UW 2005 NEPTUNE Regional Cabled Ocean Observatory Workshop

November 15-16, 2005
The University of Washington Club
Meeting Report

On-line version available at
http://www.neptune.washington.edu/workshops/index.jsp?keywords=UW2005&title=UW%202005

Table of Contents

1. Introduction

Scientific, engineering and educational activities within the ocean sciences are undergoing a major transformation. The traditional expeditionary approaches to ocean studies are being increasingly complemented by the deployment of highly capable long-term sensor networks that are designed to monitor ocean processes over a wide range of spatial and temporal scales. One of the most ambitious examples of this new approach is the NEPTUNE regional cabled ocean observatory that is being installed off the Pacific Northwest coast on the Juan de Fuca tectonic plate (http://www.neptune.washington.edu). The NEPTUNE system will comprise up to 3000-km of fiber-optic/power cable connecting 30 nodes with heavily instrumented distributed sensor networks, providing unprecedented power and bandwidth to the seafloor.

The northern third of the NEPTUNE network is scheduled for installation by NEPTUNE Canada in 2007-8 (http://www.neptunecanada.ca); the U.S. portion is being organized within the framework of the NSF's Ocean Research Interactive Observatory Networks (ORION) program (http://www.orionprogram.org) and the $310 million Ocean Observatories Initiative (OOI) within the NSF Major Research Equipment and Facilities Construction account. Funding for the OOI is slated to begin in FY 2007.

Since the late 1990s, the University of Washington has played a key role in the development of the regional cabled observatory concept and is ideally situated both intellectually and geographically to contribute extensively to all aspects of its implementation. The UW has led the international consortium developing NEPTUNE and, in the future, seeks to add additional partner institutions and play a major role in the installation and operation of NEPTUNE.

In addition to extensive planning for science experiments, NEPTUNE requires many other long-lead-time, continuing activities, including the development of (1) a wide range of new sensors and sensor network technologies; (2) the shore-side infrastructure and techniques to manage and exploit real-time multidisciplinary data streams; (3) innovative educational and outreach programs, including interdisciplinary efforts among the sciences, humanities, social sciences, and the arts; and (4) law and policy strategies related to implementation and operation of NEPTUNE.

In November 2005, a two-day open workshop aimed primarily at members of the University of Washington community was held at the University of Washington Club to explore opportunities within the NEPTUNE regional cabled ocean observatory. The goals of the meeting were the following:

- Update UW community on the status of NEPTUNE.
- Form expert groups to explore and identify the full-range of opportunities offered by NEPTUNE.
- Initiate long-lead-time activities to support cutting-edge science, engineering, and education/outreach programs.
- Encourage and support UW groups to submit NEPTUNE-related proposals.

About 70 people participated in the meeting and about 20 more expressed interest but were unable to attend. This report summarizes the proceedings and the plans for meeting follow up.

The on-line version of the report is available at http://www.neptune.washington.edu/workshops/index.jsp?keywords=UW2005&title=UW%202005 and includes links to many of the presentations and breakout group notes.

2. Presentations

The agenda for the meeting can be found in Appendix A. Mary Lidstrom, UW Vice Provost for Research, made some introductory remarks to open the meeting. She noted the administration's support for NEPTUNE and the Program's potential impact on research and educational activities within the University. She expressed the hope that the meeting would help catalyze long lead-time activities across campus.

Overview of NEPTUNE. The first talk was an "Overview of NEPTUNE" presented by John Delaney, Director of the NEPTUNE Program and a UW Professor of Oceanography. After a brief description of the extent and operational goals of the NEPTUNE network, the remainder of the talk was divided into two parts. The first dealt with the scientific motivation for NEPTUNE and related observatories and presented the vision for what NEPTUNE can accomplish over the network's 30-year lifetime. Satellites can monitor long-term processes at the surface of the oceans such as El Niño/Southern Oscillation (ENSO), but an interactive observational presence within the oceans will be necessary to understand many processes occurring within the water column and beneath the seafloor. The oceans represent a major sink for CO_2 and studies of carbon cycling in the oceans are important components of climate change research. To illustrate the potential capabilities of NEPTUNE, John Delaney described the use of autonomous underwater vehicles and genomic sensors within the NEPTUNE network to monitor a microbial bloom within its physical oceanographic framework.

NEPTUNE will also play an important role in understanding a variety of subseafloor processes, including plate-tectonic processes that lead to a major seismic hazard along Cascadia subduction zone and processes that form gas hydrate deposits on the continental shelf and slope. NEPTUNE will play a critical role in understanding how seafloor volcanoes support chemosynthetic life both above and below the seafloor, and their potential role in the early evolution of life on Earth and other planetary bodies. John described aspects of the work he has undertaken with Deborah Kelley and other colleagues at the UW to study the black smoker hydrothermal vents at the Endeavour and how NEPTUNE could expand this research.

