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Title:	An Interdisciplinary Ocean Observatory Linking Ocean Dynamics, Climate, and Ecosystem Response from Basin to Regional Scales
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Area:	NE Pacific

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Permission to post abstract on ORION Web site: ☑ Yes ☐ No

Abstract: (*400 words or less)*

The Regional Cabled Observatory (RCO) provides an unprecedented opportunity to measure ocean processes across a broad continuum of temporal and spatial scales. We propose twelve sites for initial implementation for full water column measurements using a moored sensor network to address priority research questions related to ocean turbulence and dynamics, the role of the ocean in global climate, and non-equilibrium ecosystem dynamics. The emphasis is on interdisciplinary observations of water-column processes offshore of the continental margin, a region forced by basin-scale atmosphere and ocean phenomena, variations in the North Pacific circulation, air-sea interactions, and shelf-slope interactions with the deep sea. Moored profiling capability throughout the water column at each site, coupled with acoustic tomography measurements between sites, are vital to advancement of ocean turbulence, ocean dynamics and climate studies, and assessing their impact on marine communities. Long-term simultaneous measurements of physical, chemical, and biological parameters are crucial to advancing from correlative observations to understanding the mechanisms that lead to ecosystem change and the role of biological feedbacks. Many of the principal sensors (e.g., acoustic and optical imaging systems) to investigate these key science questions require high power, high bandwidth, and precision timing for which the RCO is the sine non qua. The near real-time data and two-way communication will permit adaptive sampling of episodic events and provide data for assimilation into operational biophysical models. A fixed grid system fitted with sensors allows for simultaneous long-term monitoring over a wide range of spatial scales. Long-term sustained time-series also are the only viable approach for resolving variability and trends in multidisciplinary processes extending from the air-sea interface, through the water column, to the sea floor. The RCO will provide the tools needed to map the ocean in four dimensions and provide sufficient data to models to improve predictive skill and our understanding of dynamical systems.

Please describe below key non-standard measurement technology needed to achieve the proposed scientific objectives: (*250 words or less*)

- Full water-column profiling capability
- Integrated acoustic system
- New and improved chemical and biological sensors (biofouling, longer duration, capability of withstanding greater depths)

Proposed Sites:

Site Name	Position	Water Depth (m)	Proposed Duration			Site-specific Comments
			Start Date	Deploy (months)	Revisits during deployment	
See Appendix Tables A and B						

List of Project Participants

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An Interdisciplinary Ocean Observatory

Linking Ocean Dynamics, Climate, and Ecosystem Response

from Basin to Regional Scales

1. OVERVIEW

The Regional Cabled Observatory (RCO) in the northeast Pacific Ocean offers an unparalleled opportunity to achieve significant advances in ocean science. Despite the fact that the oceans cover more than 70% of our planet and have a profound impact on global climate, weather patterns, and agriculture, our ability to make sustained measurements of ocean processes has been limited. The RCO network of observatories linked by fiber-optic/power cables, as well as permanent and relocatable moorings and buoys, will permit high-frequency, *in situ* measurements of dynamic physical, chemical, and biological properties that occur over varying spatial and temporal scales. The RCO infrastructure will transform our understanding of ocean processes owing to recent technological advances and improved capabilities of observation and model prediction.

The breadth and complexity of science questions that may be addressed using the RCO are illustrated in Figure 1. A number of different groups responding to the NSF's Request for Assistance (RFA) are proposing to use the RCO for investigations related to basin-scale ocean dynamics, coastal ocean processes, fisheries and marine mammal distributions and flux, plate scale-tectonic studies, volcanic and ridge crest studies, subduction zone studies, gas hydrate research, transform fault research, and mid-plate hydrologic studies associated with the Integrated Ocean Drilling Program. These studies will complement those associated with the NEPTUNE Canada Program (www.neptunecanada.org), which are focused on a wide-ranging suite of research foci as well. Integration of these diverse and inter-related efforts will ultimately provide a powerful tool for advancing our understanding of interdisciplinary ocean processes.

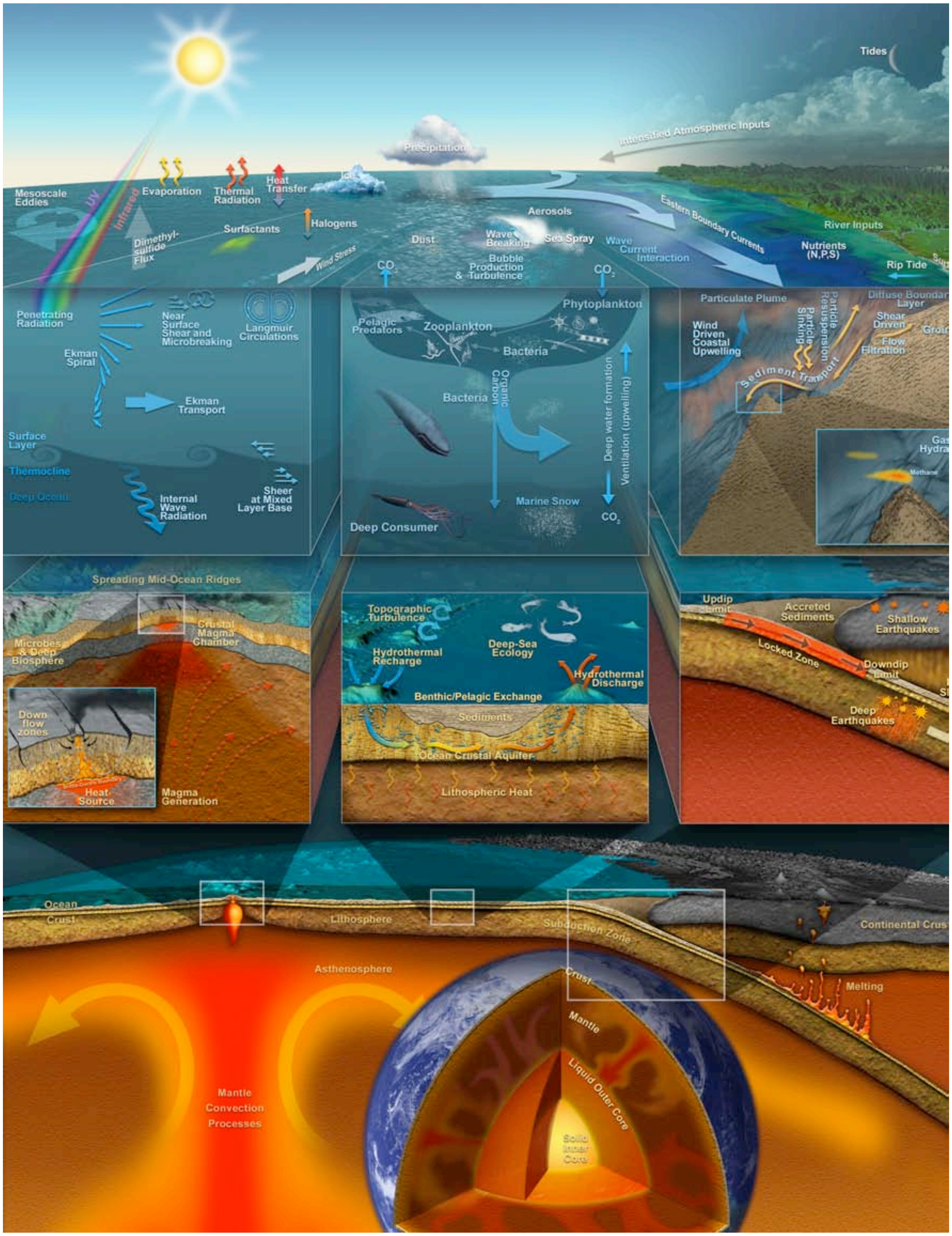

Figure 1.The breadth of atmosphere, ocean, and Earth processes that will be investigated using the Regional Cabled Observatory (Source: NEPTUNE Program)

2. PROGRAM RATIONALE AND KEY SCIENTIFIC HYPOTHESES

This proposal describes science experiments and sensor system infrastructure for the Regional Cabled Observatory (RCO) that are designed to address three of the grand challenges identified in the NSF's Ocean Science Millennium Report (2001): ***(1) ocean turbulence, (2) the role of the ocean in global climate, and (3) non-equilibrium ecosystem dynamics*.** These key questions are also highlighted in many subsequent documents, such as the Science Planning for NEPTUNE report (Howe et al., 2003), the RECONN report (Purdy and Karl, 2004), and the Ocean Observatories Initiative Science Plan (Brink et al., (in press) 2005). Here, we focus on a subset of RCO sites (Fig. 2) offshore of the continental shelf, recognizing the linkages in processes between the basin-scale, the regional (this proposal), and the coastal-slope proposals described in the Overview Section. We propose that these sites be provided with a water-column capability through the installation of deep-sea profiling moorings supplied with power and bandwidth from an RCO node. These water-column locations and the infrastructure of the entire RCO will allow investigation of many of the most pressing environmental challenges facing the ocean community today, as well as provide promising opportunities for discovery and new understanding of many ocean processes during the next three decades. We view this proposal as an initial effort to collect sustained measurements for the lifetime of the RCO and to set the stage for future focused experiments using new instrument systems as they become available, autonomous vehicles, shipboard measurements, and satellite data.

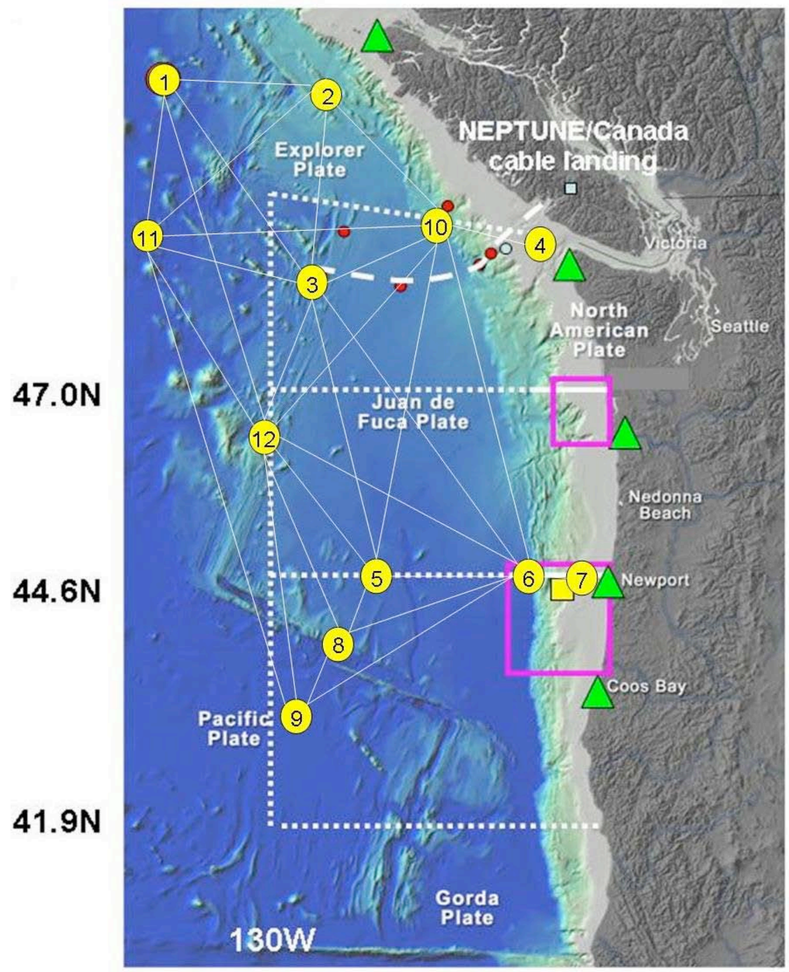

Figure 2: Location of proposed deep-water and coastal profiling moorings (numbered yellow circles) and tomography sites for the regional cabled observatory. Other elements proposed by the Barth et al.: Endurance Lines (solid white E-W lines near coast at 44.6 and 47.0°N); Pioneer Arrays (magenta rectangles); glider lines (dotted white). The dashed white line connects elements of NEPTUNE Canada forming a northern "E-W" line.

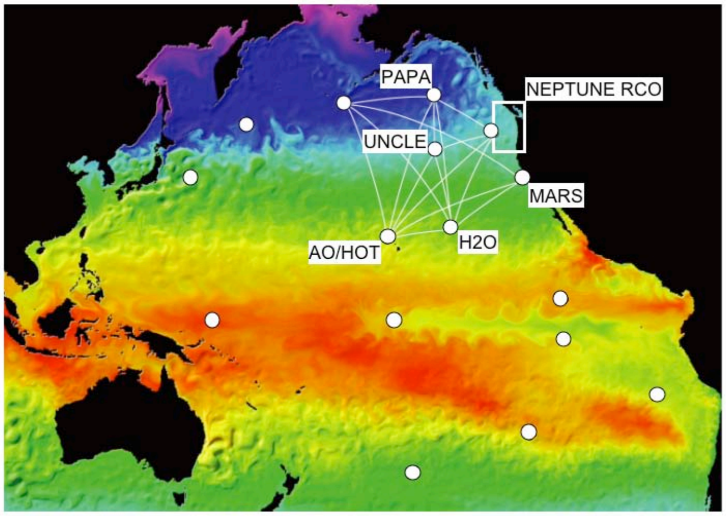

Figure 3. Pacific Ocean basin showing the pattern of sea surface temperature, with locations of tomography transceivers and paths (white circles and lines), the Global Buoys (PAPA, UNCLE, HOT), and the Regional Scale Observatory. The base image is output from a ROMS model (12.5 km, 30 layers, t1950-2000 integration; color is coded by temperature; picture is plotted in shaded-relief format, using the slope of sea surface height (courtesy of Y. Chao, JPL).

The northeast Pacific exhibits a range of oceanographic features spanning multiple spatial and temporal scales (Fig. 3 & 4). The West Wind Drift (WWD) (Fig. 4) is a major eastward wind-driven current that forms the boundary between the North Pacific subtropical gyre and subarctic gyre, each having fundamentally different physical, biological, and biogeochemical characteristics. The position of the boundary front between the gyres migrates seasonally north and south about 1000 km (Fig. 5) and may vary substantially during El Niño/Southern Oscillation (ENSO) events (Polovina et al., 2001). Models (Fig. 3) and satellite images (Fig. 5) both suggest that there is considerable mesoscale (20–100 km) eddy and meander activity along this boundary. The WWD bifurcates within the RCO region to produce the Alaska Current flowing north and the California Current flowing south along the eastern boundary of the North Pacific. This boundary region is characterized by frequent strong winter storms, seasonal wind reversals, moderate upwelling in spring and summer, significant freshwater runoff, strongly seasonal primary and secondary production, and patchy spawning by epipelagic fish (U.S. GLOBEC, 1994). Basin-scale climate phenomena, such as ENSO and the Pacific Decadal Oscillation (PDO) (Fig. 6) influence ocean processes in the northeast Pacific on time scales ranging from sub-inertial to decadal. Within the area covered by the RCO, interannual to decadal variability in the magnitude of the WWD and the position of its bifurcation should

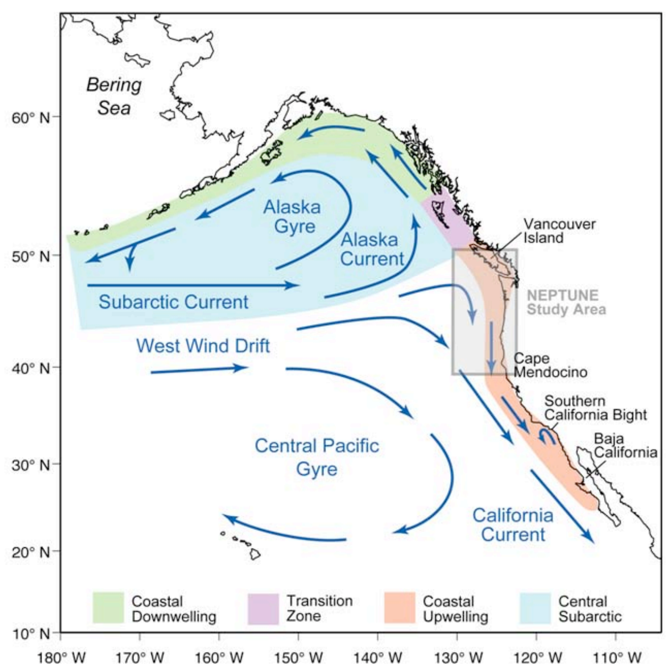

Figure 4. Major circulation features in the Northeast Pacific ocean in relation to the location of the RCO. (From Howe et al., 2003).

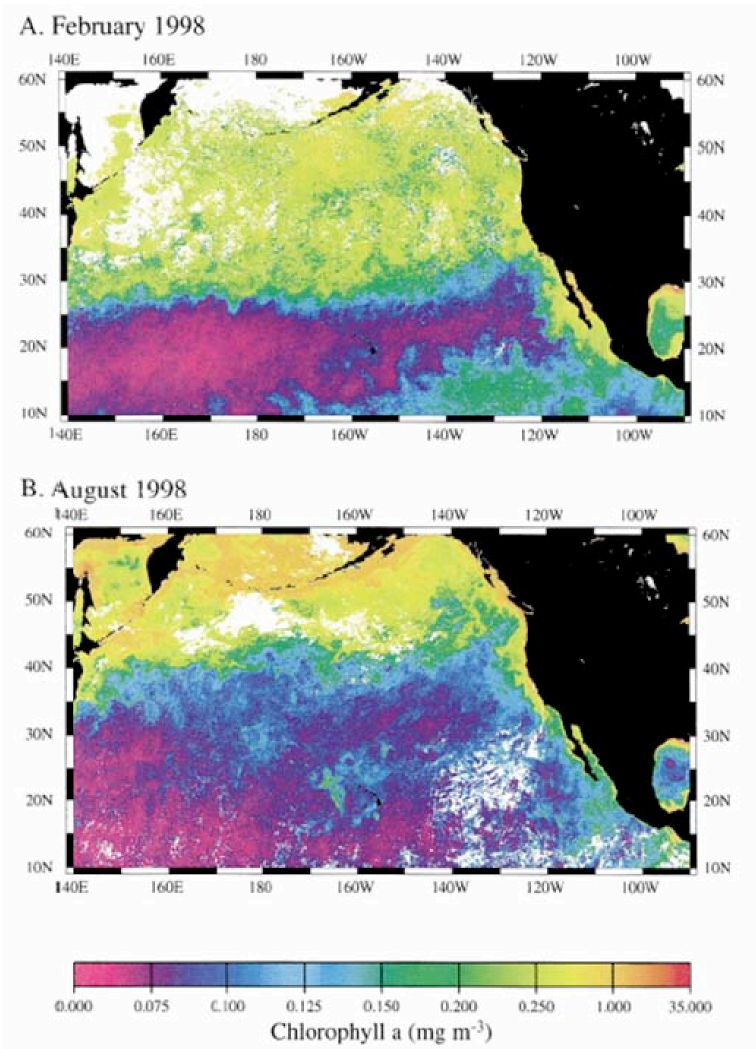

Figure 5. Seasonal surface chlorophyll density estimated from SeaWiFS ocean color showing the 1000 km north/south seasonal migration of the front between the Subarctic and Subtropical gyres (after Polovina et al., 2001).

result in coupled variations in volume transports of the California and Alaska Currents.

