



## UPDATE

December 2002

# A Regional-Scale Ocean Observatory for Interactive, Real-Time, Long Term Ocean and Earth Studies

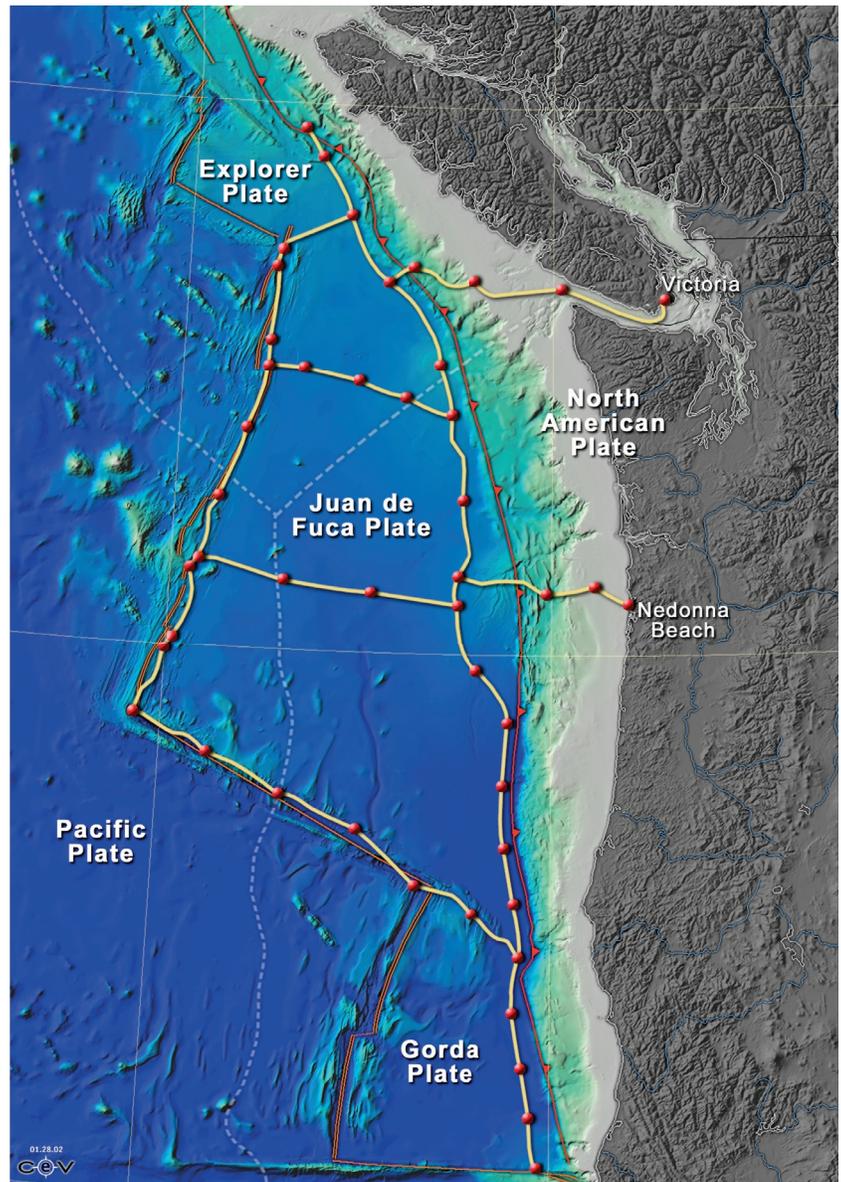
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### *What is NEPTUNE?*

NEPTUNE is a multi-institutional, international project that is part of a worldwide effort to develop coastal, regional, and global ocean observatories. The Project's 3,000-km network of fiber-optic/power cables will encircle and cross the Juan de Fuca tectonic plate in the northeast Pacific Ocean, an area roughly 500 km by 1,000 km in size. Approximately 30 experimental sites will be established at nodes along the cable and will be instrumented to interact with physical, chemical, and biological phenomena that operate within the ocean and in the underlying crust across multiple scales of space and time. The network will provide real-time command-and-control capabilities to shore-based users. Remotely operated and autonomous undersea vehicles will reside at depth, recharge at nodes, and respond to events such as submarine volcanic eruptions. The NEPTUNE infrastructure will have an expected lifetime of more than 30 years.