The second part of this talk covered the history and current status of the NEPTUNE program. NEPTUNE Canada has received $62.4M from the Canada Foundation for Innovation and the British Columbia Knowledge Development Fund and will install the northern third of the network in 2007/8. The US component of the infrastructure will be supported by the regional cabled observatory component of the NSF Ocean Observatories Initiative (OOI), which is overseen by the Ocean Research Interactive Observatory Networks (ORION) program. The OOI has been recommended for funding by NSF's Major Research Equipment and Facilities Construction account. Over the course of six years, the regional cabled observatory on the Juan de Fuca plate (likely NEPTUNE) is slated to receive about half the ~$300M that has been requested to acquire facilities that will further coastal, regional and global oceanographic observatory studies. The OOI has cleared all the hurdles for funding short of appropriation and

the first year of funding forms part of President Bush's FY2007 budget request to Congress. John noted that the MREFC account is likely to fund only acquisition of the cabled observatory backbone infrastructure. It is important to begin aggressive efforts to secure funding to operate the network and deploy the full array of experiments proposed for NEPTUNE. The UW has played the central role in the development of the NEPTUNE concept and will compete aggressively to lead a consortium to build and operate the US portion of the system. The University's intellectual breadth and geographic proximity make the UW ideally suited to lead the NEPTUNE Program.

Ecogenomic Sensors. Ginger Armbrust is a UW Associate Professor in the School of Oceanography and Deirdre Meldrum is a UW Professor of Electrical Engineering and they gave a joint presentation on "Ecogenomic Sensors". Ginger Armbrust spoke first. Ecogenomic sensors are biological sensors that detect which microorganisms are present and what they are doing. The oceans are currently a net sink in the global carbon cycle and it is important to understand the role of marine microorganisms. Efforts are presently under way to characterize and catalog the genes of communities of marine microorganisms. Although some capabilities already exist to characterize the genetic makeup and functions of microorganisms in real time, many techniques are still in development and need transitioning from the lab to real time sensors. The technology is evolving very rapidly towards smaller, faster, and more accurate techniques and within a decade it will likely be feasible to analyze single cells and sequence a genome for ~$1000.

Deirdre Meldrum introduced the audience to the Microscale Life Sciences Center (MLSC), an NIH National Human Genome Research Institute (NHGRI) Center of Excellence in Genomic Science. The goal of MLSC is to develop microscale modules to measure multiple parameters in living cells in real time in order to correlate cellular events with genomic information. One example of the work in MLSC is the development of a technique to measure the oxygen consumption of individual cells using a microwell sensor array chip. Deidre Meldrum concluded the talk by describing the concept of sensorbot swarms that would be hosted by a seafloor observatory and would make simultaneous water column measurements in time and controlled space.

MARS. Keith Raybould is the Chief Operations Officer at Monterey Bay Aquarium Research Institute and the Project Manager for the installation of the Monterey Accelerated Research System (MARS) cabled observatory. MARS will serve as a test-bed for the NEPTUNE regional cabled observatory. Keith presented an "Overview of MARS". The system comprises a single cabled seafloor node that will be located 50 km offshore in Monterey Bay and that will provide 100 Mbit/s bi-directional telemetry and a total of 10 kW of power to 8 science ports. It can be expanded in the future. The seafloor node is designed to be trawl resistant and its development has been somewhat delayed and is expected to be installed in Fall 2006. The permitting process has been quite difficult , requiring interactions with multiple agencies and interest groups. The cable landing will require horizontal directional drilling over a distance ~1 mile. The cable and node will be installed by Alcatel/MariPro in 2006. Keith concluded by listing the lessons learned from the MARS system. Disciplined systems engineering is critical. When work is apportioned between institutions, the interfaces must be clearly defined, good mechanisms for quality control must be established, and there must be frequent face-to-face

contact between participants. Some costs in the MARS project were very hard to control because the system that had not been fully specified at the time the commercial contracts were signed. The lessons learned from MARS will contribute substantially to the successful implementation of the regional cabled observatory.

Engineering of Ocean Observatories. Gary Harkins, Department Head of Electronic Systems at the UW Applied Physics Laboratory, and Bruce Howe, Principal Oceanographer at APL, talked about NEPTUNE and the "Engineering of Ocean Observatories". Ocean observatories must supply the continuous power, communications, timing and navigation necessary to support long-term sensor networks. The best examples of the approach necessary for regional observatories are given by NEPTUNE Canada and MARS. Cabled observatories can be subdivided into the 1) backbone infrastructure comprising the primary junction boxes/primary nodes, main cable, and coastal shore station, and 2) sensor networks that connect sensors via tertiary and secondary nodes to the primary nodes. For NEPTUNE, most of the initial infrastructure costs will be associated with the backbone, but over its lifetime the costs of sensor networks and operations and maintenance will dominate. Some critical elements of the backbone still require further development including the observatory control system, "T" junctions, and extension cables used in sensor networks. It is important to optimize the design of the backbone to reduce operations and maintenance costs and thus minimize the total cost of the system. Gary and Bruce discussed several examples of sensor network infrastructure including a ridge observatory at Axial Volcano and a profiling mooring. They discussed the challenges of acoustic navigation and positioning, and some potential applications of acoustic imaging. There is a critical need to develop reliable long-term sensors for many scientific applications, and sensor designs must account for calibration and biofouling. The talk concluded by highlighting some of the long-term engineering challenges of building effective sensor networks.