Many aspects of all three grand challenge questions listed above require instruments with power and/or bandwidth specifications that exceed those possible without cabled delivery. In addition, all three require an extended time presence in the ocean, partly because physical and biogeochemical parameters are highly variable and linked over a wide range of temporal scales (seconds to decades), but also because a wide range of evidence is forcing us to consider that episodic events are of great, possibly dominant, importance to all three questions. A recent example is the discovery that the major sediment transport events on shallow shelves are associated with the sporadic occurrence of Langmuir cells that extend to the ocean bottom during strong storms (Gargett et al., 2004), a discovery made only by a cabled deployment of several months. Episodic events like these cannot be studied by scheduled cruises, moreover understanding requires several realizations of each type of event, measurements that can only come from extended deployments. The RCO offers unprecedented opportunities to address all three grand challenges for which we offer some examples below.

Ocean Turbulence and Dynamics

Many fundamental ocean processes, including those that pertain to the ocean's role in climate change, cannot be quantified without improved knowledge of ocean turbulence, from large scales of generation to microscale dissipation. Two-dimensional turbulence stirs mass, momentum, salt, heat, and nutrients in the horizontal, while small-scale, quasi-three-dimensional turbulence completes this horizontal mixing process, and plays a critical role in other diverse areas, such as maintenance of the pycnocline, air-sea gas exchange, transfer of organic material to the deep sea, and modulation of particle-encounter rates. A water-column capable RCO will allow many of these processes to be studied in places and times not previously possible. For example, it has long been recognized that a very high percentage of total mixed layer deepening over a year occurs during a single early winter storm, but we have not been able to understand what makes this "the perfect storm" for mixed layer deepening because we have not been there (or able to make measurements if there!): the RCO will provide many realizations of mixed layer deepening under intense storms. Knowledge about the properties and dynamics of the upper ocean boundary layer also is important. Breaking waves generate turbulence, which is coupled to more slowly evolving vertical motions aligned with the wind (Langmuir circulation) which, together with convective motions, mix momentum, heat, bubbles, dissolved gases and other properties down through the water column. Bubbles play a significant role in air-sea gas exchange at higher wind speeds. Additional small-scale turbulence questions that can be studied at the RCO are the influence of topography on interior turbulence (at sites on both the mid-ocean ridge and the Blanco fracture zone), the influence of vent plumes on water-column processes (Thomson et al., 2003; Thomson et al., 2005), and the role of double diffusion in the upper waters of the subtropical gyre (Gargett & Schmitt, 1982). The real-time data and remote instrument control offered by a cabled observatory provides a critical access in that these relatively high-bandwidth measurements can be switched to high-frequency sampling only when desired and/or when certain conditions are met, decreasing the need for massive data handling/archiving.

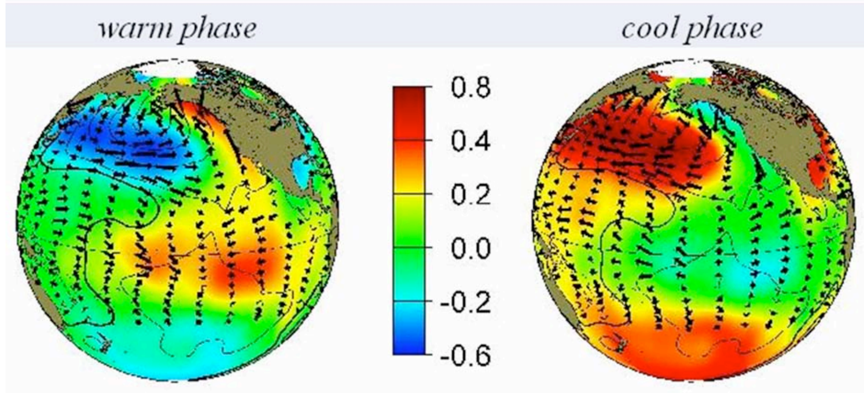

Figure 6. Pacific Decadal Oscillation (PDO) showing typical winter sea surface temperature (colors), sea level pressure (contours), and surface windstress (arrows) anomaly patterns during warm and cool phases of PDO (source: http://tao.atmos.washington.edu/pdo/).

Continuous long time measurements of mesoscale characteristics in the region could quantify the role of horizontal transport/stirring by mesoscale eddies, as well as interannual variability in mesoscale eddy activity along the eastern boundary, suggested by numerical models, and possibly associated with gyre "condition" as determined by ENSO/PDO states. Barotropic variability is one of the most poorly observed components of the ocean's circulation, as it is not easily studied using standard hydrography. Hypotheses related to potential energy sources of sub-inertial oscillations, such as wind forcing or meridionally trending currents, will be investigated. Other physical processes to be studied with the RCO include wind-forced barotropic Rossby waves, which have been shown to influence biological productivity (Sakamoto et al., 2004), and tsunami and infra-gravity waves. Many of these processes are common to other ocean systems; thus, results from the RCO will act as a model for other regions.

The Role of the Ocean in Global Climate

The RCO offers new opportunities to investigate the ocean-atmosphere climate system, in particular to assess the interrelationships among carbon, heat, and climate variability in ways that cannot be adequately addressed using traditional sampling methods. For example, thermal inertia of the oceans ensures that many of the cycles of interest occur over longer time scales than those we currently sample. Superimposed on low frequency (decadal) cycles is significant variability due to higher-frequency variation in the climate system (interannual, ENSO, etc). This natural variability of the climate system has kept previous research programs from obtaining quantitative measures of feedback mechanisms between climatic forcing and the ocean carbon cycle. Temporal changes in atmospheric temperature, precipitation, and winds affect regional ocean stratification and turbulent mixing, with consequences for biological productivity and elemental fluxes in the sea. Changes in ecosystem structure and/or the interactions between producers and consumers impact the amount of export flux of carbon from the surface to the ocean interior, with potential feedback effects on the atmosphere (Denman et al., 1996). Despite the importance of the biological pump, the particulate carbon flux to depth is not well resolved, partly because of the episodic nature of phytoplankton bloom dynamics.

The North Pacific is impacted by both ENSO (Mackas et al., 2004) and the PDO (Mantua et al., 1997). These variable atmospheric forcing fields induce changes in the upper ocean, which strongly influence biological productivity patterns in both gyres and the California and Alaska Current systems and result in large shifts in community structure and distributions through all trophic levels. The RCO will provide the time-series observations from permanent sensor networks that are needed to quantify both the physical and ecosystem responses of the ocean to climate variability, as a first step towards resolving the questions of climate feedbacks. In addition, it will determine both the mean and variance of parameters associated with episodic ecosystem events, allowing us to quantify their importance to global productivity and to assess how that might change under the predictions of global climate change (e.g., an increase in extreme atmospheric forcing events).

Non-Equilibrium Marine Ecosystems

The temporal and spatial sampling capability of the RCO and its support of sophisticated sensing systems will accelerate knowledge of marine ecosystem biodiversity, biogeochemical cycling, functional ecology, and non-equilibrium and non-linear ecosystem dynamics (Hsieh et al., 2005). The characterization of external forcing, across a spectrum of scales from turbulent mixing and diffusion to basin-scale remote forcing from atmospheric teleconnections, is vitally needed to better understand what factors govern the ocean-atmosphere climate system and ecosystem variability, and to wisely manage and sustain marine ecosystems. It is now recognized that marine ecosystems are commonly in disequilibrium. Relatively rapid, dramatic changes in marine communities may result from non-linear responses to small perturbations. Basin-scale shifts in ecosystem state (i.e., regime shifts) in the North Pacific have occurred several times during the last century as evidenced by phytoplankton, zooplankton and salmon populations (Venrick et al., 1987; Brodeur &Ware, 1992; Karl et al., 2001; Chavez et al., 2003; Mantua et al., 1997; Mackas et al., 2004), however the underlying mechanisms remain uncertain (Polovina, 2005). Decadal regime shifts are thought to be a response to variations in ocean and atmosphere processes and are therefore relatively coherent with climate change. Climate and ocean indices suggest that changes in energy flow from the base of the ecosystem are responsible for regime shifts, but in some cases climate-induced changes in apex predators also result in top-down, trophic cascade responses (Polovina, 2005). Arguments for 'bottom-up' control of trophic linkages in the highly productive region off the coast of Washington and southern British Columbia are supported by observations of strong correlations in spatial distribution of primary production, zooplankton and fish stocks (Ware & Thomson, 2005). Furthermore, Gargett (1997) suggested an optimal stability window hypothesis for fluctuating fish stocks, a scenario in which the strength of the wintertime Aleutian Low affects water-column stability, with consequences for primary and secondary production (Fig. 7). Hypotheses such as this could be tested using the time-extended observations from the RCO.

The northeast Pacific region is an excellent location to investigate a number of key ecosystem questions, including ecosystem shifts, the temporally and spatially variable evolution and demise of phytoplankton blooms, the episodic nature of the biological pump (interactions between bacteria, phytoplankton, microzooplankton, and zooplankton near surface and in the mesopelagic "twilight" zone) and its effect on vertical flux, and the role of biological thin layers. Community response to the changing marine habitat is an ongoing "natural experiment" and another important research topic. Increases in ocean CO_2 concentrations and the resulting decrease in pH (more acid) also affect marine calcification rates. Research opportunities for higher trophic levels include assessing fish and squid population dynamics, distribution, and habitat use, tracking migration patterns of whales (Fig. 8), assessing the response of whales to ocean variability, and quantifying food availability for top predators. Because many whales range across remote regions of the ocean, including the offshore regions of the RCO, little is known about their ecology and behavior. The assessment of top predators will be covered more fully in a proposal by Horne and colleagues.

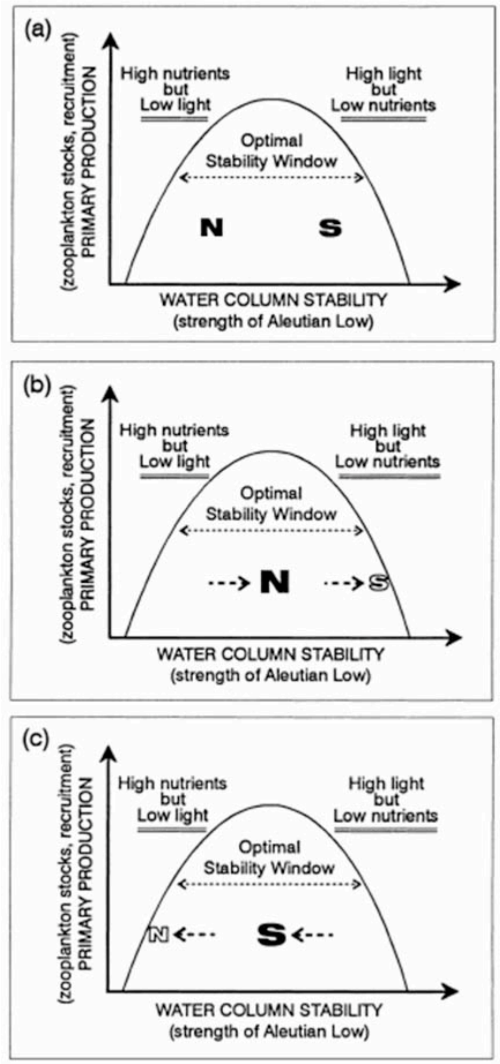

Figure 7. Schematic of an optimal "window" for water column stability, whereby primary production is at a maximum at an intermediate stability value, where light and nutrient availability is highest. The subarctic and subtropical gyres are assumed to be two end members on the stability scale. If water column stability varies in phase between regions, then primary production and salmon survival will vary out of phase (after Gargett, 1997).

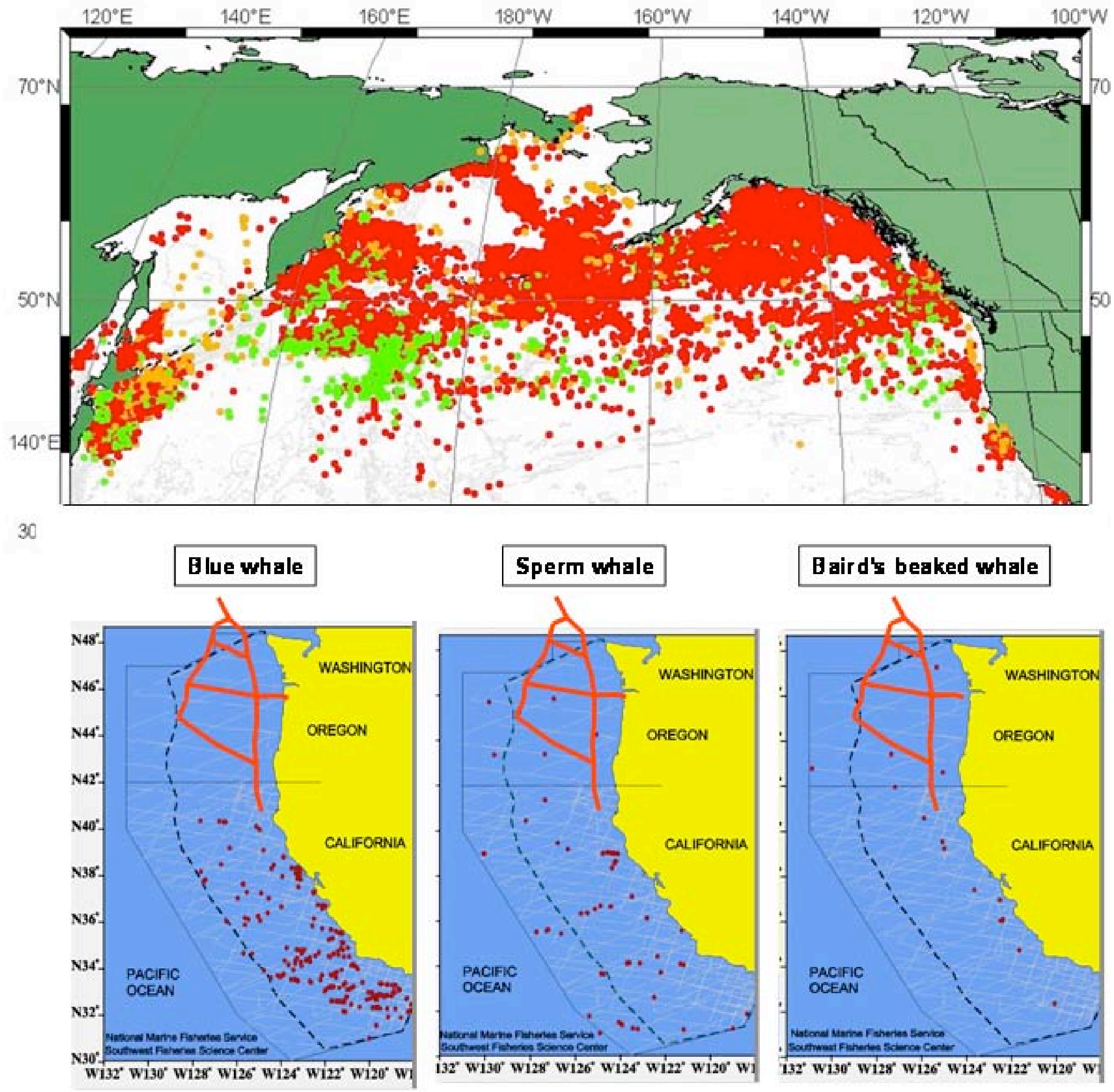

Figure 8. Whale distributions in the North Pacific, (a) Humpback whale catch data reported to the International Whaling Commission (courtesy of K. Stafford, NOAA), (b) whales observed along NMFS survey tracks in 1990's (courtesy of D. Mellinger, OSU).

In summary, the RCO provides an unprecedented opportunity to measure ocean processes across the continuum of temporal scales over which they occur. A cabled infrastructure with profiling capability throughout the water column is vital to advancement of ocean turbulence, ocean dynamics and climate studies, and to the assessment of their impacts on marine communities. Fixed-point time-series stations are the only viable approach for resolving variability and trends in multidisciplinary processes extending from the air-sea interface, through the water column, to the sea floor. In the design stages, it will be necessary to estimate the degree of spatial aliasing introduced by the chosen array, using existing data, numerical models, and observing system simulation experiments (OSSEs). However, the possibility of spatial aliasing should not keep us from establishing water-column time series at the earliest stage of observatory deployment, any more than the reality of temporal and spatial aliasing has kept us from making shipboard measurements for the past century. Lastly, the RCO will provide the tools needed to map the ocean in four dimensions and provide sufficient data to models to improve predictive skill and to improve our understanding of these dynamical systems.

3. SCIENTIFIC QUESTIONS

Our scientific objectives range from short-term (ca. current NSF grant duration) experiments to those requiring decades, recognizing that the RCO will need to demonstrate immediate results as well as a long-term vision. Many of the science questions require an interdisciplinary approach and, therefore, are not easily organized under a single science theme. Also the questions listed below are clearly not all inclusive, but were identified in workshop reports as a high priority and are intended to demonstrate the range of science objectives that could be achieved given the implementation of critical assets. The emphasis is on experiments and objectives targeted at interdisciplinary water-column processes offshore of the continental margin forced by basin-scale atmospheric and ocean processes, North Pacific circulation, air-sea interactions, and shelf-slope interactions with the deep sea. The following section on Experimental Design and Observing Requirements describes the proposed observatory elements to address these questions.

Ocean Turbulence and Dynamics

- What is the long-term trend of barotropic and baroclinic variability in relation to atmospheric forcing and bathymetry?
- How are the properties of tsunamis and infra-gravity waves affected by propagation over areas of rough, shoaling seafloor topography?
- What factors drive the interannual variability of the location of the West Wind Drift bifurcation and transport volume flux?
- What factors control the seasonal depth of the surface mixed layer, the entrainment of stratified waters into the mixed layer, and air-sea exchange?
- Is the structure of Rossby waves altered by bottom topography?
- Do instabilities from meridionally trending currents provide a potential energy source to the interior ocean in addition to wind forcing?
- What is the relative importance of tides, internal waves intersecting topography, double diffusion, intrusions, shear, and fronts on diapycnal mixing? How does seafloor roughness influence mixing rates in deep water? For example, does barotropic turbulence driven by mid-ocean ridge topography influence diapycnal mixing and abyssal stratification?
- Is non-linear interaction among tides and inertial motions in rough topographic regimes important for cascade of tidal and wind energy to higher-frequency motions?
- What is the role of vertical mixing in the distribution of heat, momentum, and dissolved gas?
- What is the role of near-surface vertical and horizontal mixing, as it modulates irradiance, nutrients, and biological encounter rates, in determining plankton community structure and function?
- What is the spatial variation (onshore to deep waters) of turbulence in the photic zone, the nutricline and the benthic boundary layer? How does that variation affect the distribution of plankton and fish as mediated by behavioral responses (e.g., vertical migration)? How does the variation in these processes affect plankton population dynamics through recruitment, mortality, and lateral transport?