The NEPTUNE construction partners are the University of Washington (UW), the University of Victoria (UVic), the Woods Hole Oceanographic Institution (WHOI), Canada's Institute for Pacific Ocean Science and Technology (IPOST), Caltech's Jet Propulsion Laboratory (JPL), and the Monterey Bay Aquarium Research Institute (MBARI).



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*“The lack of extensive, more-or-less continuous time-series measurements in the oceans is probably one of the most serious impediments to understanding of long-term trends and cyclic changes in the oceans and in global climate, as well as episodic events such as major earthquakes, volcanic eruptions or submarine landslides. We recommend strong support for the development, deployment and maintenance of long-term observing systems.”*

Ocean Sciences at the New Millennium, 2001

## Guest Editorial

*This is the first in a series of Guest Editorials to be published in the NEPTUNE Update. We invite readers to submit their candid views of cabled observatory efforts. Please submit editorials to Nancy Penrose, Update editor, <penrose@ocean.washington.edu>. The editor reserves the right to modify submissions for the purposes of clarity and effective communication with a broad audience.*

I often wonder what masochistic tendency drove us to become marine geologists, geophysicists, or ocean engineers. Clearly we are compelled by a passion to understand the Earth, but why, then, did we choose to focus our energy on that part of the Earth's surface that is so far removed from our sight and grasp. Is it that we believe we are fundamentally brighter than our terrestrially oriented colleagues who need only a sturdy pair of boots and a rock hammer to collect their samples – or perhaps we seek to hide our ignorance and insecurity under the protective cover of the water column. Whatever the motivation, the reality is that we have chosen the path less traveled – the challenging task of trying to make measurements, extract information, and understand processes hidden under the veil of thousands of meters of water. It is precisely this challenge, and the vast expanse of our “field area,” that has made us so dependent on technology for the advancement of our science. From the lead-line to the single beam echo sounder to the multibeam sounder – from the tallow on the bottom of the lead line to the pipe dredge to scientific ocean drilling – from the early days of one pound charges and a single receiver to modern seismic arrays and multichannel receivers – technical innovations have revolutionized our perception of the seafloor and our understanding of Earth processes.

Technical innovations come in both small increments and great leaps. Building on years of incremental development, we are now poised to take a great leap – to bring together a range of technologies from disparate fields and establish, for the first time, a network of long-term observatories with the bandwidth and power needed to support a wide array of experiments and provide an unprecedented observational presence over vast areas of the seafloor. The timeliness of this technological leap is being recognized worldwide; many nations are planning ocean observatory programs. The U.S./Canadian NEPTUNE initiative to instrument the Juan de Fuca Plate is blazing the path with scientific and technical planning well ahead of most other initiatives. Given its proximity and the range of oceanographic, geologic, and tectonic processes represented in a relatively small area, the Juan de Fuca plate is an ideal candidate for such an effort. The scientific programs already planned for NEPTUNE are exciting, but what I find even more exciting is the enabling technology that NEPTUNE and other observatories will bring for science not yet planned or conceived.

The NEPTUNE propagandists often refer to NEPTUNE as a “fiber-optic telescope to inner-space.” I look at it slightly differently. To me the analogy is the space station – the infrastructure that will allow us to deploy a range of experiments, planned and not yet imagined, for years to come. Those of us old enough to remember the world before the Internet have seen the remarkable changes brought about by the Internet infrastructure. With NEPTUNE and other observatories like it, we are, in essence, bringing this connectivity (and lots of power) to the seafloor and, in doing so, are establishing a framework for a fundamentally new way of doing deep-sea science.

And so once again technology is driving us ahead as we gradually lift the veil. We now have the ability to completely map and image the morphology of an entire plate with unprecedented detail. NEPTUNE provides the opportunity to add a temporal dimension to this spatial context. It will not be easy. There will inevitably be technological, financial, and perhaps even political challenges. One of our biggest challenges may be our ability to adjust to the new ways of thinking required by the new opportunities presented. As I watch my own children and their friends use the Internet in ways I never imagined, I realize that we will not be the ones who will take full advantage of what NEPTUNE and the other observatories have to offer. It will be the next generations of marine scientists who will be so much more attuned to thinking about 4-dimensional ocean studies. It is our job to make sure they have the opportunity – we owe it to them and to our science.