Cyberinfrastructure for Ocean Cabled Observatories. Larry Smarr is the Director of the California Institute for Telecommunications and Information Technology and the Harry E. Gruber Professor of Computer Science and Engineering at the University of California, San Diego (UCSD). Along with John Orcutt at UCSD, John Delaney and Ed Lazowska at the UW, and Mark Abbott at Oregon State University, Smarr is a principal investigator on the LOOKING (Laboratory for the Ocean Observatory Knowledge Integration Grid) Project, an NSF-funded effort to develop a prototype cyberinfrastructure for the ORION Program. His presentation was entitled "Cyberinfrastructure for Ocean Cabled Observatories". The underlying message of the talk was that ongoing increases in computer network throughput will radically alter the nature of global scientific collaboration. He described the architecture for data acquisition from complex seafloor sensor networks and the CalIT^2 Direct Access Core architecture for supporting access and *in situ* analysis of massive instrumental datasets. Wavelength division multiplexing is leading to dramatic increases in the throughput of optical networks. The National Lambda Rail (NLR) and TeraGrid networks provide multiple 10 Gbit/s lambdas (wavelengths) and have enabled demonstrations such as remote brain imaging using real time HDTV image steering and a live HDTV presentations across the Pacific Ocean. Tiled walls of high-resolution monitors allow streaming of extremely high-resolution video, portions of which can be captured and transmitted to web browsers over the National Lambda Rail. Scientific interactions with large databases will be revolutionized by combining telepresence with remote interactive analysis of data over the NLR. Throughout the talk Larry Smarr repeatedly emphasized that the

cyberinfrastucture envisioned and being developed by NEPTUNE and the ORION program is well in advance of most other scientific fields.

Learning Opportunities Through NEPTUNE. Véronique Robigou is a research scientist at the UW School of Oceanography and the Director of the NSF-funded REVEL project and COSEE – Ocean Learning Communities Center. Philip Bell is a UW Associate Professor of cognition and technology who focuses most of his research on issues of science education in the College of Education. He directs the efforts of the "Everyday science and technology" research group and is one of the co-Leads on the LIFE Center (Learning in Informal and Formal Environments Center). Their talk was entitled "Learning Opportunities Through NEPTUNE." NEPTUNE research will be conducted in an environment that is engaging to a diverse community of learners.

Véronique's presentation highlighted two types of programs that could provide collaborative opportunities with the NEPTUNE community. The University of Washington has just been awarded a grant by the National Science Foundation to establish a thematic Center for Ocean Sciences Education Excellence (COSEE). This NSF-sponsored initiative is building a national network of centers that provide a catalytic environment for partnerships between ocean scientists and educators by fostering communication and coordination between these two groups. The centers also promote ocean sciences education as a charismatic interdisciplinary tool for improving ocean literacy. The COSEE – Ocean Learning Communities, a collaborative effort led by the University of Washington, is the first center to involve partnerships with industry. The center will initially focus on using Oceans and Human Health to develop approaches to better understand the process of creating effective collaborations involving non-traditional stakeholders. Once these approaches are tested, the center will focus on other scientific themes important to ocean literacy. Ocean observatory science issues will likely be among them.

The REVEL (Research and Education: Volcanoes, Exploration and Life) Program is a personal and professional development program for K-12 teachers who are eager to bring ocean science research into their classrooms. The REVEL teachers participate as members of the scientific party in a seagoing research cruise where they are fully immersed in the research process. They attend pre- and post-cruise workshops, organize a lecture series and web site while at sea, and are supported to incorporate their experience into classroom activities and other outreach activities. REVEL-type experiences have the potential to incorporate teachers and their students as active participants in and contributors to NEPTUNE scientific studies.