- How do ocean productivity and plankton stocks respond to variations in external forcing? What is the relative importance of high- and low-frequency forcing, such as seasonal, interannual (e.g., ENSO), and interdecadal (e.g., PDO)?

Role of the Ocean in Global Climate

- Does the oceanic eastern boundary current upwelling system act as a source or sink for atmospheric carbon dioxide and will that role vary in response to additional climate forcing?
- What are the mean and varying budgets of heat, salt, and biogeochemical variables in a 3-D volume within the study area?
- How do CO_2 profiles vary as a function of sea surface temperature, surface fluxes (boundary transport and breaking waves), biological activity estimated from the effects of net production, and exchange through the base of the mixing layer and horizontal gradient advection?
- How do climate-driven changes in physical and chemical properties and biological community composition modulate the particulate and dissolved elemental composition and flux near-surface and in the mesopelagic zone?
- To what extent do fluctuations in food web structure and function control elemental fluxes compared to the fluctuations in abiotic physical/chemical processes?
- What factors influence variability in the strength and efficiency of the biological pump in different locations over time?
- What is the ecological response to increasing ocean CO_2 concentrations and lower pH in surface waters?

Non-Equilibrium Ecosystem Dynamics

- What factors govern the spatial variation (N/S, onshore-offshore) and timing of the evolution of phytoplankton blooms?
- What are the spatial scales of variation (N/S, onshore-offshore) in water mass characteristics, turbulence, and ecosystem response to PDO and ENSO events?
- What factors control the development and demise of biological thin layers?
- What role do episodic or extreme events (e.g., storms, ENSO, earthquakes) play in restructuring marine ecosystems?
- What is the long-term variability in near-bottom flow and turbulence, which affect the physical dispersion, lateral transport and subsequent settlement of benthic organisms that inhabit the central plate and Juan de Fuca Ridge?
- How do episodic megaplume eruptions from vents influence the chemistry and biology of the overlying and downstream water column?
- What are the causal mechanisms of regime shifts in marine communities and what controls the synchrony or lack of synchrony among different organisms and between different regions?
- Do food webs respond to the mean state of forcing mechanisms/events, or to the frequency and magnitude of events?
- Are regular migration patterns and fluxes of nektonic species (i.e., fish and invertebrates) disrupted during episodic, physical events?

4. EXPERIMENTAL DESIGN AND OBSERVATORY REQUIREMENTS

We propose a multi-scale ocean observatory combining north-south and east-west elements that will complement and intersect with cross-margin Endurance Lines, focused Pioneer Arrays, and an acoustic tomography array jointly proposed with the coastal component (Barth et al.). Basin-scale information will be obtained from deep-sea buoys, other cabled observatory sites, and acoustic tomography within the subtropical and subpolar gyres (see Fig. 3 and Worcester RFA response). The broad spacing of the offshore arrays is appropriate for studies requiring independent point measurements or integral quantities (like transport) or for studies of phenomena with very large scales of variability (and large correlation scales) such as barotropic Rossby waves. It is envisioned that mobile platforms, such as gliders and AUVs, will be integral to this system to provide greater spatial coverage and help resolve mesoscale structures in survey and adaptive sampling modes of operation. We anticipate that the RCO also will be expanded from this initial footprint by adding extension cables with associated instrument systems at varying distances from the primary nodes to provide enhanced spatial coverage. Medium-scale arrays, with element spacing of 10–100 km, will be appropriate for studying baroclinic eddy variability, the interaction of the eddies with the mean flow, and dynamics of the baroclinic flows. Small-scale arrays, with element spacing under 10 km, are appropriate for examining the horizontal structure of turbulence and wave-driven rectified flows near the boundary with associated chemical and biological processes. Innovative process studies conducted from ships within the RCO array will be essential to investigate many fundamental questions. Our intent here is to recommend the minimal number of initial sites and measurements needed to address strategic science questions and to set the stage for future experiments.

4.1. Site Locations

We propose twelve sites for initial implementation for full water-column measurements (Fig. 2). Table A (see Appendix) lists the sites, the rationale for their selection, and associated science objectives, and Figure 2 shows the site locations relative to those proposed for the RCO coastal sites (Barth & colleagues) and the larger-scale tomography effort (Worcester & colleagues) with some sites and sampling efforts in common between these proposals. Coordinates and depths are given in Table B (see Appendix). These sites were selected by RECONN workshop participants as locations of broad scientific interest. Sampling at all sites with common measurements is very important to obtain a coherent observing array antenna.

The proposed sites are located on all major bathymetric features (continental shelf, continental slope, deep basin, abyssal basin, mid-ocean ridge, transform fault). The distribution of high-priority stations spans several gradients in ocean productivity, ranging from gradients in the intensity of coastal upwelling, north-south gradients in productivity (related partially to the WWD), and major onshore/offshore gradients in ocean temperature and upper-ocean productivity. Specifically, the sites will allow monitoring of the north-south variation in the location and transport of the WWD and comparison of different ocean ecosystem provinces, such as the southern edge of the productive, micro-nutrient limited, High Nutrient Low Chlorophyll (HNLC) sub-Arctic gyre, the productive shelf region, and a low-productivity region associated with the macronutrient limited subtropical gyre. Sustained measurements over multiple years will allow researchers to quantify and better understand relationships between event-scale biophysical processes and more slowly varying parts of the climate system like the seasonal cycle, (interannual) ENSO variations, and the PDO. Sustained measurements of the physical environment (e.g., temperature and salinity profiles) at all locations also will support efforts to establish a global climate monitoring system.

These sites have other attributes in addition to those listed in Table A. **Sites 2, 10, and 4** are located in a highly dynamic and ecologically diverse region of the Northeast Pacific that should provide insights into climate-scale (seasonal-to-interannual and interdecadal time scale) impacts on regional physics and ecology. This area includes exceptional food-web productivity and diversity due to the combined influences of subarctic inflows, inland seas outflows, and seasonally intermittent coastal upwelling. Measurements obtained from these sites will support a variety of research objectives as well as the management of valuable marine resources (e.g., U.S. NOAA Fisheries and Canada's DFO management decisions involving commercially valuable fish stocks, harmful algal blooms, and marine mammals). Furthermore, knowledge of fluxes into the eastern subtropical gyre at its northern boundary provides an essential upstream condition for biophysical conditions within the entire California Current system. The increased spatial resolution of arrays in the vicinity of coastal **Sites 4 and 7,** as proposed by Barth and colleagues, will greatly enhance understanding of this complex, dynamic shelf region. **Sites 5-7** take advantage of the long-time-series observations along the "Newport Line," which has been occupied since 1961. In addition, measurements at **Sites 4, 10, 6, and 7** will support a variety of research objectives as well as the management of valuable marine resources (e.g., NOAA Fisheries management decisions involving commercially valuable fish, harmful algal blooms, and marine mammals). **Site 6** also is located at a methane hydrate-rich environment with associated chemosynthetic communities (i.e., Hydrate Ridge). Major seamounts are common near **Site 11** and therefore will provide access to unique deep-sea communities. Near-bottom current and microstructure measurements over the rough topography of the shelf break, and the ridge crest and the transform fault separating the Pacific Plate from the Juan de Fuca Plate (**Sites 2, 3, 12, 5-9, 10, and 6**) also will provide data necessary to better understand and model boundary mixing processes that may be vital to understanding the maintenance of the observed abyssal stratification.

4.2. Proposed Moored Sensor Network

We propose a moored sensor network connected to the RCO that can support both full water column profiling and fixed instrument clusters near surface, mid depth, and at the bottom. Figure 9 depicts the proposed configuration of sensor instrument packages, platforms, and junction boxes (J-boxes) on the mooring that make up the sensor network. Profiling moorings have the advantage of producing high vertical-resolution measurements using just one sensor suite package, as opposed to multiple copies of sometimes expensive instruments in the vertical. Sensors at fixed depths also often miss or alias dynamics events. Profilers are more economical than fixed sensor systems, have lower operating costs, less data processing, and less sensor service time required. Furthermore, profilers can "hide" at depth to help minimize biofouling, which is greatest in the upper-ocean euphotic zone. The major reason for a fixed mid-depth "node" is to support acoustic tomography instrumentation that serves to sample the ocean between moorings, to support vertical fish/squid echosounders, and have a duplicate set of some sensors to "calibrate" those on the profilers.

Much of our ecosystem and upper-ocean physics research is focused on the upper 200 m of the water column where instruments will be sampling episodic events in a systematic and adaptive mode, which requires an **upper-ocean profiler**. The scientific objectives also require the ability to profile over greater depths in the deep ocean. For this purpose, we require a **deep-ocean**

profiler operating on a fixed mooring line and capable of profiling from (local) full-ocean depth (~3000 m) to within 200 m of the surface. At 200 m a stable platform (minimum wave motion and biofouling) will be provided for mounting other sensor packages and the upper-ocean 0-200 m profiler, and to facilitate autonomous underwater vehicle operations. Because these moored sensor systems will be attached to the RCO, power and communications constraints are largely absent.

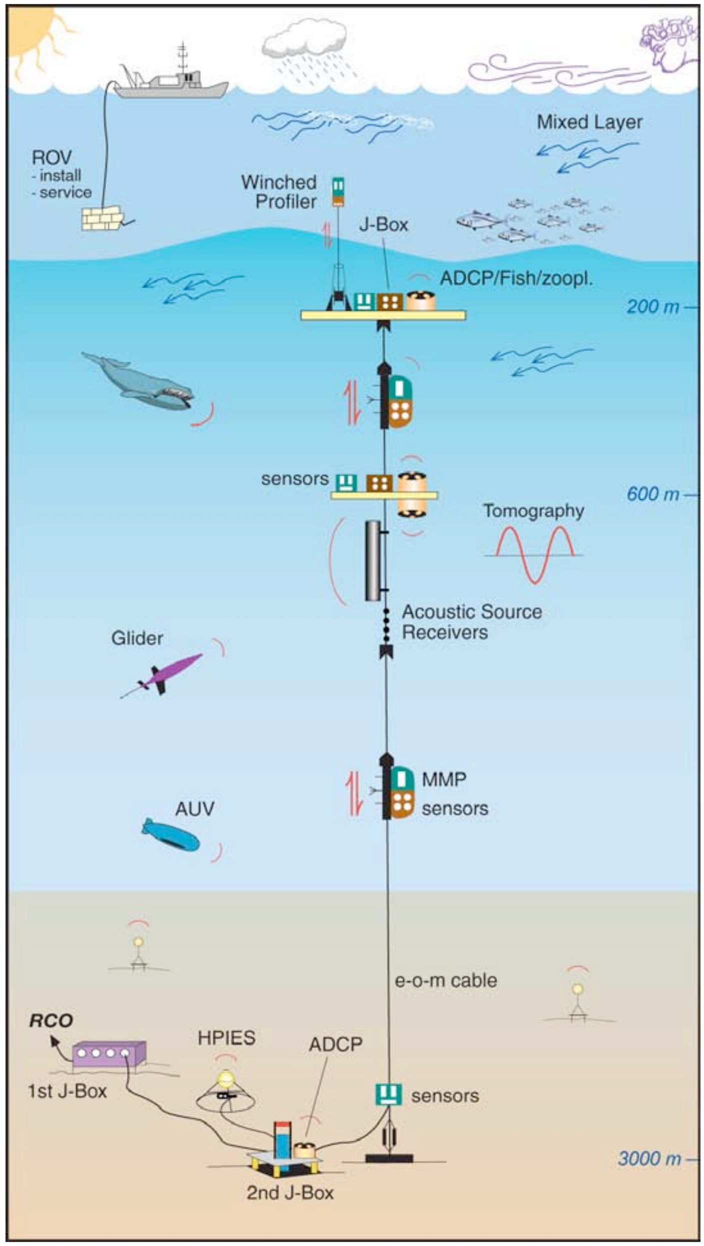

Figure 9. Full water column profiling mooring showing the upper winched profiler from a 200 m platform and two lower profilers bracketing the 600 m node.

Much of the proposed moored sensor network has been or is being developed. In 2006, Howe et al. will deploy the ALOHA/MARS cabled deep-ocean moored profiler system at the MARS observatory in 900 m water depth (www.alohamooring.apl.washington.edu). Barth et al. also are developing an upper-ocean profiler to be deployed in 2006. These two systems will have essentially all the required elements. Other proposals are currently under review; for example, one for a cable connected mooring system with an in-line acoustic vertical line array of hydrophones (Collins et al.). The proposed mooring system described below is based on these combined efforts. We begin with a description of the sensors needed to address the science questions followed by a description of the sensor network infrastructure. Individual moorings and location of sensors may vary with site (e.g., the two coastal moorings will be significantly shorter); however, for the purposes of this proposal, the description and costs are assumed to be the same for all sites.

4.2.1 Sensors

Several workshops for the RCO recommended that suites of basic sensors (at different depths) be included at all primary nodes to provide a baseline and broad coverage of fundamental variables. The first set of sensors described below was chosen because they possessed several characteristics. They are robust, proven technologies that have been deployed for extended periods of time (~ 1 year). They require little or no *in situ* calibration or are self-calibrating. Some of the sensors, especially the bottom and tomography sensors, measure unaliased integral quantities that are more representative of larger scales and are useful for multiple disciplines. Some sensors, where noted, are anticipated to be ready for long deployments within the next few years. All targeted parameters have sensors with appropriate response times (seconds) for profiling mode. Potential power requirements range from a few mW to ~250 W (the highest being for acoustic systems), which are well within the RCO system constraints. We anticipate that the data transmission rates on the cabled backbone are adequate for all of these sensors.

In the present configuration a total of about 60 sensors covering all depths are being requested for each mooring. These sensors reflect the knowledge of the proponents; however, it is recognized that additional community input will be needed to determine a final optimal array. In addition, there clearly is a need to develop instrument system packages, especially for optics and acoustics. In the description below there are multiple locations for sensors: the upper-ocean winched profiler, the subsurface float, the deep-water profiler(s), the mid-water node, and the base/anchor/bottom of the mooring.

Upper ocean sensors (profiler 200 m – surface and platform at 200 m**)**

Profiler - A suite of sensors will be deployed on the upper-ocean winched profiler to ensure high vertical resolution of all parameters throughout the upper 200 m of the water column. To address the science questions, the profiler needs to simultaneously measure the vertical distribution of physical structure (temperature, salinity, density), physical dynamic processes (turbulence, bubbles, internal waves, current velocity, irradiance), chemical properties (pH, dissolved oxygen and carbon dioxide, nutrients), and distribution and characteristics of plankton (phytoplankton, zooplankton). Thus the profiling package will include a CTD (measures water-mass properties), an acoustic current meter (ACM), pH, O_2 (water-mass tracer and evaluates net biological production) and CO_2 sensors, an optical nitrate sensor (e.g., ISUS), optical sensors for measuring inherent optical properties of dissolved and particulate material, and acoustic sensors for measuring zooplankton, finescale velocity, and bubbles.

Optical sensors should consist of a high spectral resolution absorption and attenuation meter (e.g., WET Labs ac-s), a spectral volume backscattering sensor, and a fluorescence sensor for measuring chlorophyll *a*, phycocyanin, and CDOM. This suite of optical sensors will allow us to not only quantify the temporal and spatial changes in the vertical structure of phytoplankton and dissolved material, but also provide information on changes in the species composition (based on spectral shifts in absorption) and size structure (based on slope of the attenuation coefficient) of the particulate material (see Donaghay, 2004 and Sullivan et al., 2005 for examples). These IOP data also will allow us to calculate remotely sensed reflectance and thus link changes in the water column (at the 12 sites) to large-scale changes detected from satellites such as SeaWiFS and GOES-R. Zooplankton densities will be assessed using multi-frequency acoustics systems (e.g., TAPS-6: 120-1800 kHz). An acoustical resonator will provide vertical transects of bubble size distribution from 20 to 400 microns through the mixed layer. These observations represent an important ancillary measurement for testing models of near-surface circulation and for calculating bubble-induced transfer of weakly soluble gasses. With their high target strength at resonance, bubble creation yields a distinct source of ambient sound and bubble clouds have well-characterized acoustical scattering properties providing strong motivation for the use of acoustical methods in upper ocean studies.

Platform - A set of sensors will be located on the subsurface float to provide boundary conditions for interpreting the profiler measurements, as well as to monitor conditions that may affect adaptive sampling decisions, e.g., storms or plankton-bloom events. This package will include a CTD, an upward-looking 300-kHz 5-beam vertical Acoustic Doppler Current Profiler (VADCP; current velocity, turbulence, and relative acoustic backscatter intensity, which is related to biological scatterers in the upper ocean boundary layer), pH, O_2, CO_2, nitrate, ac-s, spectral volume backscattering, and fluorescence sensors. An upward-looking fish/squid echosounder (splitbeam 38 kHz) will provide total reflected energy (i.e., backscatter) and echoes from individual organisms (i.e., target strengths) that will be used to monitor vertical movements and horizontal fluxes at each mooring. Three-dimensional distributions and movements will be continuously tracked over temporal scales ranging from seconds to years. In addition to tracking ephemeral events, daily migrations, annual cycles, and responses to climatic trends, these data will enable the construction of a quantitative Stommel diagram (Stommel, 1963; Haury et al., 1978) for pelagic biomass in the open ocean. In addition, we propose an array of broadband passive hydrophones to detect whales, wind-driven wave noise, and hence wind speed stress (10 Hz – 20 kHz), and rainfall (5-20 kHz). A slant-oriented, four-transducer fan-beam Doppler sonar operating at 100 kHz will provide measurements of the surface gravity wave directional spectrum, simultaneously with the distribution of micro-bubbles in the active wave layer. Lastly, acoustic transducers for navigation and communication will be included as a community service. With some additional development the navigation transducer may be used for geodesy as well.

This suite of sustained physical, chemical, and biological measurements is required for making fundamental advancements in understanding the science questions and will be used to quantify water-mass properties and current velocity and direction; to investigate processes related to surface exchange, vertical mixing/stratification, seasonal cycles of internal waves, mesoscale eddies, and small-scale turbulence; and to assess the mean and variance of physical and chemical properties and biological productivity in relation to large-scale forcing.

An example of a compelling short-term (few years) experiment embedded in the longer term observations (decades) would be to estimate the spatial and temporal variation in annual diapycnal diffusivity using time-series of T, S, and velocity profiles. This process takes place over centimeter scales driven largely by internal waves (hourly to daily time scales), but profoundly affects processes on all scales in a non-linear fashion, including the general circulation (megameter scales). Profile measurements of physical parameters also allow calculations of shear, strain, and turbulent dissipation, and observations of internal tides, thermocline evolution, and double-diffusive layers.

Another experiment would be to determine the variability of the biological pump. Changes in oxygen, carbon dioxide, and nitrate concentrations in the upper mixed layer during summer relative to those in deeper water, along with data on phytoplankton and zooplankton density, would provide information on the spatial (N/S, onshore/offshore) and interannual variation of the strength and efficiency of the biological pump.

