marine worlds. Augmented reality technology will complement the virtual reality by overlaying 3-D virtual imagery on real-world, real-time video.

Educational Partnerships. NEPTUNE is in the process of establishing partnerships with the formal and informal science education communities. Three workshops on related to NEPTUNE education and outreach have already taken place and reports published (http://www.neptune.washington.edu/pub/education/education.html). Future workshops will address the development of a high-quality, immersive and collaborative science education experience delivered in an interactive 3-D format to major North American aquariums, museums, and science centers located in cities with access to high-bandwidth network nodes. Current plans call for local teams of designers and educators to develop site-specific content to match local educational interests and needs.

NEPTUNE is committed to offering a spectrum of possibilities for participation, ranging from a low-bandwidth modem connection on a home computer to an interactive IMAX or other immersive environment in a museum. For example, a child at home in his or her living room, will be able to use an inexpensive, low-bandwidth game console to remotely navigate a submersible through a 3-D immersive environment in a museum, interacting with participants physically present in the museum space.

In the meantime, NEPTUNE has embarked on a partnership with the REVEL Project (see *REVELing in Seafloor Exploration* on page 13) to facilitate access to cutting-edge oceanographic research by K-12 science teachers throughout the U.S. This partnership will gradually build a community of educators that will have experienced the challenges and explorative nature of technology-based research focused on earth and ocean sciences. These educators will in turn

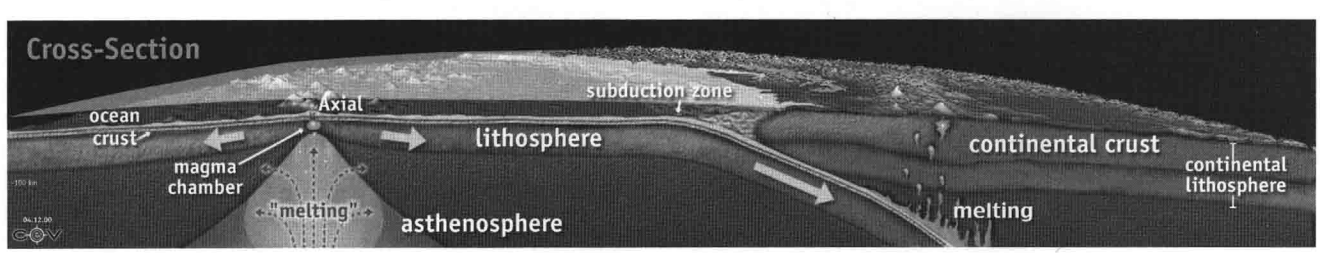

Figure 3: Major geological components of the Juan de Fuca tectonic plate system are show in this west-to-east cross-section.

prepare a generation of students that will use "real-time" observatories to learn and utilize technology-driven, and inquiry-based learning as recommended by the science education reform (NRC, 1996).

NEPTUNE SCIENCE

As part of the Project's Feasibility studies undertaken in 1999 and 2000 (NEPTUNE, 2000), NEPTUNE convened ad hoc groups of scientists to brainstorm ideas for ways in which the network could be used for science. Fields of inquiry span the spectrum of the sciences and include seismology and geodynamics, hydrogeology and biogeochemistry, subduction zone processes, cross-margin particulate flux, fisheries and marine mammals, water-column processes, ridge-crest processes, and deep-sea ecology (Delaney et al., 2000).

Results of the brainstorming sessions demonstrated that NEPTUNE's provision of continuous power and telecommunications will enable transformative approaches to the earth and ocean sciences in each of the fields discussed. One of many possible examples is how the NEPTUNE network could be used to better understand the earthquake and deformation patterns associated with the creation, aging, and destruction of oceanic plates. For the first time, using NEPTUNE's capabilities, it will be possible to examine these patterns in a continuous, integrated fashion for decades. Although the theory of plate tectonics produced a profound change in our view of the Earth, it has been difficult to quantify many of the fundamental processes associated with that theory. The NEPTUNE area is an ideal location to study these processes for it includes all major types of oceanic plate boundaries, including the Cascadia subduction zone and the Juan de Fuca ridge spreading center (see Figure 4). NEPTUNE's plate-scale seismograph array will enable the assumptions of plate tectonic theory to be tested against the behavior of a complete plate both in the long-term and in response to episodic events.

Seismometers on the seafloor are sparse and many oceanic earthquakes are not detected by land-based seismograph networks. NEPTUNE, however, will create an extensive network of seafloor seismometers that will include the capability to capture the earliest signals from great subduction zone earthquakes. Such earthquakes pose a significant hazard to the major population centers of Vancouver, B.C., Seattle, and Portland, all of which are near the Cascadia subduction zone.