Philip Bell started his presentation by referencing a new report from the National Academy of Sciences entitled "America's Lab Report: Investigations in High School Science." Science labs in American schools are often focused only on the prescriptive confirmation of established scientific concepts as opposed to providing a context for inquiry and learning. Instead science labs should be an environment in which students undertake a simplified "knowledge discovery" process. High-quality, publicly available data from distributed sensor networks such as the NEPTUNE cabled observatory can be productively analyzed by students if learner-centered design is used. Two examples of programs that seek to do this are the Geographic Data in Education (GEODE) Initiative and the Web-based Inquiry Science (WISE) environment (http://wise.berkeley.edu). There are several consensus reports on what we know about learning

and teaching, but additional research is required on the educational uses of large data sets. The Learning in Informal and Formal Environments (LIFE) Center (http://life-slc.org) was one of the first four Science of Learning Centers to be funded by NSF. The Center's purpose is to create and test interdisciplinary theories of learning for infants, children, and adults across informal and formal settings in order to explore the multiple ways in which learning and transfer occur.

Regional Policy Context and Opportunities for NEPTUNE. Marc Hershman is a UW Professor in the School of Marine Affairs and a member of the U.S. Commission on Ocean Policy (USCOP). His presentation was entitled "Regional Policy Context and Opportunities for NEPTUNE." The USCOP preliminary report recommends the establishment of regional ocean information programs "to improve coordination and set regional priorities for research, data collection, science-based information products, and outreach activities in support of improved ocean and coastal management." USCOP has overseen the formation of an Interagency Committee On Ocean Science and Resource Management Integration, a National Science and Technology Council Joint Subcommittee on Ocean Science and Technology (JSOST), and a Subcommittee on Integrated Management of Ocean Resources (SIMOR). Each west coast state has also established bodies to consider ocean policy and protection issues. By the end of 2006, JSOST will develop a national marine research plan with input from SIMOR, and SIMOR will establish a joint federal state task team. The west coast submission for the research plan includes fisheries conservation, nearshore ecology, anthropogenic effects on coastal ecosystems, coastal hazards and shoreline processes, regional ocean processes and climate change, and marine science outreach. NEPTUNE should engage state and local political interests to avoid the fear of the unknown and define the potential benefits including informational products that are relevant to management, economic benefits and educational opportunities. There may be opportunities for collaboration such as the Washington State Life Sciences Discovery Fund.

Citizens (Governance), Science and Policy. Tom Leschine is the Director of the School of Marine Affairs and spoke on "Citizens (Governance), Science and Policy." He started his talk by noting that there are a number of factors that influence the use of scientific information in policy including the utility of the information, the forum in which its pertinence is deliberated, the capacity of the governance system to assimilate information and economic value of incorporating information. A recent technical report published by the Woods Hole Oceanographic Institution estimated the regional benefit of ocean observing systems and concluded that the largest benefits would accrue to recreational boaters, fishers and beachgoers because of the large number of participants. The goal of NEPTUNE should be to provide an integrated assessment of the reciprocal impacts and feedbacks between natural and human social systems with the management goal of promoting resilience in coupled human-environmental systems. The interactions between humans and natural systems will be non-linear and it will be necessary to develop the capacity for scale translation so that changes detected at broad spatial and temporal scales can be translated to local implications that are relevant to future managers.

VISIONS05 Cruise and the Challenges of Work in Extreme Environments. Deborah Kelley is an Associate Professor in the School of Oceanography and opened the second morning with a talk on "VISIONS05 Cruise and the Challenges of Work in Extreme Environments." Deborah and John Delaney were co-chief scientists on VISIONS'05 cruise (www.visions05.washington.edu), which sailed in September of this year to the Endeavour

hydrothermal vents. Deborah described the scientific research that was being conducted at this site to understand the linkages between physical, chemical and biological processes at mid-ocean ridge hydrothermal systems and the role of submarine volcanoes in supporting life. With funding from the W. M. Keck Foundation, the University of Washington is leading a prototype NEPTUNE experiment to investigate the linkages between geological deformation, fluids fluxes through the seafloor, and microbial productivity at oceanic plate boundaries. The VISIONS‘05 cruise was the first to send real-time high-definition video images of the seafloor via satellite and the spectacular footage of the seafloor vents was broadcast live by the ResearchChannel. The VISIONS’05 cruise demonstrated the potential media impact of real-time data streams from the NEPTUNE system.

NEPTUNE Canada. Brian Bornhold is a Professor at the University of Victoria and a co-chief scientist of the NEPTUNE Canada project, the topic of his talk. After a brief general introduction to the NEPTUNE concept he showed the current plans for the NEPTUNE Phase 1 (NEPTUNE Canada) backbone and listed the NEPTUNE Canada partner institutions and members of the project team. NEPTUNE Canada has chosen to focus on five research themes: plate tectonic processes and earthquake dynamics; dynamic processes of fluid fluxes and gas hydrates in the seabed; regional oceanic/climate dynamics and effects on the marine biota; deep-sea ecosystem dynamics; and engineering and computational research. He described the acquisition plan for both the cable network infrastructure and scientific instrumentation. The backbone and some instrumentation will be installed in 2007 with the remainder of the instrumentation installed in 2008. At present the project has received $62.4M Canadian from the Canada Foundation for Innovation and the British Columbia Knowledge Development Fund. This is sufficient to install a system with two scientific nodes at Endeavour and Barkley Canyon and two breakout points at the Ocean Drilling Project Holes 889 and 1027 where scientific nodes could be easily installed in the future when funding is available. A pending proposal for an additional $20M Canadian would substantially expand the scope of the initial science experiments.