Data from this suite of sensors also will allow hypotheses to be tested for lower and upper trophic levels, including plankton, fish (e.g., the optimal “window” of water column stability; Gargett, 1997), and whales. Information on episodic small-scale physical-biological interactions will provide critical information for understanding non-linear ecosystem dynamics and their affect on elemental flux to depth or transfer to upper trophic levels. Passive and active acoustics will provide much needed information on fish and marine mammal distributions and their behavior in relation to prey. The near real-time data return, two-way communication, and adaptive capability of the winched profiler will allow experiments to be performed during storms (i.e., assess deep mixing, gas exchange, nutrient injection, biological response), transient physical mesoscale activity such as eddies (i.e., assess irradiance, nutrients, and biological response) or during vent megaplume events (i.e., assess chemistry, biological response), intermittent small-scale activity (e.g., planktonic thin layers), individually or simultaneously at different nodes, over a broad remote region of the ocean that cannot be comprehensively sampled by ships. Furthermore, the information will be important for validating satellite remote sensing data and for parameterizing models.

Additional sensors are urgently needed to measure other priority analytes, such as phosphate, silicate, and iron, and combined carbon system parameters (i.e., pH, pCO_2, plus total alkalinity). These parameters are important for assessing the role of the ocean as a source or sink of CO_2, carbon sequestration in the ocean, ocean acidification, and understanding the underlying factors contributing to ecosystem regime shifts and other environmental changes. A number of sensors capable of measuring these parameters are currently undergoing additional development so that they will be capable of long deployment and likely will be available for the installation of the RCO (Daly et al., 2004). *In addition a combination of acoustic and optical imaging is strongly recommended.* Observations of organisms along with physical and chemical measurements need to be made at the space and time scales relevant to an organism's behavior and physiology. Optical sensors resolve targets at small spatial scales (μm to m), while acoustics is the only method available that can detect zooplankton and fish over large spatial scales (cm to km) and provide a visualization of biophysical interactions. Assuming that all sensors detect representative distributions of aquatic organisms, the integration of acoustic and optic instruments on the same platform provides "groundtruthing" of acoustic targets and extends the range of optical sensors. Density and abundance estimates are expected to differ between the two types of sensors but data channels from the two sensor types will be used to examine different size classes of organisms and map fluctuations in population abundances over time. There are several promising optical imaging technologies (e.g., SIPPER, http://www.marine.usf.edu/sipper; and holographic systems) that should be available for extended deployments in the next few years and therefore are incorporated here.

There are many other sensors that will be useful for more specific experiments. For example, mass spectrometers, flow cytometers, and automated species-detection using molecular probes (e.g., Environmental Sample Processor (ESP), http://www.mbari.org/microbial/ESP), which are in various stages of development, will greatly enhance the basic set of measurements by providing information on nanomolar chemical concentrations and identification of dominant biota.

Deep water-column sensors

Profiler 200 - 600 m – A reduced set of sensors is requested for the profiler for this depth range to assess carbon flux, zooplankton vertical migration, plankton and particle dynamics in the so-called mesopelagic "twilight" zone, and to assess deep-dwelling fish and squid. The primary sensors here are a CTD, ACM, pH, O_2, CO_2, optics for particle size distribution (i.e., small vs. large phytoplankton, marine snow aggregates; e.g., LIST) and a fluorometer (phytoplankton vs.

detrital sinking particles), a zooplankton acoustic echosounder, and a broadband hydrophone (synthetic acoustic aperture for tomography and ambient sound). Even though about 90% of the sedimenting particulate flux disappears within these depths, the biology and chemistry of this depth region is poorly known. This depth region also is characterized by a deep scattering layer composed of a number of zooplankton, primarily copepods and euphausiids, and fish and squid. The diel vertical migration of these animals is likely one important source of the particulate and dissolved flux. In addition, some whales routinely feed at these depths (e.g., sperm and beaked whales). The RCO provides the opportunity to observe basic patterns and their variation and to guide other hypotheses and experimentation.

Node at 600 m - An in-line mooring "node" at ~600 m will support a CTD, pH, O_2, and CO_2 sensors, an optical backscatter sensor and a fluorometer, an upward-looking (splitbeam 38 kHz) and a downward-looking fish echosounder (18 kHz, 4,000 m range), and acoustic tomography transceivers. The use of upward- and downward-looking fish echosounders will provide entire, or nearly entire, insonification of pelagic biomass throughout the water column.

It is important to note that the acoustic tomography component also is called for in the Barth et al. RFA response. The acoustic tomography transceivers can remotely sense the ocean *between* the moorings providing the large scale, low wavenumber velocity and temperature fields (Fig. 3), and thus the context for interpreting the high resolution (in the vertical) profiling measurements at each site. Individual fixed paths between transceivers give temperature and absolute velocity averaged along the path. One-way/average travel time measured along a path gives sound speed (temperature), while reciprocal travel times (in each direction) give velocity (sound travels faster with a current than against). For an array, many paths at many horizontal angles are used to reconstruct the fields of interest using inverse methods. The measurement is fundamentally synoptic at the speed of sound (1500 m/s). These methods are the only way to obtain direct, large-scale, low-noise vorticity measurements. As the number of instruments N increases, the number of paths (data) to the other instruments grows as N^2, a result achievable now with the multi-node RCO infrastructure. In Figure 2 with 10 transceivers, there are ~30 paths drawn. Given a nominal area of 500 km X 1000 km, the resolution is about 130 km. In this region, the amount of depth dependent information will range between two and four independent measurements per horizontal path, and will depend on the details of the acoustic propagation (e.g., the bathymetry and the seasonal sound-speed structure).

Profiler 600 m to sea floor – The profiler will carry a CTD, an ACM, pH and O_2 sensors, optics for particle size distribution, a fluorometer (detection of sedimenting particles), acoustics for zooplankton, and a broadband hydrophone. Deep zooplankton scattering layers have been observed between 400 and 900 m depth in this region and also in the vicinity of hydrothermal plumes at 1200-1900 m (Burd & Thomson, 1995). The diel vertical migration of these small (mm) animals is one the greatest migrations undertaken within the animal world. Little is known about the dynamics or behavior of the organisms comprising deep-scattering layers. This depth region also remains largely unexplored throughout the world's oceans. Use of these sensors for ocean mixing experiments is described in the section below.

Bottom sensors

It is important that measurements be made near the ocean bottom for much of the research proposed here (i.e., within a few meters and without the observations being disturbed by the measurement platform). **Near-bottom instrumentation** should include a CTD, a 300 kHz

VADCP (for turbulence measurements), an upward-looking 75 kHz ADCP (longer-range velocity profiles), an inverted echosounder (to measure heat content and baroclinic currents), a horizontal electrometer (to measure barotropic currents), an optical backscatter sensor (suspended particle load), and a fluorometer. Bottom-boundary layer measurements should be made on a stable platform. These measurements will be cross calibrated with those on the profiler.

Bottom pressure, horizontal electric fields, and seafloor-to-sea surface acoustic travel time are what have been termed integrating variables because they are dominated by the currents and thermal variability with the largest vertical scales (and sometimes the largest horizontal scales). As such, these variables are ideal for observing the meso- to gyre-scale variations of the ocean circulation that are most likely related to climate change. In a currently funded NSF project (Sanford & Luther) a new electric-field sensor is being integrated with the IES plus Pb instrument (called PIES) developed by R. Watts at URI; the combination is called HPIES (pronounced h-pies). In the next two years instruments will be tested in Puget Sound and then at a deep-ocean site, such as the Hawaii Ocean Time-series (HOT), for long-term evaluation.

4.2.2 Sensor Network Infrastructure

The purpose of the moored sensor network infrastructure is to distribute power and provide communication and timing capability in support of the instruments and sensing systems throughout the water column. (See Appendix for a sample power budget from the MARS profiling mooring, as well as system diagrams.)

Upper-ocean profiler - The upper-ocean profiler (Fig. 9) is currently being developed (Barth et al.) and will consist of a completely self-contained, modularly integrated sensor, instrument controller, winch, power and telemetry system and a biofouling-resistant and hydrodynamic profiling platform. The mooring and RCO infrastructure will enable nearly continuous profiling and direct communication with shoreside computers and remote programming/control of system operations. These real-time connections will allow data from these sensors to be used to control adaptive sampling by the imaging optical sensors, molecular probe samplers, and flow cytometers (Babin et al., 2005).

Deep-ocean profiler - The moorings will have two deep-ocean profilers covering the water column on each side of the tomography transceiver situated at ~ 600 m, one between 200 m and 600 m and the second between 600 m and the bottom (~2000 m - ~3000 m in the NEPTUNE area). When a profiler is docked at one end of its travel, a docking station with an inductive coupler will transfer power from the cabled mooring system to the profiler (currently a McLane moored profiler, MMP). The MMP has had more than 20 successful 1- to 2-year deployments on different moorings in a variety of environments and, therefore, is a proven technology. Additional development (see below), however, is needed to build a more robust device capable of handling a larger number of sensors. A MMP-type profiler will permit near-continuous profiling (>90 % duty cycle), at 0.25 m s^{-1}. Further, inductive communications will be used to offload profiler data at modest rates in real-time; this crucial feature will enable true adaptive sampling capability. Having many of the same sensors on the profiler and at the fixed endpoints top and bottom will provide cross-calibration and improved overall robustness.

Secondary junction boxes - J-boxes will be placed on the subsurface float, the mid-water in-line node, and on the seafloor immediately adjacent to the mooring. The J-boxes provide access via

ROV-mateable connectors to the 400 V / 100 Mb/s / 1 μs mooring network backbone. On each J-box, several ROV-mateable connector ports (or more, as needed or anticipated) will be provided. The same ports will be used to link to the backbone system as well as used for sensors; if for sensors, ports will also provide 48 V and the precise timing signal. A micro-controller will communicate with the shore power and communication control systems; the J-box itself will be an instrument in this context. For communications, a high-reliability commercial Ethernet switch will be used that takes multiple input/outputs and sends the packets to the appropriate locations, whether commands to instruments or data going to the scientist and the data archive on shore. The user 48 V and 400 V power supplies will have ground fault and overcurrent protection. Packaging will be based on the ALOHA/MARS experience, using titanium and plastic, with connector manifolds constructed for easy ROV access and service.

Science Instrument Interface Modules (SIIMS) - Each connector on a junction box will have 400V and 48V and 10/100baseT Ethernet; this is the standard that is evolving for cabled ocean observatories (Maffei et al., 2001). The interfaces to the other sensors will be modified using "science instrument interface modules" (SIIMS) that will convert to the standard, as well as serving as local multiplexers. The interface module will append metadata (e.g., serial number, calibration coefficients, etc.) to the main data stream from a sensor if necessary.

Mooring cable and components - The mooring cable has 6 #18 conductors with polyethylene insulation for long immersion, 4 loose fibers in a 2-mm diameter steel tube (3 spare), Kevlar strength member, armor wires (for fish bite protection) enclosed in a polyurethane jacket, and an overall diameter of 21 mm. The Kevlar strength member is the expensive part of the cable; it is necessary to keep elongation within the limits set by the optical fibers. To prevent the build up of torsional stress, swivels (e-o-m) will be used at the mid-water node and at the top beneath the subsurface float.

Subsurface float and platform - The 2-m diameter disc-shaped syntactic foam float will serve as the platform for sensors, the upper-ocean profiler winch, and the J-box (Fig. 9). With the available power and communications, the ADCP and other acoustic sensors can be run at their maximum ping rates and the winched profiler is feasible and can run continuously (limited only by fatigue and reliability concerns). The instrument mounts on the float will permit addition, removal, and servicing of sensors and the other components by ROV (designed with the direct involvement of MBARI ROV pilots). This type of disc buoy provides 2000 lb of buoyancy resulting in a taut mooring to minimize horizontal and vertical motion. It has been used with success for the last 20 years for ocean acoustic tomography moorings. Vertical hydrophone arrays (VLAs, 1-inch electromechanical cable) off Point Sur, California, had typical horizontal displacements at tidal frequencies of 30 m (water depth 1800 m). Just to the south of the island of Hawaii in 5000 m water depth, a similar VLA had typical horizontal displacements of 100 m. We have modeled the effects of surface gravity waves on the mooring. The vertical float velocity for float depths of 40, 100, and 200 m is estimated to be 20, 7, and 0.05 cm s^{-1} rms, respectively. We have chosen 200 m as a compromise taking into account wave stresses, wear on the profilers, ranges of ADCPs and other devices, float attitude and impact on ADCP and other data, light levels and biofouling, mixed layer depths, and expected lifetime. The platform provides the capability of adding additional sensors and infrastructure (such as an AUV dock) using an ROV leaving the mooring in place.

Mid-water in-line node at 600 m - As mentioned above, a platform similar to the subsurface float will be inserted in the mooring cable at 600 m to support a secondary junction box and fixed instrumentation.

Seafloor cable - An electro-optical-mechanical cable will connect the RCO primary node port to the port on the seafloor secondary J-box. Because the ports are all electrical, at each end of the cable in a small pressure case, in-line media converters will convert the RCO electrical ethernet communications protocol to/from the optical domain, necessary for high data rates and the 2-km distance to the mooring. This 2-km electro-optical cable will be deployed using a special ROV tool sled (already demonstrated by MBARI, JAMSTEC, and the oil industry) between the RCO J-box and secondary J-box at the base of the mooring. Short cables then connect the J-box to the connector at the base of the mooring and the local instruments. This will be demonstrated with the ALOHA/MARS mooring in 2006.

Power and data budgets - The amount of power that can be delivered to the various loads along the mooring system depends on the cable resistance, voltage, and current, and the need to keep voltages above 250 V, at which point the dc-dc converters drop out. As an example, the power budget for the ALOHA/MARS mooring currently being developed is given in the adjacent table. It has a total cable length of 3.5 km, and one profiler that draws 321 W when charging (average, 32 W). The major loads for the moorings proposed here are two profilers (average, 64 W), the winched profiler (70 W) and the acoustic tomography source (~200 W when transmitting). A combination of adding more copper (easy and inexpensive) to the cables, scheduling major loads to not conflict, and providing energy storage (e.g., rechargeable batteries or ultracapacitors for peak loads) will be used, in that order.

Estimated power requirements for profiling mooring	
	Power (W)
Fixed Sensors	82
Moored profiler charging	321
Guest ports	296
Hotel load	59
System losses	442
Totals	1200

Data rates are modest and will not stress the RCO system (but would any other). The current maximum rate requirement is for the broadband hydrophones at ~ 10 Mb/s. There is adequate margin for additional sensors and network components, both for power and communications.

Command and control - At the most basic level, the moored sensor network control system (which may simply be a scaled version of the higher level observatory control system) on shore will monitor voltages, currents, ground faults, etc., throughout the sensor network so that it can take corrective action if necessary, such as opening a breaker on a particular J-box connector. Given power and communications "contracts" with the different users (which may change dynamically given adaptive sampling), it will determine if there are conflicts and be the ultimate arbiter; this will be especially important in coordinating the operation of the profilers and the acoustic transmitters, and (possibly) the ultra-capacitor energy storage, given the finite amount of power available far from the RCO node.

Instrument command and control capabilities are essential for realizing the observational power of the proposed sensor network and the adaptive sampling. Real-time sensor status will be essential for monitoring the sensor and platform performance, and the ability to change profiler programming will be used to diagnose, possibly even overcome, profiler system crises (e.g., fouling of the mooring line). Sensor/system failure detection will trigger alerts with mooring managers and PIs. To facilitate two-way communication with nearby autonomous instruments and mobile platforms, acoustic modems will be distributed at the fixed points on the mooring and seafloor.

Further development - For more effective use of the regional cabled observatory, the following additional developments over the next ~5 years will be necessary. For the ALOHA/MARS 2006 deployment of the deep profiler: high-rate inductive (or other) communications at every docking; increase speed to 0.4 m s^{-1}; increase the payload capacity (weight, volume, power, communications); and modify so it can dock top and/or bottom to provide more flexibility and robustness, or multiple ones on a mooring; make all active components ROV serviceable, especially the profiler (replaceable); interface the upper ocean profiler winch system to sit on the subsurface float, extending the observatory infrastructure to the surface; develop energy storage capability on mooring/seafloor to accommodate high peak loads (such as AUV battery charging, video lights, pumping, or for autonomous operation); interface many sensors, including: acoustic (hydrophones, ADCPs, acoustic lens, modems, etc), physical, bio-optic, chemical, biological, video, etc.; deal with biofouling issues; conduct extensive testing to improve survivability and reliability, while reducing cost; and work on more energy efficient profiler, perhaps buoyancy driven (see http://www.oceanorigo.com).

A plan also needs to be developed to integrate and coordinate all acoustic systems within the ocean observatories (navigation, communication, fish, passive) by documenting existing and future applications, defining the layout of elements, establishing standards and interfaces that will be essential to unify the field (e.g., signal protocols), and providing the mechanism for managing the acoustic spectrum. *In addition, development is needed for a broad-purpose acoustic package that would accommodate a wide range of science objectives to decrease the number of deployed sensors.*

4.3. Other Proposed Sensor Platforms

Deep-sea buoys - (proposed in several RFA responses). Two deep-sea buoys are being proposed to be located in the subpolar gyre (Papa 50°N, 145°W) and directly to the south in the subtropical gyre (Uncle 40°N, 145°W). Meteorological observations will be helpful for improving atmospheric circulation models, the output from which is important as the driving force for regional ocean circulation and ecosystem models of the northeast Pacific. Observations in the upper 1000 m of the water column of temperature, salinity, velocity, chlorophyll fluorescence, light backscatter, nutrients (nitrate) and dissolved oxygen will provide the far-field values necessary for tracking the low-frequency changes in source water characteristics for the eastern North Pacific. These deep-sea buoys will provide important information for comparing and contrasting upper-ocean ecology in the two gyre systems.

Autonomous Vehicles - (proposed in RFA response by Barth et al.). Autonomous underwater vehicle gliders are being proposed to obtain long-term, repeated measurements of upper-ocean volume transport and water property flux. The proposed set of east-west and north-south lines forming a control volume is shown as they extend from the northeast Pacific continental margin to the edge of the proposed regional cabled observatory on the Juan de Fuca plate (Fig. 2). This will expand the spatial measurements of the fixed sites. The four E-W glider lines are each 400-500 km long and can be transited in 16-20 days at glider speeds of 25 km/d. A N-S line along 130°W will close the control volume and measure the east-west transport of water and the material it contains in the North Pacific Current. The 41.9°N line will not only allow estimates of the flux of coastal water and the material it contains into the CCS, but also serves to set the upstream boundary conditions for the northeast Pacific during winter when the Davidson Current adjacent to the coast is flowing northward. By using multiple gliders, we can obtain at least monthly measurements along these lines, sufficient to address our scientific objectives regarding the seasonal and interannual variations in ecosystem response to physical forcing. Gliders must be capable of operating for at least 3 months, sampling to at least 1000 m and capable of carrying the following sensors: temperature, conductivity, pressure, chlorophyll fluorescence, dissolved organic matter fluorescence, and optical backscatter.