There is broad support and endorsement within the scientific community for scientific themes that can be addressed best using cabled observatories such as NEPTUNE, themes that were explored in detail at a recent National Science Foundation-sponsored workshop on Scientific Cabled Observatories for Time Series (http://www.coreocean.org/Dev2Go.web?id=240421&rnd=5446). These themes coincide with and encompass the NEPTUNE fields of inquiry:

- Ocean climate and biogeochemical cycling, including oceanic uptake of anthropogenic carbon;
- Fluids and life in ocean crust, such as the microbes that are released from the seafloor during submarine eruptions;
- Dynamics of the lithosphere and imaging of Earth's interior, such as the movements of faults associated with the Juan de Fuca tectonic plate;
- Coastal ocean processes, such as episodic sediment transport from land to sea during storms;
- Turbulent mixing and biophysical interactions, as evidenced by bottom currents that affect benthic ecosystems; and
- Ecosystem dynamics and biodiversity, including studies of marine mammal migrations, and fishery stocks.

PROJECT STATUS

NEPTUNE is well on its way to becoming a reality. Many people–scientists, engineers, managers, educators at all levels–have contributed significant effort thus far and continue to demonstrate the kind of strong commitment to bring NEPTUNE into full existence. Power and communications systems are under development; test-bed construction is in progress; instrument development is under way; and the program office has been established at the University of Washington. Funding has been derived from all the partner institutions, several federal agencies, and private foundations and individuals.

Although located on the Juan de Fuca plate, NEPTUNE is a project that belongs to the world. Sharing the excitement of scientific discovery with a global audience and increasing our understanding of planetary processes as they change through time are among its most important missions. NEPTUNE will create opportunities to develop a holistic understanding of a complex and ever-changing natural environment the size of a tectonic plate. It will allow students to fully participate in the scientific investigative process; to learn that it is okay to fail, as scientists often do in their search for answers to their questions; and to learn from those failures and develop solutions.

As Delaney explains, "During the lifetime of many of today's students, the art of scientific discovery will depend more than ever on our ability to rise to the challenge of documenting and understanding change in all four dimensions." NEPTUNE will be at the leading edge of this challenge.

NANCY PENROSE is Communications Coordinator for NEPTUNE. Involved with oceanography since she first went to sea on a research vessel as an undergraduate. She has accumulated 20+ years' experience in ocean-related research, writing, and editing. She is based in the NEPTUNE Program Office at the University of Washington, Seattle, and is involved with the Project's education and outreach efforts.

MARK STOERMER directs the Center for Environmental Visualization at the University of Washington (UW). This Center is involved in visualizing earth science data and developing virtual marine worlds. He has 20+ years' experience in the scientific visualization of marine environments and holds degrees in systems engineering and ocean engineering. For the last 13 years he has worked in the UW College of Ocean and Fishery Sciences.

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National Research Council, 1996: *National Science Education Standards*, National Academy Press, Washington, DC, 262 pp.

FOR INFORMATION AND ACTIVITIES RELATED TO THIS ARTICLE THE BRIDGE RECOMMENDS:

Ocean AdVENTure
http://www.thinkquest.org/library/lib/site_sum_outside.html?tname=18828&url=18828/%3ftqskip=1

NOAA Ocean Explorer: Deep East Lesson Plans
http://oceanexplorer.noaa.gov/explorations/deep-east01/background/education/media/lessonplans.html

REVEL Project
http://www.ocean.washington.edu/outreach/revel/

Estuary Live
http://www.estuarylive.org/

Dive and Discover
http://www.divediscover.whoi.edu/

9 Degrees North
http://www.marinetech.org/nine_degrees/index.html

Jason XIV: From Shore to Sea
http://www.jason.org/

@Sea
http://www.at-sea.org/

The Ocean Adventure: Internet Expeditions
http://www.theoceanadventure.com/web.html

Sustainable Seas Expeditions
National Geographic:
http://www.nationalgeographic.com/seas/
National Marine Sanctuary Program:
http://sustainableseas.noaa.gov/

Student Connection
http://atsea.nmfs.hawaii.edu/

Search for Giant Squid
http://partners.si.edu/squid/default.html

GalapagosQuest
http://quest.classroom.com/archive/galapagosquest1999/default.asp

NeMO Cruises
http://www.pmel.noaa.gov/vents/nemo/index.html

American Museum of Natural History Expedition: Black Smoker
GOTOBUTTON BM_|_ http://www.amnh.org/national-center/expeditions/blacksmokers/

Reefs of the Gulf
GOTOBUTTON BM__
http://gulftour.tamu.edu/home.html

Palau: Paradise of the Pacific
http://www.pbs.org/edens/palau/

GOALS (Global Online Adventure Learning Site)
http://www.goals.com/Index.htm

Princess America Project
http://www.princessamerica.org/