Larry Mayer  
Director, Center for Coastal and Ocean Mapping  
Chase Ocean Engineering Lab  
University of New Hampshire

## Ocean Observatories

Ocean observatories are being developed at a variety of scales by nations that include the U.S., Canada, the United Kingdom, Japan, Germany, and the European Union. Within Canada, the Canada Foundation for Innovation has made a major financial commitment, subject to the meeting of specific conditions, to the NEPTUNE Canada efforts. Within the U.S., the National Science Foundation's Ocean Observatories Initiative (OOI) was developed to take advantage of

the recent convergence of basic research, societal needs, and accelerating advances in technical capabilities. The OOI has three components: an expanded network of coastal observatories, several deep-sea observatories based around a system of buoys that will contribute to global studies, and a regional-scale observatory. NEPTUNE anticipates proposing to become a regional-scale component of the OOI.

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## NEPTUNE Characteristics

*These characteristics are design goals, subject to modification from science input*

- 3000 km of cable in the Northeast Pacific, largely along the margins of the Juan de Fuca plate, connected to two shore stations likely to be located in Oregon and British Columbia
- 30-year infrastructure lifetime
- Approximately 30 nodes spaced at roughly 100-km intervals; "extension cords" to permit location of instruments 50 km or more from a node; the basic backbone will be expandable
- Scientific instruments connected to system using standard "plug and play" interface; interface will be user friendly, with each device having its own IP address for easy access and control
- Average of 3 kW and peak of 10 kW power available for scientific instrumentation at any single node (48 and 400V); greater than 100 kW system-wide total power available
- 10/100 Mb/s Ethernet user connection; up to 1 Gb/s data rate available at any single node; 10 Gb/s maximum aggregate data transmission rate
- Reliability design target of 95% probability that entire infrastructure will be available to science experiments 95% of time
- Cable breakage or catastrophic failure at any single point will not shut down system
- Data management and archiving system handles incoming data totaling approximately 1 petabyte ( $\sim 10^{15}$  bytes) per annum at data rate of  $\sim 260$  mbits/sec (after 5 years of operations); archives data; makes data accessible via the Internet; uses metadata (e.g., location, calibration, and equipment description) in relational databases to enable data mining; architecture designed to accommodate anticipated growth in data
- Time stamps accurate to 1 microsecond
- Scientific instruments connect to nodes via wet-mateable connectors; installation, recovery, and maintenance using standard deep-sea research vessels and ROVs; autonomous and tethered vehicles and nodes similarly serviceable

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## Scientific Opportunities with NEPTUNE

NEPTUNE is intended to serve as a resource for the entire oceanographic community. By necessity, a smaller number of organizations will install the infrastructure of the observatory, but the user base is intended to encompass all interested national and international researchers. In addition, the technologies developed for NEPTUNE will be available for cabled observatories elsewhere.

NEPTUNE will enable a new approach to studies within a wide spectrum of scientific fields, including those listed to the right. Science white papers and reports on most of these topics were produced as part of the feasibility studies processes and are available on the U.S. NEPTUNE and NEPTUNE Canada web sites.

- Water column processes
- Cross margin particulate flux
- Seismology and geodynamics
- Hydrogeology and biogeochemistry
- Subduction zone processes
- Fisheries and marine mammals
- Ridge crest processes
- Deep sea ecology
- Carbon cycling in the oceans
- Global climate change

If you are interested in participating in NEPTUNE science workshops, please provide your contact information via [www.neptune.washington.edu](http://www.neptune.washington.edu). A variety of workshops are being planned including regional and topical workshops for NEPTUNE and a major ocean community workshop on science and education planning for global, regional, and coastal observatories, September 15–19, 2003. Details of these meetings will be posted on the NEPTUNE web sites and distributed to the NEPTUNE mailing list.

### Education and Outreach

NEPTUNE's educational strengths closely parallel its scientific motivations: the same Internet technology that will offer scientists continuous, long-term access to the



study area will offer 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. Learners of all ages will explore worlds on, above, and below the seafloor, designing and carrying out experiments.