4.4. Models: An Integrative and Decision-Making Tool

The integration of observations with physical circulation and ecosystem models is critical to the success of ocean observing system science. Models will be important in formulating hypotheses that will be tested using the Ocean Observatories Initiative (OOI) infrastructure, they will be used to determine the time and space scales over which ocean phenomena need to be sampled, and they will be an important tool for integrating multiscale, interdisciplinary data collected across all OOI components. OSSEs (Observational System Simulation Experiments) are expected to be important in planning for the OOI, where prognostic models with known dynamics are interfaced with hypothetical space-time sampling schemes to understand what measurements (when incorporated into the model) will yield optimal coverage. OSSEs also can be used to make informed cost-benefit analyses that allow intelligent tradeoffs between using limited resources and obtaining optimal results within realistically constrained budgets.

Because the ocean will always be undersampled, models will be an essential tool to synthesize the available field data and extrapolate it to a full 4-D real-time view. Data assimilative modeling of parameters obtained from observatories in near real-time will be an essential tool for ship-based experiments to determine where and when to sample ocean processes. Modeling also can be used for retrospective studies, since we cannot go back in time to make additional measurements to understand a set of observations.

Model forecasting will be another essential application to address questions related to national security, hazardous waste spills, tsunami prediction, and marine resource management. In analogy with synoptic and long-range weather forecasts provided for marine transport, aviation, agriculture, and other sectors of the economy, the data obtained from the RCO will help develop the capacity to predict tidal currents, ocean circulation, water-property structure, ecosystem variability, and other types of oceanic change for the waters of the northeast Pacific. Modeling research will involve the development of advanced numerical models capable of providing data assimilating nowcasts and forecasts of oceanographic properties from days to years and decades.

It is important to note that the northeast Pacific region has been the focus of extensive modeling efforts owing to several recent oceanographic programs (e.g., GLOBEC, CoOP), thus providing a foundation for observatory science. Further development of models is needed to link basin-scale models with nested coastal models having a higher grid resolution, to improve parameterization of boundary conditions, especially for coastal and bottom regions, to improve subgrid-scale parameterizations, and to link coupled physical-biological models, and ecosystem models. Tremendous progress has been made in recent years and is continuing. For example, currently under development is a 3-dimensional variational data assimilation method (3DVar) that will be incorporated into an operational ROMS forecast system. The 3DVar has been implemented in major meteorological centers, but not yet been applied to coastal oceanic forecast system. The 3DVar is selected because it can propagate observational information, which is often sporadically and irregularly distributed, in both horizontal and vertical directions. In addition, web-based modeling tools need to be developed that would allow the visualization of data and model output for data exploration and hypothesis testing.

5. PROJECT MANAGEMENT CONSIDERATIONS

The ORION program and the ocean community will need to carefully consider how best to manage the overall observatory enterprise, as well as a community experiment project such as the one proposed here. This is a large project by oceanographic standards. It will be embedded within an even larger project, the ORION/OOI regional observatory (including the RCO and coastal components, extending to basin), and then finally the entire ORION program. It is daunting. To make it tractable, the right level of modularity in the management is required, and we recommend a fair degree of local autonomy.

In the large context, the complete decadal time-scale community experiment science project includes:

- Project management (science and engineering) – includes the internal organization of the subtasks as well as the external coordination with other programs. A project like this truly forces (hopefully marries) the disciplines together. The external coordination will be especially important, as the only way a project of this magnitude will succeed is to find synergies with other projects and even with other sponsors to share the burden.
- Field/instrumentation/operations and maintenance – these form a major part of this conceptual proposal (and the budget). As described in the budget justification, the formation of an engineering project group with long-term continuity will be essential. Several workshop reports recommended establishing a dedicated instrument facility to maintain and calibrate sensors and associated support infrastructure. As for project management, it will be necessary to coordinate and share common activities with other projects.
- Data quality control and handling – we assume ORION will provide for the design and implementation of a Data Management and Archiving System (DMAS); the LOOKING project, within NSF's Information Technology Research Program, is a step in this direction. Our task will be to help define the requirements for it. Given a DMAS, it will still be the responsibility of this community experiment to implement quality control procedures for its data. Given the large number (60) of diverse sensors per mooring and ~12 moorings, the mechanical aspects of maintaining all of them could be daunting and could force new methodologies; there will be a learning curve! Some of us have dealt with real-time data streams and with trying to produce near-real time products. It is not easy and adequate resources must be available.
- Data analysis – there must be a cadre of scientists, post-docs, and students looking at the raw data and then processing and analyzing these data to extract the obvious pearls, perhaps exploratory in nature, perhaps looking at some phenomena to puzzle out the first simple models.
- Modeling and data assimilation – existing models must be continually refined and tuned and new ones developed, especially true for chemistry, biology (including higher trophic

levels), and biogeochemistry, rigorously combining the data and models to constantly find weak points in the latter.

- Integration and synthesis – a high-level goal of ORION (we believe) is to understand the Earth as one intricately coupled system. This begins with understanding all the coupling between the various phenomena within the regional observatory (e.g., from atmosphere through the water column into the deep Earth). A major assumption behind the establishment of the regional observatory is that phenomena acting on this scale can directly translate to other locations. Thus, we will need to use (sparser) results on the global scale to confirm this.
- Education and outreach activities are spread throughout the effort, but require the side-by-side work of scientists with education professionals.

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7. BIOGRAPHICAL SKETCHES

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A. PROFESSIONAL PREPARATION

University of Colorado, Physics (Cum Laude), B.A., 1982

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B. APPOINTMENTS

Professor, COAS, OSU (2001-present)
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Associate Professor (Senior Research), COAS, OSU (1995-1996)
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Research Associate (Postdoctoral), College of Oceanography, Oregon State University (1987-1989)

C. PUBLICATIONS

Most Closely Related to Proposed Project

Barth, J. A. (1994) Short-wavelength instabilities on coastal jets and fronts, Journal of Geophysical Research, 99:16095-16115.
Shearman, R. K., J. A. Barth and P. M. Kosro (1999) Diagnosis of the three-dimensional circulation associated with mesoscale motion in the California Current, Journal of Physical Oceanography, 29:651-670.
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Other Significant Publications

Barth, J. A., T. J. Cowles, P. M. Kosro, R. K. Shearman, A. Huyer and R. L. Smith (2002) Injection of carbon from the shelf to offshore beneath the euphotic zone in the California Current, Journal of Geophysical Research, 107(C6), 3057, doi:10.1029/2001JC000956.
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D. SYNERGISTIC ACTIVITIES

- Participant in science planning activities: Global Ocean Ecosystems Dynamics Eastern Boundary Current Program Implementation Team, 1993-1994; NSF Coastal Ocean Processes (CoOP) Wind-Driven Transport Experiment Planning, 1993; NSF Advances and Primary Research Opportunities in Physical Oceanography Studies Workshop Steering Committee, 1997-1998;

Coastal Ocean Processes and Observations: Advancing Coastal Research, CoOP Observatory Science Workshop Organizing Committee, 2002; Coastal Observatory Research Arrays Meeting Organizing Committee, 2003.

- Public science lectures: Active participant in Operation Pathfinder Teacher Education Program, OSU Hatfield Marine Science Center, Newport, OR; Presentations at local elementary schools and mentoring of Boy Scouts on Oceanography Merit Badge; Led public tours of R/V Wecoma, R/V Thomas G. Thompson and R/V Roger Revelle as part of COAST and GLOBEC NEP (2001-2002).
- Input to ocean policy: Oregon Ocean Policy Advisory Council Dialogue With Experts, Newport, OR, February 2002; Coastal Processes and Ballast Water Workshop, Pacific States Marine Fisheries Commission, Gladstone, OR, March 2002; Review Panel Member for Huntington State Beach, CA, Shoreline Contamination Study, 2002-2003.
- Leadership of national programs: Global Ocean Ecosystems Dynamics Northeast Pacific Program Exec. Comm., 2000-present; NSF Coastal Ocean Processes (CoOP) Steering Comm., 2000-2004; Pacific Coast Ocean Observing System (PaCOOS) Board of Governors, 2003-present; NSF ORION Executive Steering Committee, 2004-present.
- Service to scientific community: National Center for Atmospheric Research Scientific Computing Division Advisory Panel, 1992-1994; Eastern Pacific Oceanic Conference (EPOC), Secretary, 1992-1996, President, 1998-2001; NSF Physical Oceanography Panel, Nov. 1995.

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AWARDS

1996, Lew Allen Award for Excellence, Jet Propulsion Laboratory
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RECENT RELEVANT PUBLICATIONS**:**

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Five most relevant publications:

1998 Cowles, T.J., R.A. Desiderio, and M-E. Carr. Small-scale planktonic structure: persistence and trophic consequences. *Oceanography* 11: 4-9

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2002 Barth, J.A., T.J. Cowles, P.M. Kosro, R.K. Shearman, A. Huyer, and R.L. Smith. Injection of carbon from the shelf to offshore beneath the euphotic zone in the California Current. *J. Geophys. Res.* 107: (C6), doi:10.1029/2001JC000956.

2003 Cowles, T.J. Planktonic layers: physical and biological interactions on the small scale. In: *Handbook of Scaling Methods in Aquatic Ecology: Measurements, Analysis, Simulation.* CRC Press, Boca Raton, FL. , pp 31-49.

2005 Barth, J.A., S. D. Pierce, and T.J. Cowles. Mesoscale structure and its seasonal evolution in the Northern California Current System. *Deep-Sea Research II*: *in press*

Five other publications:

1993 Cowles, T.J., R.A. Desiderio, and S. Neuer. *In situ* characterization of phytoplankton from vertical profiles of fluorescence emission spectra. *Mar. Biol*. 115: 217-222

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C. PUBLICATIONS RELATED TO PROPOSED RESEARCH

Daly, K.L., R.H. Byrne, A.G. Dickson, S.M. Gallager, M.J. Perry, and M.K. Tivey. 2004. Chemical and biological sensors for time-series research: Current status and new directions. *Marine Technology Society Journal* 38 (2):122-144.

DiTullio, G.R., M.E. Geesey, D.R. Jones, K.L Daly, L. Campbell, and W.O. Smith, Jr. 2003. Phytoplankton assemblage structure and primary productivity along 170ºW in the South Pacific Ocean. *Marine Ecology Progress Series* 255: 55-80.

Daly, K.L., W.O. Smith, Jr., G.C. Johnson, G.R. DiTullio, D.R. Jones, C.W. Mordy, R. A. Feely, D.A. Hansell, and J.-Z. Zhang. 2001. Hydrography, nutrients, and particulate and dissolved carbon pools in the pacific sector of the Southern Ocean: Implications for carbon flux. *Journal of Geophysical Research* 106: 7107-7124.

Daly, K.L. 2000. Sensor technology for remote, interactive aquatic experiments. *EOS* 81: 580.

Daly, K.L. and WO Smith, Jr. 1993. Physical-biological interactions influencing marine plankton production. *Annual Review in Ecology and. Systematics* 24: 555-585.

ADDITIONAL PUBLICATIONS

Daly, K.L. 2004. Overwintering growth and development of larval *Euphausia superba*: An interannual comparison under varying environmental conditions west of the Antarctic Peninsula. *Deep-Sea Research* II 51: 2139-2168.

Daly, K.L., D.W.R. Wallace, W.O. Smith, Jr., A. Skoog, R. Lara, M. Gosselin, E. Falck, and P.L. Yager. 1999. Non-Redfield carbon and nitrogen cycling in the Arctic: Effects of ecosystem structure and dynamics. *Journal of Geophysical Research* 104: 3185-3199.

Daly, K.L. 1998. Physioecology of juvenile Antarctic krill (*Euphausia superba*) during spring in ice-covered seas, edited by M. Lizotte and K. Arrigo, Antarctic Sea Ice: Biological Processes. *AGU Antarctic Research. Ser*ies 73: 183-198.

Daly, K.L. 1997. Flux of particulate matter through copepods in the Northeast Water Polynya. *Journal of Marine Systems* 10: 319-342.
Macaulay, M., K. Wishner, and K.L. Daly. 1995. Acoustic scattering from zooplankton and micronekton in relation to a whale feeding site near Georges Bank and Cape Cod. *Continental Shelf Research* 15: 509-537.

D. RECENT SYNERGISTIC ACTIVITIES

Developed Ocean Sensor Database as a web resource for the ocean science community (http://sensors.marine.usf.edu).
Member, GLOBEC National Executive Steering Committee and Science Steering Committee (2002-present)
Member, ORION Executive Steering Committee (advisory committee for the NSF Ocean Observatories Initiative) (2004-present)
Chair, ORION Sensor/Technology Subcommittee (2004-present)
Member, Steering Committee for the NSF Ocean Research Interactive Observing Networks (ORION) Workshop, January 2004, Puerto Rico.
Organizing Committee for "Coastal Ocean Processes and Observatories: Developing a New Vision for Coastal Research", May 2002, Coastal Ocean Processes Program (CoOP) workshop.

E. COLLABORATORS (other than co-authors listed above)

R. Beardsley (WHOI), D. Chu (WHOI), G. Flierl (MIT), R. Harvey (CBL), E. Hofmann (ODU), M. Jech (NMFS), S.J. Ju (CBL), J. Klinck (ODU), E. Pakhomov (UBC), P. Wiebe (WHOI), M. Zhou (UMass).

ADVISEES

K. Scolardi (M.S. 2004), Kelly Kowal (M.S.), Sarah Luchessi (M.S.), Adam Spear (M.S.), Katie Rathmell (M.S.), Marina Marrari (Ph.D.)

ADVISORS

L. Cooper (Oak Ridge National Laboratory), R.C. Francis (University of Washington), W.O. Smith, Jr. (University of Tennessee)

Grant B. Deane

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University of California, San Diego
San Diego, CA 92093-0238

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(858) 534-7641 (fax)
email: gdeane@ucsd.edu

a. Degrees and Honors:

University of Auckland, NZ, B.Sc., Physics, 1982
University of Auckland, NZ, M.Sc. (with honors), Physics, 1983
Oxford University, England, D.Phil., Mathematics, 1989
A.B. Wood Medal jointly awarded by the Acoustical Society of America, USA and the Institute of Acoustics, UK in 1997.

b. Professional Appointments:

July 2004 to present	Marine Physical Lab SIO	Scripps Institution of Oceanography, UCSD La Jolla, CA	Research Oceanographer
July 2000 to June 2004	Marine Physical Lab SIO	Scripps Institution of Oceanography, UCSD La Jolla, CA	Assoc. Research Oceanographer
April 1995 to June 2000	Marine Physical Lab SIO	Scripps Institution of Oceanography, UCSD La Jolla, CA	Assistant Research Oceanographer
Nov 1992 to March 1995	Marine Physical Lab SIO	Scripps Institution of Oceanography, UCSD La Jolla, CA	Assist. Project Sci. II Assist. Project Sci. III
Nov 1991 to Oct 1990	Marine Physical Lab SIO	Scripps Institution of Oceanography, UCSD La Jolla, CA	Postgraduate Res. VIII
Nov 1990 to Oct 1991	Marine Physical Lab SIO	Scripps Institution of Oceanography, UCSD La Jolla, CA	Postgraduate Res. VII

c. Publications:

i) Relevant to the proposal

Deane, G. B. and M. D. Stokes, Scale dependence of bubble creation mechanisms in breaking waves, Nature 418, 839-844 (2002).

Stokes, M.D., G.B. Deane, S. Vagel and D.M. Farmer, Measurements of large bubbles in open-ocean whitecaps, in Gas Transfer at Water Surfaces, Donelan, M.A., W.M. Drennan, E.S. Saltzman and R. Wanninkhof, eds. *Geophysical Monographs* 127, 279-284 (2001).

Deane, G. B. and M. Dale Stokes, Air entrainment processes and bubble size distributions in the surf zone. Journal of Physical Oceanography 29, 1393-1403 (1999).

Farmer, D. M., G. B. Deane and S. Vagle, The influence of bubble clouds on acoustic propagation in the surf zone, IEEE Journal of Oceanic Engineering 26, 113-124 (2001).

Deane, G. B., Sound generation and air-entrainment by breaking waves in the surf zone, Journal of the Acoustical Society of America 102(5), Pt. 1, 2671-2689 (1997).

ii) Additional significant publications

Stokes, M.D., G.B. Deane, M.I. Latz and J. Rohr, Bioluminescence Imaging of Wave-Induced Turbulence, J. Geo. Res. – Oceans 109, 1871-1880 (2004)

Deane, G. B., 'Long time-base observations of surf noise. J. Acoust. Soc. Am. 107(2) 758-770 (2000).

Deane, G. B., A model for the horizontal directionality of breaking wave noise in the surf zone, Journal of the Acoustical Society of America 107(1), 177-192 (2000).

Dantkzer, M. S., G. B. Deane and J. W. Bradbury, Directional acoustic radiation in the strut display of male sage grouse *Centrocercus Urophasianus*, The Journal of Experimental Biology 202, 2893-2909 (1999).

Deane, G.B., Acoustic hot-spots and breaking wave noise in the surf zone, J. Acoust. Soc. Am. 105 3151-3167 (1999).

d. Synergistic Activities:

I am a Fellow of the Acoustical Society of America, and serve on the Acoustical Oceanography and Underwater Acoustics Technical Committees of that society. I review papers for the Acoustical Society of America, IEEE Journal of Oceanic Engineering, The Journal of Sound and Vibration, The Journal of Computational Acoustics, the Journal of Physical Oceanography, the Royal Society, and review proposals for the National Science Foundation, MIT's Department of Mechanical Engineering and the U.S. Civilian Research & Development Foundation. I am also an associate editor for Acoustic Research Letters Online, a publication of the Acoustical Society of America.

e. Collaborators:

(i) Dr. J. Preisig, Woods Hole Oceanographic Institution
Dr. Chris Tindle, University of Auckland, New Zealand.
Dr. M. D. Stokes, Scripps Institution of Oceanography, UCSD
Dr. J. Leichter, Scripps Institution of Oceanography, UCSD
Dr. M. Latz, Scripps Institution of Oceanography, UCSD
Dr. M J. Buckingham, Scripps Institution of Oceanography, UCSD
Dr. S. Vagle, Institute of Ocean Sciences, Canada
Dr. M. Johnson, Woods Hole Oceanographic Institution
Dr. D. Cato, Defense Scientific and Technology Organization, Australia
Dr. D. M. Farmer, University of Rhode Island
Dr. K. Commander, Coastal Systems Station, Panama City
Mr. Tom Weber, Penn State University, Penn State
Dr. Tony Lyons, Penn State University, Penn State

(ii) Graduate and Postdoctoral Advisors
Masters. Dr. Chris Tindle, Physics Department, Auckland University, New Zealand
D.Phil. Prof. Les Woods, Mathematics Department, Oxford University, England

BIOGRAPHICAL SKETCH

John R. Delaney

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PROFESSIONAL PREPARATION

Ph.D.	1977	Geology	University of Arizona
M.S.	1967	Geology	University of Virginia
B.A.	1964	Geology	Lehigh University

APPOINTMENTS

1988-present	Professor, School of Oceanography, University of Washington
1983-1988	Associate Professor, School of Oceanography, University of Washington
1982-1983	Research Associate Professor, School of Oceanography, University of Washington
1977-1982	Research Assistant Professor, School of Oceanography, University of Washington
1977-1980	Visiting Scientist, Lunar and Planetary Institute and Johnson Space Center
1968-1972	Mineral Exploration Geologist & Graduate Student, Tucson, Arizona
1965-1967	Mineral Exploration Geologist, North American Exploration, Inc., Charlottesville, VA

SCIENTIFIC EXPEDITIONS

1980-2004	26 cruises as Chief Scientist, including 12 using Alvin, 4 using the Jason ROV and 5 using the Canadian ROPOS ROV.