Educational Opportunities. Patricia Wasley is Dean of the UW College of Education. She spoke briefly and then answered questions about the role the College of Education can play in NEPTUNE. In terms of the number of teachers trained, the UW ranks behind other institutions in the state such as Western Washington University. However, by taking advantage of our status as a major research institution and targeting the science coordinators and other key personnel in each school district, the UW could have a major impact on science education in the state. The College of Education is currently searching for a director for the UW Institute for Science and Mathematics Education. The broad goal of the institute is to advance science, mathematics, and technology education at the pre-school to graduate level within the University, the state, and nationally. The NEPTUNE program can be an important part of this process.

3. Lightning Introductions

On each day, time was set aside to allow meeting participants a few minutes to introduce their research interests in lightning presentations. Twenty-five participants chose to participate and the following table lists their area of interests and includes links to presentations:

Name	Department	Area of Interest
Atlas, Les	EE	Sensor Signal Analysis and Classification.
Barker, Gail		Acoustics
Beauchamp, Dave	Fish	Effects of climate on salmon and other epipelagic species
Bordia, Raj	Mat Sci	Underwater power sources and the protection of sensors in the ocean environment
Burnett, David	EE	Sensor system engineering
Chen, Antao	APL	Micro resonators on side-polished fiber as a potential fiber optic sensor platform
Gallucci, Vince	Fish	Tracking mature sixgill sharks
Hannaford, Blake	EE	Biorobotics
Haugan, Peter	APL visiting scholar	European seafloor observatories, climate change
Howe, Bruce	APL	Physical and acoustical oceanography, sensor networks
Jaruwatanadilok, Sermsak	EE	Electromagnetic remote sensing
Kelley, Deb	Ocean	Seafloor hydrothermal systems, life in extreme conditions
Kumpf, John	Ocean	Engineering services in the School of Oceanography
Lilley, Marvin	Ocean	Long-term, in-situ chemical measurements in hydrothermal systems
Lih, Lin	EE	Quantum dot integrated circuits, opto-plasmonic tweezers, optical characterization of bioluminescence.
Marquardt, Brian	Chem	Submersible optical instrumentation and sensors
Moore, Sue	APL	Whale acoustics
Noble, Peter	CEE	Microbiology, bioinformatics
Parsons, Jeff	Ocean	Sediment gravity flows
Penrose, Nancy	Ocean	Outreach: Communicating with NEPTUNE's Many Audiences
Strunz, Kai	EE	Power circuits and systems
Stuetzle, Werner	Stats	Interactive data visualization, 3-D photography, machine learning
Thompson, Luanne	Ocean	Physical oceanographic modeling
Trabant, Brad	IRIS	IRIS (Incorporate Research Institutions for Seismology) data management
Vidale, John	UCLA	Seismology, Pacific Northwest Seismic Network
Wilson, Denise	EE	Distributed Microsystems

4. Breakout Groups

The meeting included two breakout sessions in which the participants subdivided into four groups with interest in seafloor science and sensors; water column science and sensors; wet-plant infrastructure design challenges; and education and outreach. The groups were given the following list of questions and task to help guide their deliberations.

- *What are the opportunities offered by NEPTUNE?*
- *Identify those that require long-lead time planning and preparation*
- *Identify those that would benefit new/enhanced cross-disciplinary collaborations*
- *What groups in the UW should be involved and what can they contribute?*
- *How do we foster NEPTUNE "expert groups" within the UW?*
- *How can these groups work effectively with other institutions?*
- *What are the potential funding sources for different activities?*
- *What are the specific plans for moving forward in each field?*
- *Are there proposal ideas with identified proponents that can move forward immediately?*

Seafloor Science and Sensors (Group notes)
Discussion Leaders: David Butterfield and Marvin Lilley

NEPTUNE will provide an opportunity to conduct long-term observational experiments on the seafloor of a type that are not feasible using standalone instruments. The power available on NEPTUNE will facilitate the deployment of power-hungry sensors such as mass spectrometers, gas chromatographs, laser spectrographs, and emerging genomic sensors. The connectivity of the NEPTUNE system will allow the integration of data from a network of offshore seismometers into the day-to-day operations of the Pacific Northwest Seismic Network. Both human and automatic intervention will be possible in response to events detected on multiple sensors. For instance the seismicity associated with the onset of a volcanic eruption on the Juan de Fuca Ridge might lead a scientist to increase instruments sampling rates on hydrothermal and geodetic sensors, collect vent fluid samples, and deploy an autonomous underwater vehicle to take measurements in the water column and collect additional samples. NEPTUNE will also facilitate anthropogenic perturbation experiments such as the pumping of chemical tracers into the subsurface.