NEPTUNE is in the process of establishing partnerships with the formal and informal science education communities; three workshops have already been held and reports are posted at [www.neptune.washington.edu](http://www.neptune.washington.edu). 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 educational curricula and content to match local educational interests and needs, including alignments with math and science education standards.

### Engineering Systems

WHOI has taken prime responsibility for the design of the communications system with funding from NSF and matching funds from WHOI and industry. Power-supply design is being undertaken by the UW and JPL, primarily with funds from NSF. The international review panel convened in June 2002 for the NEPTUNE power system concept design review approved the prototype, a parallel power system utilizing flexible DC/DC power supplies that automatically adjust to changing load conditions with a multi-layered, reliable protection system.

A multidisciplinary, multi-institutional system engineering team oversees the engineering studies crucial to design and system integration. This team has undertaken a study to consider an alternate communications system based on an all optical backbone, i.e., using standard telecommunications repeaters and optical add/drop modules at each node. This study will be completed in winter 2003. A concept design review of the communications system will follow the completion of the alternate system study. A system-wide concept design review is scheduled for mid 2003.

### Test Beds

#### *Deep-Water Test Bed: MARS*

The Monterey Accelerated Research System (MARS) project will install an advanced cabled observatory in Monterey Bay to serve as an engineering and science test bed for a regional ocean observatory such as NEPTUNE. MARS will be located offshore of the Monterey Bay Aquarium Research Institute (MBARI) and will be open to the full range of users within the scientific and educational communities. Funding for MARS is provided by the National Science Foundation and the Packard Foundation.

Science experiments on MARS will take advantage of several oceanographic features that are particularly well represented in Monterey Bay. For example, the Monterey Canyon is a large and active submarine canyon that is a major conduit for the transport of sediment and organic carbon into the deep sea. As is typical of such undersea transport events, however, they are episodic, ephemeral, and unpredictable—they cannot be forecasted and little is known about the actual transport processes. The MARS cabled observatory will enable monitoring of conditions and events in real time. Installation is scheduled for 2005.

#### *Shallow-Water Test Bed: VENUS*

Canada's Victoria Experimental Network Under the Sea (VENUS) is a shallow-water test bed. The three cable sites will be into the anoxic basin of Saanich Inlet, across the Strait of Georgia with a spur along part of the Fraser River

delta front, and across the Strait of Juan de Fuca. Funding for VENUS has come from the Canada Foundation for Innovation, the British Columbia Knowledge Development Fund, and from a variety of industry and government partners.

Sensor development and testing for VENUS will allow scientific users and instrument developers to gain experience with the NEPTUNE technology: VENUS will use subsets of the NEPTUNE system, including the NEPTUNE data management and archiving system (DMAS) under development by the Herzberg Institute of Astrophysics (National Research Council). VENUS organizers hope to see the first data in 2004, with final installation anticipated in 2006.

### Current Efforts and Project Timeline

NEPTUNE is a four-phase program: Phase 1 (1999-2000) included the work done for the feasibility studies, science reports, and white papers; Phase 2 (2000-2005), Development, includes all tasks from the end of the feasibility studies through test bed design, development, and installation, to the point where bids for the entire system are issued and system design is complete; Phase 3 (2004-2008), Installation, includes procurement and installation of the cables, nodes, and the first community experiments; Phase 4 (2007-2036) is the operations phase.

Current efforts are focused on securing funding, designing the network, science planning, developing the education and outreach plan, and planning for installation. Science planning is focusing on developing integrated science experiments for the VENUS and MARS test beds and on building communities of scientists who will be ready to use NEPTUNE when the full network comes online. The continued iterative interaction between science planning groups and the engineering groups will be especially important in refining the network's technical requirements and ensuring that the science is being served by the technology.

Plans call for start-up logistical support to be provided in the coming year for working groups of scientists interested in deploying "community" experiments on NEPTUNE. Community experiments are those which, because of their scope, duration, and importance to multiple disciplines or programs, cannot be supported by one or a small group of principal investigators.