PROFESSIONAL ACTIVITIES

1999-present	NEPTUNE Project, Chair and Program Director
2003-present	NASA Science Definition Team for the Jupiter Icy Moons Orbiter Mission.
1996	NASA Committee to plan the Europa Orbiter Mission.
1992-1994	NAE Committee on undersea vehicles and national needs, Member.
1990-1994	InterRidge, Chair.
1988-1992	RIDGE Steering Committee, Chair.
1987	NAS Workshop on the mid-oceanic ridge: a dynamic global system, Convener.
1985	NATO Advanced research institute on marine resource assessment.
1984-1987	NSF Oceanography panel, Marine geology and geophysics.
1985	Workshop on long-term ocean bottom observatories, Convener.
1983-1986	JOI U.S. Science advisory committee.
1983-1984	JOI U.S. Shipboard science sub-committee, Chairman.
1983-1987	JOIDES Lithosphere panel.
1983	Workshop on long-term ocean bottom observatories, Co-Convener.

FIVE MOST RELEVANT PUBLICATIONS

Kelley, D.S., J.A. Baross, **J.R. Delaney**, **2002** Volcanoes, Fluids, and Life at Mid-Ocean Ridge Spreading Centers. *Ann. Rev. Earth. Planet. Sci.,* 30, 385-491.

Karson, J.A., M.A. Tivey, and **J.R. Delaney 2002** Internal structure of uppermost oceanic crust along the western Blanco transform scarp; implications for subaxial accretion and deformation at the Juan de Fuca Ridge. *J. Geophys. Res.,* 107, 9-17.

Kelley, D.S**., J.R. Delaney**, and D.A. Yoerger, **2001** Geology and venting characteristics of the Mothra Hydrothermal Field, Endeavour Segment, Juan de Fuca Ridge, *Geology*, 29, 959-962.

Delaney, J.R., D.S. Kelley, M.D. Lilley, D.A. Butterfield, J.A. Baross, R.W. Embley and M. Summit, **1998**, The quantum event of oceanic crustal accretion: Impacts of diking at mid-ocean ridges, *Science,* 281, 222-230.

Wilcock, W. S. and **J. R. Delaney**, **1997**, Mid-ocean ridge sulfide deposits: Evidence for heat extraction from magma chambers or cracking fronts, *Earth Planet. Sc. Lett.,* 145, 49-64.

FIVE OTHER PUBLICATIONS

Delaney, J.R., D.S. Kelley, R.E. McDuff, D.A. Butterfield, M.D. Lilley, and .W.D. Wilcock, **2004,** Tidal Perturbations in High-Temperature Submarine Hydrothermal Systems. Final draft complete, to be submitted March, **2005** to *Earth. Planet. Sci. Lett.*

Schrenk M.O., D.S. Kelley, **J.R. Delaney,** J.A Baross **2003** Incidence and diversity of microorganisms within the walls of an active deep-sea sulfide chimney. *Appl. Enviro. Micro.,* 69, 3580-3592.

Thomson, Richard E. and **John R. Delaney, 2001**, Evidence for a weakly stratified Europan ocean sustained by seafloor heat flux, *J. Geophys. Res.,* 106 , 12,355-12365.

Delaney, J.R., D.S. Kelley, E. A. Mathez, D.R. Yoerger, J. Baross, M. Schrenk, M.K. Tivey, J. Kaye, V. Robigou, **2001** Edifice Rex Sulfide Recovery Project: Analysis of a Sulfide-Microbial Habitat from a Submarine Hydrothermal System, *EOS, Trans. Amer. Geophys. Union*, 82, 67-73.

Delaney, J.R., G.R. Heath, A.D. Chave, B.M. Howe, and H. Kirkham **2000**, NEPTUNE: Real-time ocean and earth sciences at the scale of a tectonic plate, *Oceanography*, 13, 71-83.

SYNERGISTIC ACTIVITIES

Chair and Program Director of NEPTUNE, a project that is developing a plate-scale ocean observatory in the northeast Pacific Ocean based on a heavily instrumented network of fiber-optic/power cables; Co-Director of REVEL, a program that provides middle- and high-school teachers with opportunities to participate in sea-going research; and development of novel instruments for hydrothermal vents research.

OTHER COLLABORATORS:

D. Yoerger, A. Chave, D. Butterfield, M. Lilley, R. Thomson, J.E. Dixon, A. Schultz, F.N., M. Tivey, D. Kadko, D. Stakes, E. DeLong, E. Mathez.

Graduate Advisor:

Dr. J. Ganguly, University of Arizona

GRADUATE STUDENTS ADVISED AND POSTDOCTORAL SCHOLARS HOSTED:

Students: V. Baht, A. Daly, B. Holmen, J. Karsten, D. Kelley, D. Naidoo, J. Palmer, C. Parker, M. Rovetta, M.K. Tivey, S. Veirs, K.F. Shaw, B. Kristall

Postdocs: P. Nehlig

BIOGRAPHICAL SKETCH

PERCY L. DONAGHAY
Graduate School of Oceanography
University of Rhode Island
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Born: February 23, 1946
SSN: 194-38-8447
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EDUCATION

Ph.D. Oregon State University (Biological Oceanography), 1979.
M.S. Oregon State University (Biological Oceanography), 1975.
B.A. University of Delaware (Biology), 1968

PROFESSIONAL EXPERIENCE

2001- Senior Marine Research Scientist and Oceanography Professor in Residence, GSO/URI
1997-2001 Senior Marine Research Scientist and Adjunct Professor of Oceanography, GSO/URI
1994-1997 Associate Marine Research Scientist and Adjunct Professor of Oceanography, GSO/URI
1992-1993 Associate Marine Scientist and Adjunct Professor of Oceanography GSO/URI
1985-1992 Associate Marine Scientist, GSO/URI
1981-1985 Assistant Marine Scientist, GSO/URI
1979-1981 Research Associate (Post Doc), School of Oceanography, Oregon State University

PROFESSIONAL ACTIVITIES

Guest Co-Editor, Bulletin of Marine Science, 1992-3.
Co-Editor, GLOBEC Optics and Acoustics Workshop Report.
Member, ICEES/IOC Working Group on Harmful Algal Blooms (1994-present).
Contributing Editor, ECOHAB National Plan (1996).
Chair, ONR Layers Initiative Steering Committee (1995-2003)
Guest Co-Editor, Special Issue of Oceanography on Thin Layers (1998)
Panelist, National Research Council meeting on fisheries technology (1999)
Member, SCOR Working Group 115 Standards for the Survey and Analysis of Plankton (2002-present)
Co-Chair, Turbulent mixing and biophysical interactions, NSF cabled regional observatory report, (2003)
NSF Ocean Technology panel and NSF Major Research Instrumentation panel (2004)
Steering committee, ONR Layered Organization in the Coastal Ocean initiative (2004-present)

AWARDS

NSF Oceanographic Technology Creativity Award for "Design, construction, and evaluation of a submersible pulsed holocamera for deep sea detection of particle characteristics and motions" (1995).

RESEARCH INTERESTS

Biological, physical and bio-physical control of plankton ecology and plankton patch dynamics; development of theoretical and numerical models of the underlying processes at both small and mesoscale; development of instruments and sampling techniques to simultaneously quantify controlling finescale biological and physical structure and processes; development of inverse techniques for extraction of physical, optical and biological dynamics from field data. Much of my research over the last 10 years has focused on the dynamics and impacts of thin layers of phytoplankton and zooplankton. A key component of this effort has been the development of new instruments and deployment techniques need to simultaneously sample physical, chemical and biological structures and processes at centimeter scales. These instrumentation efforts have included development of centimeter-resolution profiler (Donaghay, et al, 1992), development of a finescale in situ chemical analyzer with Alfred Hanson (Hanson and Donaghay, 1998), development of a submersible motion sensing holocamera with Joseph Katz at JHU (Katz et al, 1999), development of techniques for calibration and micro-scale profiling of dissolved and particulate material with spectral absorption and attenuation meters (Twardowski et al, 1999), and the development of the Ocean Response Coastal Analysis System (ORCAS) for autonomous 4-D profiling of finescale physical, chemical, optical and biological structure (Donaghay, 2004) These efforts have been funded by ONR, NSF instrumentation and NOPP and have played an important role in graduate training.

5 MOST RELEVANT PAPERS

Donaghay, P.L., H.M. Rines, and J. McNeil Sieburth, 1992. Simultaneous sampling of fine scale biological, chemical and physical structure in stratified waters, Arch. Hydrobiol. Beih., 36:97-108.

Hanson, A.K., Jr., and P.L. Donaghay, 1998. Micro to fine scale chemical gradients and layers in vertically stratified coastal waters, Oceanography, 11(7): 10-17.

Katz, J., P. L. Donaghay, J. Zhang, S. King, and K. Russell, 1999. Submersible holocamera for detection of particle characteristics and motions in the ocean, Deep-Sea Research I, 46:1455-1481.

Twardowski, M. S., J. M. Sullivan P. L. Donaghay, and J.R.V. Zaneveld, 1999. Microscale quantification of the absorption by dissolved and particulate material in coastal waters with an ac-9. J. Atmos. Ocean. Tech., 16: 691-707.

Donaghay, P.L., 2004. Profiling systems for understanding the dynamics and impacts of thin layers of harmful algae in stratified coastal waters. Proceedings of the 4th Irish Marine Biotoxin Science Workshop, 44-53.

5 RELATED PAPERS

Holliday, D.V., P.L. Donaghay, C.F. Greenlaw, D.E. McGehee, M.M. McManus, J. M. Sullivan, J.L. Miksis, 2003. Advances in defining fine- and micro-scale pattern in marine plankton. Aquatic Living Resources, 16(3): 131-136.

McManus, M.M., A. Alldredge, A. Barnard, E. Boss, J. Case, T. Cowles, P. Donaghay, L.B. Eisner, D. Gifford, C.F. Greenlaw, C. Herren, D.V. Holliday, D. Johnson, D. McGehee, S. MacIntyre, M.J. Perry, J.E.B. Rines, JD.C. Smith, J.M. Sullivan, J.M.K.Talbott, M.S. Twardowski, A. Weidemann, and J.R. Zaneveld, 2004. "Changes in characteristics, distribution and persistence of thin layers over a 48 hour period." Marine Ecology Progress Series. 261: 1-19.

Sullivan, J.M., M.S. Twardowski, P.L. Donaghay and S. Freeman, 2005. Using optical scattering to discriminate particle types in coastal waters. Applied Optics 44 (9): 1667-1680.

Gentien, P., P. Donaghay, H. Yamazaki, R. Raine, B. Reguera, and T. Osborn, 2005. Harmful algal blooms in stratified environments. Oceanography. 18(2): 152-163.

Babin, M., J.J. Cullen, C.S. Roesler, P.L. Donaghay, G.J. Doucette, M. Kahru, Marlon R. Lewis, C A. Scholin, M.E. Sieracki, and H.M. Sosik, 2005. New approaches and technologies for observing harmful algal blooms. Oceanography. 18(2):

PhD ADVISOR: Dr. Lawrence F. Small, OSU

STUDENTS and POST DOCS: Dr. Michael S. Twardowski (PhD), Research Scientist WET Labs; Dr. Margaret A. McManus (Post Doc), Assist. Prof. UH; James Sullivan (Post Doc).

DAVID M. FARMER

Research Interests: Upper ocean physics, waves, wave-breaking, bubbles, Langmuir circulation, nonlinear internal waves, stratified flow past topography, acoustical oceanography.

Academic background, professional appointments, fellowships, etc:
McGill University, 1964–1969. *BC., MSc.*(Dept. Marine Sciences).
University of British Columbia, 1969–1972. *PhD* (Dept. of Physics).
Appointments:
2001 – present: Dean & Professor, Graduate School of Oceanography, U Rhode Island.
1974 – 2001: Institute of Ocean Sciences; final level, Senior Scientist.
1972 – 1974: Pacific Environment Institute: Head, Coastal Oceanography.
Adjunct Appointments: Professor, Center for Earth & Ocean Sciences, U Victoria;
Professor, Dept Oceanography, University of British Columbia.

Publications
(i) Relevant to proposal:

- Farmer, D.M., C. McNeil, and B. Johnson, 1993, Evidence for the importance of bubbles to the enhancement of air–sea gas flux, ***Nature***, 361, 620–623.
- Ding, L. and D. Farmer, 1994, Observations of breaking surface wave statistics, ***J. Phys. Oceanogr.***, 24(6), 1368–1387.
- Farmer, D.M. and M. Li, 1995, Patterns of bubble clouds organized by Langmuir circulation, ***J. Phys. Oceanogr.***, 25(6), 1426–1440.
- Farmer, D.M., S. Vagle, and A.D. Booth, 1998, A free flooding acoustical resonator for measurement of bubble size distributions, ***J. Atmos. Oceanic Technol.***, 15(5), 1132–1146.
- Turbulence in the presence of Breaking Waves: Gemmrich, Johannes R.; David M Farmer, 2004, ***Journal of Physical Oceanography***, **34** (5), 1067-1068.

(ii) Additional significant publications:

- Moum, J., David M Farmer, W Smyth, L Armi, S Vagle, (2003)Structure and Generation of Turbulence at Interfaces Strained by Internal Solitary Waves Propagating Shoreward over the Continental Shelf, , ***J. Phys Oceanogr***, **33**, 2093-2112.
- Garrett, C., M. Li and D. Farmer, 2000, The connection between bubble size spectra and energy dissipation rates in the upper ocean, ***J. Phys. Oceanogr.,*** 30, 2163-2171.
- Farmer, D.M., & L. Armi, 1999, Stratified flow over topography: the role of small scale entrainment and mixing in flow establishment, ***Proceedings of the Royal Society, A***, v 455, pp. 3221-3258.
- Gemmrich, J. R. and D.M. Farmer, 1999, Observations of the scale and occurrence of breaking surface waves, ***J. Phys. Oceanogr.,*** 29, 2595-2606
- Farmer, D.M., and L. Armi, 1999, The generation and trapping of internal solitary waves over topography, ***Science,*** 283(5398), 188–190.

Synergistic Activities:

Created a graduate studies and research group in Acoustical Oceanography through the University of British Columbia, the University of Victoria and the Institute of Ocean Sciences, focusing on observations and analysis of the Upper Ocean Boundary Layer, and Stratified Flow past topography, turbulence in coastal waters and related topics. This group graduated numerous students now employed in a broad range of academic, government research and industrial positions. New technologies were developed for acoustical measurements ranging from the application of acoustical scintillation for measurement of turbulence to techniques for measurement of bubble size distributions. David Farmer is a Fellow of the American Geophysical Union, the Acoustical Society of America and the Royal Society of Canada; he is a recipient of the Walter Munk Award, the Rosenstiel Award and the President's Prize, Canadian Meteorological and Oceanographic Society.

Collaborators:

Dr. C. Garrett, University of Victoria
Dr. Grant Deane, Scripps Institution of Oceanography, UCSD
Dr. L Armi, Scripps Institution of Oceanography, UCSD
Dr. S Vagle, Institute of Ocean Sciences, Sidney, BC
Dr. P Liu, Cornell University
Dr. C. C. Mei, Massachusetts Institute of Technology
Dr J Preisig, Woods Hole Oceanographic Institution
Dr John Grue, University of Oslo
Dr M Banner, University of New South Wales
Dr R Pawlowicz, University of British Columbia
Dr Bruce Johnson, Dalhousie University
Dr Jim Moum, University of Oregon

Ann E. Gargett

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Crittenton Hall, Old Dominion University
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Degrees:

1966 BSc. (Hons.) in Mathematics and Physics, University of Manitoba
1970 PhD. (Physics), University of British Columbia

Appointments:

1970 NATO PDF, held at the National Institute of Oceanography (now SOC), U.K.
1971 Research Scientist 2, Institute of Ocean Sciences, Patricia Bay
1977 Guest Investigator, Woods Hole Oceanographic Institution
1980 Visiting Scientist, Department of Oceanography, University of Washington
1982-83 Green's Fellow at Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography
1984 Research Scientist 3, Institute of Ocean Sciences, Patricia Bay
1989 Research Scientist 4, Institute of Ocean Sciences, Patricia Bay
1992 Research Scientist 5, Institute of Ocean Sciences, Patricia Bay
1994-95 Visiting Scientist, Centre IFREMER, Brest, France
2001 Professor, Old Dominion University and Emeritus Scientist, Institute of Ocean Sciences, Canada
2005 Adjunct Professor, Skidaway Institute of Oceanography

Selected Awards and Recognition:

1990 Fellow of the Royal Society of Canada, Science Academy (Canadian equivalent of the U. S. National Academy of Science)
1991 H. Burr Steinbach Visiting Scholar, Woods Hole Oceanographic Institution/MIT Joint Program
1992 Editor's Award, American Meteorological Society
1992 Editor's Award, Journal of Geophysical Research (Oceans)
1999 Warren Wooster Lecturer in Ocean and Fishery Sciences
2003 Inaugural Henry Stommel Visitor, Woods Hole Oceanographic Institution

Recent Committees:

2002-03 NAS Committee on "Implementation of a Seafloor Observatory Network for Oceanographic Research"
2003 Steering Committee for NSF "Cabled Regional Observatory Workshop"
2004 ORION Sensors Committee, ORION Coastal Observing System Committee

Current Research Funding:

NSF(OPP) Interactive effects of UV and vertical mixing on phytoplankton and bacterioplankton in the Ross Sea. 04/01/02 - 03/31/05 $248,429
NSF(OCE) Doppler turbulence techniques for ocean observatories: an interactive approach using in situ measurements and LES models. 04/01/02 - 03/31/06 $819,734
NSF(OTIC) A two-stage towing system for swath-mapping ocean turbulence. 04/01/02 - 03/31/04 $160,167

A. Selected Related Publications:

Gargett, A., J. Wells, A. E. Tejada-Martinez and C. E. Grosch. 2004. Langmuir supercells: a mechanism for sediment resuspension and transport in shallow seas. Science 306, 1925-1928.

Di Orio, D. and A. Gargett. 2005. Studies of turbulent processes using Doppler and acoustical scintillation techniques. Ch. 20 in Sounds in the Sea: From Ocean Acoustics to Acoustical Oceanography, H. Medwin. Cambridge University Press, 720pp.