There are many opportunities for long lead-time activities. Many chemical, and essentially all biological sensors, need additional development. Sensors designed for hydrothermal systems must address serious materials and bio-fouling issues. For deployments in mid-ocean hydrothermal vents it will be highly desirable to develop robotic arms and tethered autonomous vehicles to manipulate sensors. Seafloor rovers could perform a similar function at sedimented seep sites. It may be necessary to develop standalone power sources such as fuel cells for some locations and there is a need to incorporate sensors. The UW has tremendous expertise in chemistry, microbiology, and engineering. By combining expertise in these areas the UW can take the lead in addressing many of these challenging problems. In order to foster activities in this area, the group suggested it might be worth establishing a focused interdepartmental seminar and searching for funds to support graduate students who would work across departmental boundaries perhaps by submitting an NSF (Integrative Graduate Education and Research

Traineeship) IGERT proposal. Funding for other activities could potentially come from a wide variety of agencies including NSF, ONR, NIH, DOE, DARPA, NASA, private foundations and the Washington Life Sciences Discovery Fund.

Water Column Science and Sensors (Group notes)
Discussion Leader: Bruce Howe

NEPTUNE will facilitate four-dimensional multi-scale sampling and observations in the water column. Topics of interest to UW scientist include the temporal behavior of thin layers of plankton near the sea surface, the characteristics of ambient sound in the oceans, and sediment transport and deposition on the seafloor. The group recognized that the large data streams would present new challenges and opportunities to develop and implement methods of adaptive data sampling and processing. Modeling will play a large role in the validation and interpretation of NEPTUNE data. A variety of new and more reliable sensors must be developed and at shallow depths bio-fouling is a particularly challenging problem for long-term deployments.

The group recommended identifying areas of importance to NEPTUNE and forming expert groups to pursue these ideas with coordination from the NEPTUNE office. The group identified many potential funding sources including NSF, DoD, DOE, IOOS, NASA, MURI, NIH, DHS, DARPA, NOAA, WaRF and private-public partnerships. Specific areas that might be suitable for interdisciplinary proposals include the following: the application of decision theory to active sampling; communication and control of multiple assets; acoustic communication methods; and biofouling.

Wet Plant Infrastructure Design and Challenges (Group notes)
Discussion Leader: Mohamed El-Sharkawi

The design, construction, and operation of the NEPTUNE observatory will present many interesting engineering challenges. UW engineers have been part of the team that has developed a power system for the NEPTUNE backbone cable and primary junction boxes. This system is being used for the MARS test bed. There are still significant challenges associated with delivering power at a stable voltage to instruments that may be up to a 100 km from a primary junction box, and it may be advantageous to develop systems to generate power and store energy locally underwater. One important topic is system stability, and this requires understanding the dynamic interaction between power consumers, converters and shore stations. Work to optimize the system reliability must take into account not only the design of the backbone but also the secondary infrastructure and sensors. Where possible the design should use components and equipment that are already proven for underwater applications. For a complex system like NEPTUNE, which will support very large numbers of differing sensors, it will be critical to develop tools to allocate and manage communications and power resources in a dynamic fashion so as to maximize the scientific output of the system.

The design of the NEPTUNE system will require a close collaboration between scientists and engineers in order to agree upon a set of realistic but scientifically optimal specifications. The UW has the personnel to contribute substantially to this process. In addition to scientists, the effort should involve the power group in EE, electrochemists, material scientists, reliability

specialists, protection engineers, experts in electromagnetic compatibility, and personnel with expertise in backhaul so that the data can be transferred from the shore station to operations and data centers.

Education and Outreach (Group notes**)**
Discussion Leader: Véronique Robigou

The education and outreach group started their deliberations with a wide-ranging discussion of the potential audiences for NEPTUNE. These include among others classroom learners, recreational users, and policy makers. The group agreed that there was no need for educational and outreach efforts to wait for the availability of high bandwidth data to start planning and identifying the needs of the different users and to develop products with existing data such as that from the VISIONS'05 cruise. NEPTUNE should involve educators and policy makers from the start – it was even suggested that NEPTUNE could include nodes that were specifically tailored to their needs.