### Funding: Past, Present, and Future

Aspects of NEPTUNE have already received substantial funding through peer-reviewed programs. Funding

for the NEPTUNE Canada Feasibility Study and related science workshop was provided through IPOST. The National Oceanographic Partnership Program (NOPP) and the NEPTUNE partners funded the U.S. NEPTUNE feasibility study. NOPP funds are supporting system engineering, science planning, and the program office, which is based at the UW. NSF has funded generic design studies for power and communications systems for cabled observatories. NEPTUNE is adopting these designs for its engineering standards. Test beds in Canada and the U.S. have been funded by the Canada Foundation for Innovation (CFI) and NSF, respectively.

#### *NEPTUNE Executive Team Members*

*Chair: John R. Delaney,*

*University of Washington*

*Vice Chair: John Madden, Institute of Pacific*

*Ocean Science and Technology*

*Christopher Barnes, University of Victoria*

*Patricia Beauchamp, Caltech Jet Propulsion*

*Laboratory*

*Alan Chave, Woods Hole Oceanographic*

*Institution*

*Marcia McNutt, Monterey Bay Aquarium*

*Research Institute*

A large grant has been awarded to NEPTUNE Canada, subject to meeting specific conditions, from the Canada Foundation for Innovation's International Access program. These funds and matching funds will be applied to constructing the portion of the NEPTUNE network that lies within Canadian waters.

NEPTUNE partners have continued to provide support, and private funding has been received from the W.M. Keck Foundation, the David and Lucile Packard Foundation, and from individuals.

Raising funds for NEPTUNE is a continuing high priority effort within the Project. NEPTUNE partners plan to respond to the request for proposals for OOI components. Efforts also extend beyond the traditional sources of Federal monies for science and engineering research projects. Support from private foundations, corporations, and individuals is being sought to contribute vital funding to NEPTUNE components such as education and outreach.

*“Ocean scientists are on the threshold of a scientific revolution enabled by rapidly emerging technologies. For the first time, the ability to enter, sense, and interact with the total ocean environment is within our grasp. We are expanding beyond short-term expeditions using research vessels. We are moving toward a long-term presence on, above, and below a section of seafloor as large as a tectonic plate.”*

U.S. NEPTUNE Feasibility Study, 2000

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## **Chronology of NEPTUNE and Related Projects**

### **2002**

- Sept** National Science Foundation (NSF) funds the Monterey Accelerated Research System (MARS) cabled-observatory test bed in Monterey Bay
- Aug** Province of British Columbia grants matching funds to Victoria Experimental Network Under the Sea (VENUS) test bed in Straits of Georgia and Juan de Fuca
- June** Roughly half of Canadian portion of NEPTUNE costs funded by Canada Foundation for Innovation (CFI), contingent (among other conditions) on matching funds from other Canadian sources
- May** Memorandum of Understanding and Rules of Operation for NEPTUNE Affiliation approved by NEPTUNE partners
- Mar** National Oceanographic Partnership Program (NOPP) funds NEPTUNE system engineering, program office, and science planning
- Feb** NEPTUNE cable-route desktop study completed
- Feb** VENUS funded by CFI, contingent on matching funds

### **2001**

- Dec** University of Victoria joins NEPTUNE partnership
- July** W.M. Keck Foundation grants award for proto-NEPTUNE experiment
- June** NSF funds development of cabled-observatory power system

### **2000**

- Oct** NEPTUNE Canada feasibility study completed and published
- Sept** Meeting at Emerald Lake, British Columbia – NEPTUNE organizational structure established; Executive Team formed of partner representatives: University of Washington, Woods Hole Oceanographic Institution, Monterey Bay Aquarium Research Institute, Institute for Pacific Ocean Science and Technology (Canada), and Caltech’s Jet Propulsion Laboratory
- June** U.S. NEPTUNE feasibility study completed and published
- June** NSF funds development of cabled-observatory data communications system

### **1999**

- June** Canada’s Institute for Pacific Ocean Science and Technology invited by U.S. to undertake feasibility study of Canadian partnership with U.S. NEPTUNE

### **1998**

- June** NOPP funds U.S. NEPTUNE feasibility study

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**For further information about NEPTUNE  
contact Nancy Penrose, Communications Coordinator,  
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