Gargett, A. E. 1999. Velcro measurement of turbulence kinetic energy dissipation rate ε. J. Atmosph. Oceanic Tech. 16(12), 1973-1993.

Gargett, A.E. 1997. "Theories" and techniques for observing turbulence in the ocean euphotic zone. In Lecture Notes on Plankton and Turbulence, eds. C. Marrasé., E.Saiz and J.M.Redondo. Scientia Marina, 61(Suppl), 25-45.

Gargett, A.E. 1994. Observing turbulence with a modified acoustic Doppler current profiler. J. Atmosph. Oceanic Tech. 11(6), 1592-1610.

B. Other Recent Publications

Gargett, A. E., D. Stucchi and F. Whitney. 2003. Physical processes associated with high primary productivity in Saanich Inlet, British Columbia. Estuarine, Coastal and Shelf Sci. 56, 1141-1156.

Gargett, A. E. 2003. Differential diffusion: an oceanographic primer. Progr. Oceanogr. 56 (3-4), 559-570.

Gargett, A. E., W. J. Merryfield and G. Holloway. 2003. Direct numerical simulation of differential scalar diffusion in three-dimensional stratified turbulence. J. Phys. Oceanogr. 33(8), 1758-1782.

Gargett, A. E. and J. Marra. 2002. Effects of upper ocean physical processes – turbulence, advection, and air-sea interaction – on oceanic primary production. The Sea, Vol.12, ed. A. Robinson, B. Rothschild and J. McCarthy, John Wiley & Sons, Inc., New York, 19-49

C. Recent Collaborators:
Greg Holloway, Bill Merryfield: Institute of Ocean Sciences, Canada; Barry Ruddick, Dalhousie University; Dave Hebert, GSO URI; Craig Woolsey, Virginia Tech; Pat Neale, Smithsonian Ecological Research Center; Wade Jeffrey, U. West Florida; Daniela Di Orio, U. of Georgia

D. Advisors and Advisees:
Graduate Advisor: P. LeBlond, University of British Columbia
Postdoctoral Advisor: S. Thorpe, U.K. National Institute of Oceanography (now SOC)
M. S. Advisees: Teresa Garner
Graduate Committees: PhD: Nandita Sarkar, Chris Klentzmann (engineering)
MS: Salim Balik (Physics)

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E-mail:
jhorne@u.wasnington.edu

Professional Preparation

Dalhousie University	Marine Biology	B.Sc. (Honours), 1985
Dalhousie University	Fisheries Ecology	M.Sc., 1988
Memorial University of Newfoundland	Fisheries Ecology	Ph.D, 1995
SUNY Buffalo State College	Fisheries Acoustics	1995-1997

Appointments

2004- Research Associate Professor -- University of Washington, School of Aquatic and Fishery Sciences. Affiliated with the Quantitative Ecology and Resource Management Program.

2001-2004 Research Assistant Professor – University of Washington, School of Aquatic and Fishery Sciences. Affiliated with the Quantitative Ecology and Resource Management Program.

1999-2000 Research Scientist – NOAA Alaska Fisheries Science Center and University of Washington, Joint Institute for the Study of the Atmosphere and Ocean.

1997-1999 Research Scientist - NOAA Great Lakes Environmental Research Laboratory. Adjunct Assistant Professor - School of Natural Resources and Environment and College of Engineering, University of Michigan.

1996-1997 Adjunct Assistant Professor - Geography and National Center for Geographic Information and Analysis. State University of New York, University at Buffalo.

Relevant Publications

Gauthier, S. and J.K. Horne. 2004. Potential acoustic discrimination of boreal fish assemblages. ICES Journal of Marine Science 61: 836-845.

Horne, J.K. 2003. Influence of ontogeny, physiology, and behaviour on target strength of Walleye pollock (*Theragra chalcogramma*). ICES Journal of Marine Science 60: 1063-1074.

Horne, J.K. 2000. Acoustic approaches to remote species identification: a review. Fisheries Oceanography 9: 356-371.

Horne, J.K. and C.S. Clay. 1998. Sonar systems and aquatic organisms: matching equipment and model parameters. Canadian Journal of Fisheries and Aquatic Sciences 55: 1296-1306.

Horne, J.K. and D.C. Schneider. 1997. Spatial variance of mobile marine organisms: capelin and cod in Newfoundland coastal waters. Philosophical Transactions of the Royal Society, London B 352: 633-642.

Other Publications

Gauthier, S. and J.K. Horne. 2004. Acoustic characteristics of forage fish species in the Gulf of Alaska and Bering Sea. Canadian Journal of Aquatic and Fishery Science 61: 1839-1850.

Jech, J.M. and J.K. Horne. 2001. Effects of *in situ* target spatial distributions on acoustic density estimates. ICES Journal of marine Science 58: 123-136.

Horne, J.K., P.E. Smith, and D.C. Schneider. 1999. Comparative examination of scale-explicit biological and physical processes: recruitment of Pacific hake. Canadian Journal of Fisheries and Aquatic Sciences 56: 170-179.

Horne, J.K. and D.C. Schneider. 1995. Spatial variance in ecology. Oikos 74: 18-26.

Clay, C.S. and J.K. Horne. 1994. Acoustic models of fish: the Atlantic cod (*Gadus morhua*). The Journal of the Acoustical Society of America 96: 1661-1668.

Synergistic Activities

Member of Acoustical Oceanography Technical Committee, Acoustical Society of America.

Founder and coordinator of the NOAA Alaska Fisheries Science Center and University of Washington, School of Aquatic and Fishery Sciences Undergraduate Summer Intern Program.

Developer of web-based simulcast of Fisheries Acoustics course lecture content.

University of Washington's research committee member of the North Pacific Universities Marine Mammal Consortium.

Co-coordinator of University of Washington and University of Alaska multicast of Acoustics Seminar course using Internet II.

Collaborators & Other Affiliations

Kelly A. Allman	Marine Mammal Center, California
Whitlow L. Au	University of Hawaii
Elizabeth L. Connors	NOAA Alaska Fisheries Science Center
Don J. Deegan	Aquacoustics Inc., Alaska
John K.B. Ford	Department of Fisheries and Oceans, Canada
Stephane Gauthier	University of Washington
R. Scott Hale	Ohio Department of Natural Resources
Elliott L. Hazen	Duke University
Sarah Hinckley	NOAA Alaska Fisheries Science Center
J. Michael Jech	NOAA Northeast Fisheries Science Center
Rudy J. Kloser	CSIRO, Australia
Richard Towler	NOAA Alaska Fisheries Science Center
Paul D. Walline	NOAA Alaska Fisheries Science Center

Graduate and Postdoc Advisors

Stephen B. Brandt	NOAA Great Lakes Environmental Research Laboratory
David C. Schneider	Memorial University of Newfoundland
Steven E. Campana	Department of Fisheries and Oceans, Canada

Thesis Advisor (total: 13) and Postgraduate-Scholar Sponsor (total: 4)

Carlos Alvarez-Flores	Alaska Fisheries Science Center
Stephen Barbeaux	University of Washington
Julian Burgos	University of Washington
Stephane Gauthier	University of Washington
Elliott Hazen	University of Washington
Mark Henderson	University of Washington
Patrick Nealson	University of Washington
Sandra Parker-Stetter	University of Washington
Carolina Parada	Alaska Fisheries Science Center

BIOGRAPHICAL SKETCH
Bruce M. Howe

Professional Preparation

Stanford University	Mechanical Engineering, Fluid Mechanics	B.Sc.	1978
	Engineering Science, Fluid Dynamics	M.Sc.	1978
University of California, San Diego	Oceanography, Ocean Acoustic Tomography	Ph.D.	1986

Appointments

University of Washington

Applied Physics Laboratory, College of Ocean and Fishery Sciences

1998 – Principal Oceanographer
1992 – 1998 Senior Oceanographer
1987 – 1992 Oceanographer

School of Oceanography, College of Ocean and Fishery Sciences

1994 – Research Associate Professor
1988 – 1992 Research Assistant Professor

Department of Electrical Engineering, College of Engineering

2004 – Adjunct Research Associate Professor

University of California, San Diego

1986 – 1987 Postgraduate Researcher, Institute of Geophysics and Planetary Physics
1981 – 1986 Research Assistant, Scripps Institution of Oceanography

Universität Karlsruhe

1979 – 1981 Research Associate, Institut für Hydromechanik

Stanford University

1976 – 1979 Research Assistant, Department of Civil Engineering

Scientific Expeditions

Participant in 30 cruises with 400 days at sea, 14 cruises as Chief Scientist, one each using DSV *SeaCliff*, the ATV ROV, and R/P *FLIP*.

Publications - Author or co-author of 43 refereed papers and 160 other works.

Selected Publications

Howe, B. M., and J. H. Miller, Acoustic sensing for ocean research, *J. Mar. Tech. Soc.*, **38**, 144–154, 2004.

Andrew, R. K., **B. M. Howe**, J. A. Mercer, and M. A. Dzieciuch, Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California coast, *Acoust. Res. Lett. On-line*, **3**(2), 65–70, 2002.

Dushaw, B. D. et al., Observing the ocean in the 2000's: A strategy for the role of acoustic tomography in ocean climate observation, Proceedings of the First International Conference on the Ocean Observing System, San Rafael, France, 18-22 October 1999, in: *Observing the Oceans in the 21st Century*, C.J. Koblinsky and N.R. Smith (eds), Bureau of Meteorology, Melbourne, Australia, 2001.

Delaney, J. R., G. R. Heath, A. D. Chave, **B. M. Howe**, and H. Kirkham, NEPTUNE: Real-time ocean and earth sciences at the scale of a tectonic plate, *Oceanography*, **13**, 71–83, 2000.

Curtis, K. R., **B. M. Howe**, and J. A. Mercer, Low frequency ambient sound in the North Pacific: Long time series observations, *J. Acoust. Soc. Am.*, **106**, 3189–3200, 1999.

Other Publications

Howe, B. M., H. Kirkham, and V. Vorpérian, Power system considerations for undersea observatories, *IEEE J. Oceanic Engr.*, **27**, 267–274, 2002.

Howe, B. M., K. Runciman, and J. A. Secan, Tomography of the ionosphere: Four-dimensional simulations, *Radio Science*, **33**, 109–128, 1998.

ATOC Consortium: A. B. Baggeroer, T. G. Birdsall, C. Clark, J. A. Colosi, B. D. Cornuelle, D. Costa, B. D. Dushaw, M. Dzieciuch, A. M. G. Forbes, C. Hill, **B. M. Howe,** J. Marshall, D. Menemenlis, J. A. Mercer, K. Metzger, W. Munk, R. C. Spindel, D. Stammer, P. F. Worcester, and C. Wunsch, Observing ocean climate change: Comparison of acoustic tomography, satellite altimetry, and modeling, *Science*, **281**, 1327–1332, 1998.

ATOC Instrumentation Group: **B. M. Howe**, S. G. Anderson, A. Baggeroer, J. A. Colosi, K.R. Hardy, D. Horwitt, F. Karig, S. Leach, J. A. Mercer, K. Metzger, Jr., L. O. Olson, D. A. Peckham, D. A. Reddaway, R. R. Ryan, R. P. Stein, K. von der Heydt, J. D. Watson, S. L. Weslander, and P. F. Worcester, Instrumentation for the Acoustic Thermometry of Ocean Climate (ATOC) prototype Pacific Ocean array, *Proc. Oceans '95 MTS/IEEE*, San Diego, California, 1483–1500, 1995.

Worcester, P. F., B. D. Cornuelle, J. H. Hildebrand, W. S. Hodgekiss, Jr., T. F. Duda, J. Boyd, **B. M. Howe**, J. A. Mercer, and R. C. Spindel, A comparison of measured and predicted broadband arrival patterns in travel time-depth coordinates at 1000-km range, *J. Acoust. Soc. Am.*, **95**, 16,365–16,378, 1994.

Synergistic Activities

2005	NEPTUNE Canada RFP Team, Member
2004 –	Global Class Science Mission Requirements, Chair of UNOLS Committee
2003 – 2004	AGU Oceans Sciences 2004 Meeting, Member of Program Committee
2003 –	Integrated Acoustics Systems for Ocean Observatories, Co-chair of ASA Committee
2003 –	Current Measurement Technology Committee, Member
2000 – 2003	Acoustical Oceanography Technical Committee, ASA, Member
1999	Fellowship, Science and Technology Agency, Japan
1997 –	NEPTUNE planning and technical activities
1992 – 2002	Scientific Use of Undersea Cables, Member of IRIS Steering Committee
1991 – 1995	Tomographic Data in Ocean Models, Chair of ONR Committee

Professional Societies

American Geophysical Union	American Meteorological Society
The Oceanography Society (charter life member)	Acoustical Society of America
American Association for the Advancement of Science	Sigma Xi

Collaborators and Other Affiliations

Collaborators and Co-Editors

R. Andrew (UW), P. Beauchamp (JPL), E. Boss (UMaine), A. Chave (WHOI), J. Colosi (WHOI), B. Cornuelle (SIO), J. Delaney (UW), B. Dushaw (UW), M. Dzieciuch (SIO), M. El-Sharkawi (UW), R. Heath (UW), H. Kirkham (JPL), C-C. Liu (UW), R. Lukas, T. McGinnis (UW), J. Mercer (UW), W. Munk (SIO), R. Spindel (UW), L. Scherliess (USU), R. Schunk (USU), V. Vorperian (JPL), W. Wilcock (UW), P. Worcester (SIO)

Graduate and Postdoctoral Advisors

Graduate Advisors: MSc: Robert Street (Stanford). PhD: Walter Munk (SIO) and Peter Worcester (SIO).
Postdoctoral: Peter Worcester (SIO)

Thesis Advisor and Postgraduate-Scholar Sponsor

PhD: Michael Zarnetske (current), Chris Walter (1999). MSc: Keith Curtis (1998)
Postgraduate: Brian Dushaw (UW).

Richard E. Thomson (CV)

Institute of Ocean Sciences
Fisheries and Oceans Canada
9860 West Saanich Road, Sidney, BC V8L 4B2 Canada
Tel (250) 363-6555; Fax (250) 363-6690
E-mail thomsonr@pac.dfo-mpo.gc.ca

Position: Senior Research Scientist (RES-05), Head, Ocean Dynamics & Processes Section
Degrees: B.Sc. 1967: University of B.C., Mathematics and Physics (First Class Honors).
Ph.D. 1971: University of B.C., Physics and Oceanography (With Distiction).

Professional Positions
- Fellow of the Royal Society of Canada (F.R.S.C.) , Academy of Sciences: 1995-.
- Research Scientist (RES-05) Canadian Federal Department of Fisheries and Oceans,. 1971- present. Promoted to the highest level (RES-05) in April 1991.
- Section Head, Ocean Dynamics & Processes Section (DFO, Sidney): 1995 - .
- Adjunct Professor, School of Earth and Ocean Sciences, University of Victoria; 1999 - .
- Adjunct Professor, Department Earth and Ocean Sciences, University of B.C.; 1989 - .
- Adjunct Graduate Faculty, Oregon State University, Corvallis (Oregon); 1986-1997.
- Adjunct Associate Professor, State University of New York, Stony Brook (Marine Sciences Center); 1984-1995.
- Visiting Professor, Mathematics Department, University of New South Wales, Sydney, N.S.W., Australia; 1989.
- Visiting Research Scientist, Australian Institute of Marine Sciences, Townsville, Queensland, Australia; 1982.
- Visiting Lecturer, Dept. Mathematics, Monash University, Melbourne, Australia; 1974.

International Appointments & Service
- Member, U.S. RIDGE-2000 Steering Committee. 2001-2004.
- Member, U.S. RIDGE Steering Committee; 1990-1995.
- Member, NASA Campaign Science Working Group for *Prebiotic Chemistry in the Outer Solar System*, Jet Propulsion Lab, Pasadena, California. (Chair: C. Chyba); 1998-2000.
- Member, U.S. and Canadian NEPTUNE Planning Programs (1999- present).
- Member, VENUS Planning Groups (1999-).
- Member and Co-Chair of five (5) U.S. RIDGE Working Groups (1987-1999).
- Co-Editor, AGU *Geophysical Monograph Series Volume* on "Physical, Chemical, Biological and Geological Interactions with Hydrothermal Systems"; 1994-1995.
- Chairman, Sea Level Group, *Committee for Climate Changes & the Ocean* (CCCO; Paris France); 1988-1993.

National Appointments & Service
- Chair, Canadian Meteorological and Oceanographic Society (CMOS) Prizes and Awards Committee (Ottawa): 1999-2003.
- Chair, Prizes and Awards Committee, Royal Society of Canada (Ottawa): 1999-2003.
- Chair, Fisheries and Oceans Canada, Fisheries Oceanography Working Group (Pacific): 1999-2001.
- Operating Grant Committee (09), Natural Sciences & Engineering Research Council (NSERC), Ottawa; 1989-1992. Chair, 1992.
- Chair of the *Marine Monitoring Advisory Group* of the Victoria Capital Regional District (CRD), Victoria (1995-2000); member from 1989-2000.

Awards
- 2005: Prix d'Excellence, Department of Fisheries and Oceans, Aquaculture and Oceans (Ottawa).

- 2005: Prix d'Excellence, Department of Fisheries and Oceans, Science (Ottawa).
- 2005: Award of Distinction, Department of Fisheries and Oceans, Science (Ottawa).
- 2004: Tully Medal in Oceanography, Canadian Meteorological and Oceanographic Society.
- 2002: Certificate of Appreciation, Fisheries and Oceans Canada, Pacific Region (Vancouver)
- 2003: R.E. Foerster Award, Fisheries and Oceans Canada, Pacific Region (Vancouver)
- 1994: Canada 125 Award, Director General, Pacific Region Fisheries and Oceans Canada (Ottawa)
- 1991: Deputy Minister's Commendation, Department of Fisheries and Oceans (Ottawa)
- 1990: Prize in Applied Oceanography, Canadian Meteorological and Oceanographic Society
- 1989: AGU 1988 Editor's Citation for Excellence in Refereeing JGR Oceans, *American Geophysical Union* (Washington, DC)
- 1983: Distinguished Technical Communication Award (Toronto)
- 1982: Merit Award, Department of Fisheries and Oceans (Ottawa)

Professional Societies
- American Geophysical Union (AGU)
- American Association for the Advancement of Science (AAAS)
- Canadian Meteorological and Oceanographic Society (CMOS)
- Royal Society of Canada, Academy of Sciences

Summary of Publications

Books	4
Chapters in Books	10
Primary Journal Publications	150
Other publications:	120+
International Patents	6

Selection of Recent Publications

Ware, D.M. and R.E. **Thomson**. 2005. Bottom-up ecosystem trophic dynamics determine fish production in the northeast Pacific. *Science* (May 20, 2005).

Thomson, R.E., Marina M. Subbotina, and Mikhail V. Anisimov. 2005. Numerical simulation of hydrothermal vent-induced circulation at Endeavour Ridge. *J. Geophys Res.-Oceans*, 110 doi:10.1029/2004JC002337.