NEPTUNE has the potential to apply cutting-edge thinking in educational processes and should seek to take the lead in understanding observatory science learning and even changing science learning. The group identified several areas in which proposals could move forward in the short term and noted that Jim Borgford-Parnell was currently writing a proposal that would incorporate NEPTUNE data into the engineering undergraduate curriculum. Potential funding sources for such include the Department of Education and NSF, as well as internal UW funding. The group suggested forming a user group that would bring experts from across the campus together on a regular basis and develop collaborations with other institutions. However, they agreed that it was essential for the NEPTUNE office to hire a national-level leader to start up and sustain the education efforts and develop funding streams. Educational efforts need to progress in parallel to the development of engineering and science efforts.

Appendix A. Agenda

Tuesday, November 15

8:00 Meeting Sign-In with coffee and light continental breakfast

8:30 Welcoming Remarks and Introduction by Mary Lidstrom

8:45 NEPTUNE Overview and Q&A – John Delaney

9:45 Ecogenomic Sensors – Ginger Armbrust and Deedee Meldrum

10:15 Break

10:30 The MARS Cabled Observatory – Keith Raybould

11:00 2-minute "lightning" introductions

12:00 Working lunch (while "lightning" introductions continue)

1:00 NEPTUNE Engineering Design Challenges – Gary Harkins and Bruce Howe

1:20 Cyber Infrastructure – Larry Smarr

1:50 Learning opportunities through NEPTUNE - Veronique Robigou and Philip Bell

2:10 Citizens, Science, and Policy – Marc Hershman and Thomas Leschine

2:40 Charge to Breakout Groups

2:50 Breakout Session I
The composition of break out groups will be determined at the meeting based on participant interest but may include groups on engineering research, sensor development and networks, cyber infrastructure, mobile platforms, control, materials, biofouling, education and outreach, and public policy. The groups will address the following:

- What are the opportunities offered by NEPTUNE?
- Identify those that require long-lead time planning and preparation
- Identify those that would benefit new/enhanced cross-disciplinary collaborations
- What groups in the UW should be involved and what can they contribute?

4:30 Plenary Session

5:00-7:00 Reception with cash bar

Wednesday, November 16

8:00 Coffee and light continental breakfast

8:30 Highlights of the VISIONS05 Cruise and the Challenges of Work in Extreme Environments - Deb Kelley and John Delaney

9:00 NEPTUNE Canada - Brian Bornhold

9:30 Opportunities for Education – Patricia Wasley

9:50 2-minute lightning introductions

10:20 Break

10:35 Funding opportunities and charge to breakout groups

10:45 Breakout Session II
Building on the results of Breakout Session I, each group will develop action plans by addressing the following:

- How do we foster NEPTUNE "expert groups" within the UW?
- How can these groups work effectively with other institutions?
- What are the potential funding sources for different activities?
- What are the specific plans for moving forward in each field?
- Are there proposal ideas with identified proponents that can move forward immediately?

12:00 Plenary Session and Meeting Wrap up

12:30 Meeting Adjourns

Appendix B. List of Participants

Name	Department (Institution for non-UW)	E-mail (replace '_AT_' with '@')
Akazawa, Katsufumi	JAMSTEC	akazawak_AT_jamstecseattle.org
Armbrust, Ginger	Ocean	armbrust_AT_ocean.washington.edu
Atlas, Les	EE	atlas_AT_ee.washington.edu
Barker, Gail		gmbarker2_AT_comcast.net
Beauchamp, Dave	Fish	davebea_AT_u.washington.edu
Bell, Phil	Ed Psych	pbell_AT_u.washington.edu
Bordia, Raj	Mat Sci	bordia_AT_u.washington.edu
Borgford-Parnell, Jim	CELT	bparnell_AT_engr.washington.edu
Bornhold, Brian	UVic	bornhold_AT_uvic.ca
Burnett, David	EE	db_AT_ee.washington.edu
Butterfield, Dave	JISAO	dab3_AT_u.washington.edu
Chalupnik, James	ME	jchal_AT_u.washington.edu
Chen, Antao	APL	antaochen_AT_apl.washington.edu
Creager, Ken	ESS	kcc_AT_ess.washington.edu
Damborg, Mark	EE	damborg_AT_ee.washington.edu
Delaney, John	Ocean	jdelaney_AT_u.washington.edu
El-Sharkawi, Mohamed	EE	elsharkawi_AT_ee.washington.edu
Emery, Ashley	ME	emery_AT_u.washington.edu
Gallucci, Vincent	Fish	vgallucc_AT_u.washington.edu
Hannaford, Blake	EE	blake_AT_u.washington.edu
Harkins, Gary	APl	harkins_AT_apl.washington.edu
Haugan, Peter	APL visiting scholar	phaugan_AT_apl.washington.edu
Hershman, Mark	SMA	hershmj_AT_u.washington.edu
Hines, Sandra	UW News and Info.	shines_AT_u.washington.edu
Horner-Devine, Alex	CEE	arhd_AT_u.washington.edu
Howe, Bruce	APL	howe_AT_apl.washington.edu
Jarauwatanadilok, Sermsak	EE	sermsak_AT_u.washington.edu
Johnson, Bob	APL	bobj_AT_apl.washington.edu
Kelley, Debbie	Ocean	kelley_AT_ocean.washington.edu
Kumph, John	Ocean	jkumph_AT_u.washington.edu
Lee, Sally	Health Sci	sallylee_AT_u.washington.edu
Leschine, Tom	SMA	tml_AT_u.washington.edu
Lidstrom, Mary	Vice Provost for Research	lidstrom_AT_u.washington.edu
Light, Russ	APL	russ_AT_apl.washington.edu
Lilley, Marv	Ocean	lilley_AT_ocean.washington.edu
Lin, Lih	EE	lin_AT_ee.washington.edu
Maquardt, Brian	Chem	brian_AT_cpac.washington.edu
McClure, Bob	Biosonics	bmcclure_AT_biosonicsinc.com
McDuff, Russ	Ocean	mcduff_AT_ocean.washington.edu
McGinnis, Tim	APL	tmcginnis_AT_apl.washington.edu
Meldrum, DeeDee	EE	deedee_AT_ee.washington.edu
Mescher, Ann	ME	mescher_AT_u.washington.edu
Moore, Sue	APL	moore_AT_apl.washington.edu
Nittrouer, Chuck	Ocean	nittroue_AT_ocean.washington.edu
Noble, Peter	CEE	panoble_AT_u.washington.edu
Nystuen, Jeff	APL	nystuen_AT_apl.washington.edu
Ogston, Andrea	Ocean	ogston_AT_ocean.washington.edu

Name	Department (Institution for non-UW)	E-mail (replace '_AT_' with '@')
Parsons, Jeff	Ocean	parsons_AT_ocean.washington.edu
Paulson, Tom	Seattle PI	tompaulson_AT_seattlepi.com
Penrose, Nancy	Ocean	penrose_AT_ocean.washington.edu
Pratt, Tom	Ocean/USGS	tpratt_AT_ocean.washinggon.edu
Raybould, Keith	MBARI	keith_AT_mbari.org
Richmond, Terese	Atty Gen Office	tcrich_AT_u.washington.edu
Robigou, Véronique	Ocean	vero_AT_ocean.washington.edu
Sahr, John	EE	jdsahr_AT_u.washington.edu
Sanford, Tom	APL	sanford_AT_apl.washington.edu
Shi, Richard	EE	cjshi_AT_ee.washington.edu
Shulenberger, Eric	Grad Sch	ericshul_AT_u.washington.edu
Smarr, Larry	UCSD	lsmarr_AT_ucsd.edu
Stoermer, Mark	COFS	mstorm_AT_u.washington.edu
Strunz, Kai	EE	strunz_AT_ee.washington.edu
Stuetzle, Werner	Stats	wxs_AT_stat.washington.edu
Thompson, LuAnne	Ocean	luanne_AT_ocean.washington.edu
Trabant, Chad	IRIS	chad_AT_iris.washington.edu
Vidale, John	UCLA	vidale_AT_moho.ess.ucla.edu
Wasley, Patricia	Dean of Education	pwasley_AT_u.washington.edu
Wilcock, William	Ocean	wilcock_AT_ocean.washington.edu
Wilson, Denise	EE	denisew_AT_u.washington.edu
Woodgate, Rebecca	APL	woodgate_AT_apl.washington.edu

The following did not attend the meeting, but expressed an interest and asked to be kept informed of NEPTUNE-related developments and activities on campus.

Name	Department (Institution for non-UW)	E-mail (replace '_AT_' with '@')
Beauchamp, Dave	Fish	davebea_AT_u.washington.edu
Bourgeois, Jody	ESS	jbourgeo_AT_u.washington.edu
Harwood, Caroline	Micro	csh5_AT_u.washington.edu
Heath, Ross	Ocean	rheath_AT_u.washington.edu
Hickey, Barbara	Ocean	bhickey_AT_u.washington.edu
Holl, Mark	EE	holl_AT_u.washington.edu
Horne, John	Fish	jhorne_AT_u.washington.edu
Ingalls, Anitra	Ocean	aingalls_AT_u.washington.edu
Keil, Rick	Ocean	rickkeil_AT_ocean.washington.edu
Kolve, Skip	APL	skip_AT_apl.washington.edu
MacCready, Parker	Ocean	parker_AT_ocean.washington.edu
Mamishev, Alexander	EE	mamishev_AT_ee.washington.edu
Mayer, George	MS&E	gmayer_AT_u.washington.edu
Nelson, Bruce	ESS	nelson_AT_ess.washington.edu
Riskin, Eve	EE	riskin_AT_ee.washington.edu
Roy, Summit	EE	roy_AT_ee.washington.edu
Strickland, Richard	Ocean	strix_AT_ocean.washington.edu