Shevchenko, G.V., A.B. Rabinovich, and R.E. **Thomson**. 2004. Sea-ice drift dynamics on the northeastern shelf of Sakhalin Island. *J. Phys. Oceanogr*. 34 (11), 2470-2491.

Whitney, F., K. Conway, R.E. **Thomson**, V. Barrie, M. Krautter, and G. Mungov. 2005. Oceanographic Habitat of Sponge Reefs on the Western Canadian Continental Shelf. *Cont. Shelf Res*. 25, 211-226.

Kulikov, E.A., A.B.Rabinovich, and R.E. **Thomson**. 2005. Estimation of tsunami risk for the coasts of Peru and Northern Chile. *J. Natural Hazards*, 35 (2), 185-209.

Fine, I.V., A.B.Rabinovich, B.D.Bornhold, R.E. **Thomson**, and E.A.Kulikov. 2005. The Grand Banks Landslide-Generated Tsunami of November 18, 1929: Preliminary Analysis and Numerical Modeling. *Marine Geology* 215, 45-57.

Thomson, R.E., S.F. Mihaly, A.B. Rabinovich, R.E. McDuff, S.R. Veirs, and F.R. Stahr. 2003. Constrained circulation at Endeavour Ridge facilitates colonisation by vent larvae. *Nature* 424, 545-549 (July 31, 2003); doi:10.1038/nature01824.

Lorenz, R.D., E. Kraal, E. Asphaug and R. **Thomson**. 2003. The Seas of Titan. *EOS*, 84 (14), 8 April 2003, 125-131.

Thomson, R.E., and H.J. Freeland. 2003. Topographic Steering of a Mid-depth Drifter in an Eddy-like Circulation Region South and East of the Hawaiian Ridge. *J. Geophys. Res.* 108, No. C11, 3341-3348, 10.1029/2002Jcoo1715.

8. BUDGET

9. BUDGET JUSTIFICATION

FOR ORION USE ONLY

SUMMARY PROPOSAL BUDGET
YEAR 1

ORGANIZATION Applied Physics Laboratory – University of Washington	PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Bruce Howe	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	6	__	__	68,309	$_____
2. Junior Scientists	12	__	__	75,417	_____
3. Senior Engineers	24	__	__	222,818	_____
4. Junior Engineers	24	__	__	153,828	_____
5. ______	__	__	__	______	_____
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	__	__	__	______	_____
7. (___) TOTAL SENIOR PERSONNEL (1-6)	__	__	__	______	_____
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES	__	__	__	______	_____
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26	__	__	143,990	_____
3. (___) GRADUATE STUDENTS				______	_____
4. (___) UNDERGRADUATE STUDENTS				______	_____
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				______	_____
6. (___) OTHER				______	_____
TOTAL SALARIES AND WAGES (A + B)				664,362	_____
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				311,586	_____
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				975,948	_____
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Mooring Equipment ______				6,186,000	
TOTAL EQUIPMENT				6,186,000	_____
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				100,000	_____
2. FOREIGN				______	_____
F. PARTICIPANT SUPPORT 1. STIPENDS $ ______ 2. TRAVEL ______ 3. SUBSISTENCE ______ 4. OTHER ______					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS				______	_____
G. OTHER DIRECT COSTS				______	_____
1. MATERIALS AND SUPPLIES				289,000	_____
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				______	_____
3. CONSULTANT SERVICES				______	_____
4. COMPUTER SERVICES				______	_____
5. SUBAWARDS				______	_____
6. OTHER Services ($289,000 and APL Prorated Direct Costs (47.8% of Salaries) $317,565)				606,565	_____
TOTAL OTHER DIRECT COSTS				______	_____
H. TOTAL DIRECT COSTS (A THROUGH G)				895,565	_____
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $1,971,514 ______				335,157	
TOTAL INDIRECT COSTS (F&A)				335,157	_____
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				8,492,671	_____
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				______	_____
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$8,492,671	$_____

M. COST SHARING: PROPOSED LEVEL $_____	AGREED LEVEL IF DIFFERENT: $_____	
PI/PD TYPED NAME AND SIGNATURE*	DATE	**FOR ORION USE ONLY** INDIRECT COST RATE VERIFICATION
ORG. REP. TYPED NAME & SIGNATURE* ______	DATE ______	Date Checked / Date of Rate Sheet / Initials-ORG

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

SUMMARY PROPOSAL BUDGET
YEAR 2

FOR ORION USE ONLY		
PROPOSAL NO.	DURATION (MONTHS) Proposed	DURATION (MONTHS) Granted
AWARD NO.		

ORGANIZATION
Applied Physics Laboratory – University of Washington

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Bruce Howe

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates. List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	6			71,042	$
2. Junior Scientists	12			78,433	
3. Senior Engineers	24			231,731	
4. Junior Engineers	24			159,982	
5. ___					
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (___) TOTAL SENIOR PERSONNEL (1-6)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES					
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26			149,750	
3. (___) GRADUATE STUDENTS					
4. (___) UNDERGRADUATE STUDENTS					
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. (___) OTHER					
TOTAL SALARIES AND WAGES (A + B)				690,937	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				324,049	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,014,986	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Mooring Equipment				6,186,000	
Mooring O&M				619,000	
TOTAL EQUIPMENT				6,805,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				100,000	
2. FOREIGN					
F. PARTICIPANT SUPPORT					
1. STIPENDS $ ___					
2. TRAVEL ___					
3. SUBSISTENCE ___					
4. OTHER ___					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				318,000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES					
5. SUBAWARDS					
6. OTHER Services ($318,000 and APL Prorated Direct Costs (47.8% of Salaries) $330,268)				548,268	
TOTAL OTHER DIRECT COSTS				866,268	
H. TOTAL DIRECT COSTS (A THROUGH G)				8,886,254	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $ 2,081,254				353,813	
TOTAL INDIRECT COSTS (F&A)				353,813	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				9,240,067	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$9,240,067	$

M. COST SHARING: PROPOSED LEVEL $_____ AGREED LEVEL IF DIFFERENT: $_____

PI/PD TYPED NAME AND SIGNATURE*	DATE	FOR ORION USE ONLY		
		INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

SUMMARY PROPOSAL BUDGET
YEAR 3

		FOR ORION USE ONLY	
ORGANIZATION Applied Physics Laboratory – University of Washington	PROPOSAL NO.	DURATION (MONTHS)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Bruce Howe	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	6	__	__	73,883	$_____
2. Junior Scientists	12	__	__	81,571	_____
3. Senior Engineers	24	__	__	241,000	_____
4. Junior Engineers	24	__	__	166,381	_____
5. ______	__	__	__	_____	_____
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	__	__	__	_____	_____
7. (___) TOTAL SENIOR PERSONNEL (1-6)	__	__	__	_____	_____
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES	__	__	__	_____	_____
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26	__	__	155,740	_____
3. (___) GRADUATE STUDENTS				_____	_____
4. (___) UNDERGRADUATE STUDENTS				_____	_____
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				_____	_____
6. (___) OTHER				_____	_____
TOTAL SALARIES AND WAGES (A + B)				718,574	_____
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				337,011	_____
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,055,585	_____
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Mooring Equipment Mooring O&M ______				6,186,000 1,237,000	
TOTAL EQUIPMENT				7,423,000	_____
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				100,000	_____
2. FOREIGN				_____	_____
F. PARTICIPANT SUPPORT 1. STIPENDS $ ______ 2. TRAVEL ______ 3. SUBSISTENCE ______ 4. OTHER ______					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS				_____	_____
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				346,000	_____
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				_____	_____
3. CONSULTANT SERVICES				_____	_____
4. COMPUTER SERVICES				_____	_____
5. SUBAWARDS				_____	_____
6. OTHER Services ($346,000 and APL Prorated Direct Costs (47.8% of Salaries) $343,479)				689,479	_____
TOTAL OTHER DIRECT COSTS				1,035,479	_____
H. TOTAL DIRECT COSTS (A THROUGH G)				9,614,064	_____
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $ 2,191,064 ______				372,481	
TOTAL INDIRECT COSTS (F&A)				372,481	_____
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				9,986,545	_____
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				_____	_____
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$9,986,545	$_____

M. COST SHARING: PROPOSED LEVEL $_____	AGREED LEVEL IF DIFFERENT: $_____			
PI/PD TYPED NAME AND SIGNATURE*	DATE	FOR ORION USE ONLY		
		INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

FOR ORION USE ONLY

SUMMARY PROPOSAL BUDGET
YEAR 4

ORGANIZATION	PROPOSAL NO.	DURATION (MONTHS)	
Applied Physics Laboratory – University of Washington		Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Bruce Howe	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	6	__	__	76,839	$_____
2. Junior Scientists	12	__	__	84,833	_____
3. Senior Engineers	24	__	__	250,640	_____
4. Junior Engineers	24	__	__	173,036	_____
5. _____	__	__	__	_____	_____
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	__	__	__	_____	_____
7. (___) TOTAL SENIOR PERSONNEL (1-6)	__	__	__	_____	_____
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES	__	__	__	_____	_____
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26	__	__	161,969	_____
3. (___) GRADUATE STUDENTS				_____	_____
4. (___) UNDERGRADUATE STUDENTS				_____	_____
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				_____	_____
6. (___) OTHER				_____	_____
TOTAL SALARIES AND WAGES (A + B)				747,317	_____
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				350,492	_____
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,097,809	_____
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Mooring Equipment 6,186,000 Mooring O&M 1,856,000 _____					
TOTAL EQUIPMENT				8,042,000	_____
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				100,000	_____
2. FOREIGN				_____	_____
F. PARTICIPANT SUPPORT 1. STIPENDS $ _____ 2. TRAVEL _____ 3. SUBSISTENCE _____ 4. OTHER _____					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS				_____	_____
G. OTHER DIRECT COSTS				_____	_____
1. MATERIALS AND SUPPLIES				375,000	_____
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				_____	_____
3. CONSULTANT SERVICES				_____	_____
4. COMPUTER SERVICES				_____	_____
5. SUBAWARDS				_____	_____
6. OTHER Services ($375,000 and APL Prorated Direct Costs (47.8% of Salaries) $357,218)				732,218	_____
TOTAL OTHER DIRECT COSTS				1,107218	_____
H. TOTAL DIRECT COSTS (A THROUGH G)				10,347,027	_____
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $ 2,305,027 391,855 _____					
TOTAL INDIRECT COSTS (F&A)				391,855	_____
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				10,738,881	_____
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				_____	_____
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$10,738,881	$_____

M. COST SHARING: PROPOSED LEVEL $_____	AGREED LEVEL IF DIFFERENT: $_____		
PI/PD TYPED NAME AND SIGNATURE*	DATE	**FOR ORION USE ONLY** INDIRECT COST RATE VERIFICATION	
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date of Rate Sheet	Initials-ORG

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SUMMARY PROPOSAL BUDGET
YEAR 5

FOR ORION USE ONLY

ORGANIZATION	PROPOSAL NO.	DURATION (MONTHS)	
Applied Physics Laboratory – University of Washington		Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Bruce Howe	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	6	__	__	79,912	$_____
2. Junior Scientists	12	__	__	88,227	_____
3. Senior Engineers	24	__	__	260,665	_____
4. Junior Engineers	24	__	__	179,958	_____
5. ______	__	__	__	_____	_____
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	__	__	__	_____	_____
7. (___) TOTAL SENIOR PERSONNEL (1-6)	__	__	__	_____	_____
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES	__	__	__	_____	_____
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26	__	__	168,448	_____
3. (___) GRADUATE STUDENTS				_____	_____
4. (___) UNDERGRADUATE STUDENTS				_____	_____
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				_____	_____
6. (___) OTHER				_____	_____
TOTAL SALARIES AND WAGES (A + B)				777,210	_____
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				364,512	_____
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,141,722	_____
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Mooring Equipment					6,186,000
Mooring O&M					2,474,000
______					
TOTAL EQUIPMENT				8,660,000	_____
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				100,000	_____
2. FOREIGN				_____	_____
F. PARTICIPANT SUPPORT					
1. STIPENDS $ ______					
2. TRAVEL ______					
3. SUBSISTENCE ______					
4. OTHER ______					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS				_____	_____
G. OTHER DIRECT COSTS				_____	_____
1. MATERIALS AND SUPPLIES				404,000	_____
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				_____	_____
3. CONSULTANT SERVICES				_____	_____
4. COMPUTER SERVICES				_____	_____
5. SUBAWARDS				_____	_____
6. OTHER Services ($404,000 and APL Prorated Direct Costs (47.8% of Salaries) $371,506)				775,506	_____
TOTAL OTHER DIRECT COSTS				1,179,506	_____
H. TOTAL DIRECT COSTS (A THROUGH G)				11,081,228	_____
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $ 2,421,228 ______					411,609
TOTAL INDIRECT COSTS (F&A)				411,609	_____
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				11,492,837	_____
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				_____	_____
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$11,492,837	$_____

M. COST SHARING: PROPOSED LEVEL $_____	AGREED LEVEL IF DIFFERENT: $_____		
PI/PD TYPED NAME AND SIGNATURE*	DATE	FOR ORION USE ONLY INDIRECT COST RATE VERIFICATION	
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date of Rate Sheet	Initials-ORG

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SUMMARY PROPOSAL BUDGET
YEAR 6

FOR ORION USE ONLY				
ORGANIZATION Applied Physics Laboratory – University of Washington	PROPOSAL NO.	DURATION (MONTHS)	Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Bruce Howe	AWARD NO.			

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	6	__	__	83,109	$_____
2. Junior Scientists	12	__	__	91,756	_____
3. Senior Engineers	24	__	__	271,092	_____
4. Junior Engineers	24	__	__	187,156	_____
5. _____	__	__	__	_____	_____
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	__	__	__	_____	_____
7. (___) TOTAL SENIOR PERSONNEL (1-6)	__	__	__	_____	_____
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES	__	__	__	_____	_____
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26	__	__	175,186	_____
3. (___) GRADUATE STUDENTS				_____	_____
4. (___) UNDERGRADUATE STUDENTS				_____	_____
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				_____	_____
6. (___) OTHER				_____	_____
TOTAL SALARIES AND WAGES (A + B)				808,298	_____
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				379,092	_____
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,187,390	_____
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Mooring O&M 3,093,000 _____ _____					
TOTAL EQUIPMENT				3,093,000	_____
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				100,000	_____
2. FOREIGN				_____	_____
F. PARTICIPANT SUPPORT 1. STIPENDS $ _____ 2. TRAVEL _____ 3. SUBSISTENCE _____ 4. OTHER _____					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS				_____	_____
G. OTHER DIRECT COSTS				_____	_____
1. MATERIALS AND SUPPLIES				144,000	_____
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				_____	_____
3. CONSULTANT SERVICES				_____	_____
4. COMPUTER SERVICES				_____	_____
5. SUBAWARDS				_____	_____
6. OTHER Services ($144,000 and APL Prorated Direct Costs (47.8% of Salaries) $386,367)				530,367	_____
TOTAL OTHER DIRECT COSTS				674,367	_____
H. TOTAL DIRECT COSTS (A THROUGH G)				5,054,757	_____
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $ 1,961,757 333,499 _____					
TOTAL INDIRECT COSTS (F&A)				333,499	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				5,388,256	_____
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				_____	_____
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$5,388,256	$_____

M. COST SHARING: PROPOSED LEVEL $_____	AGREED LEVEL IF DIFFERENT: $_____			
PI/PD TYPED NAME AND SIGNATURE*	DATE	**FOR ORION USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

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CUMULATIVE PROPOSAL BUDGET

FOR ORION USE ONLY		
PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
AWARD NO.		

ORGANIZATION
Applied Physics Laboratory – University of Washington

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Bruce Howe

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates. List each separately with name and title. (A.7. Show number in brackets)	Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted (If Different)
1. Senior Scientists	36	__	__	453,094	$_____
2. Junior Scientists	72	__	__	500,237	_____
3. Senior Engineers	144	__	__	1,477,946	_____
4. Junior Engineers	144	__	__	1,020,341	_____
5. _____	__	__	__	_____	_____
6. (___) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	__	__	__	_____	_____
7. (___) TOTAL SENIOR PERSONNEL (1-6)	__	__	__	_____	_____
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (___) POSTDOCTORAL ASSOCIATES	__	__	__	_____	_____
2. (___) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	156	__	__	955,083	_____
3. (___) GRADUATE STUDENTS				_____	_____
4. (___) UNDERGRADUATE STUDENTS				_____	_____
5. (___) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				_____	_____
6. (___) OTHER					_____
TOTAL SALARIES AND WAGES (A + B)				4,406,699	_____
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				2,066,742	_____
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				6,473,441	_____
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Mooring Equipment / Mooring O&M / _____				30,930,000 / 9,279,000	
TOTAL EQUIPMENT				40,209,000	_____
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				600,000	_____
2. FOREIGN				_____	_____
F. PARTICIPANT SUPPORT 1. STIPENDS $ _____ 2. TRAVEL _____ 3. SUBSISTENCE _____ 4. OTHER _____					
TOTAL NUMBER OF PARTICIPANTS (_____) TOTAL PARTICIPANT COSTS				_____	_____
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,876,000	_____
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				_____	_____
3. CONSULTANT SERVICES				_____	_____
4. COMPUTER SERVICES				_____	_____
5. SUBAWARDS				_____	_____
6. OTHER Services: $ 1,876,000 and APL Prorated Direct Costs (47.8% of salaries): $ 2,106,402				3,982,402	_____
TOTAL OTHER DIRECT COSTS				_____	_____
H. TOTAL DIRECT COSTS (A THROUGH G)				53,140,844	_____
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) APL Indirect Costs (17% less equipment) Base: $ 12,931,844 _____				2,198,413	
TOTAL INDIRECT COSTS (F&A)				2,198,413	_____
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				55,339,257	_____
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				_____	_____
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$55,339,257	$_____

M. COST SHARING: PROPOSED LEVEL $_____	AGREED LEVEL IF DIFFERENT: $_____		
PI/PD TYPED NAME AND SIGNATURE*	DATE	FOR ORION USE ONLY	
		INDIRECT COST RATE VERIFICATION	
ORG. REP. TYPED NAME & SIGNATURE* _____	DATE _____	Date Checked / Date of Rate Sheet	Initials-ORG

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*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

Budget Justification

For the purposes of estimating a budget for this conceptual proposal, we assume the following:

- Project costs are determined for implementation years 1-6 : 1 October 2007 – 30 September 2012.
- Estimated salaries are for 2007 and assume 4% growth with inflation; equipment costs are in current dollars.
- Funding profiles will require quasi-level funding, requiring a phasing of the work.
- In all years, constant funding is required for the project group consisting of a senior scientist (fraction 0.5), junior scientist (1), senior engineers (2), junior engineers (2), and technicians (2). Salaries, benefits, and overhead rates used are for Applied Physics Lab (APL) at UW.
- Capital equipment consists of 12 complete moorings + 1 spare = 13 moorings total
- Distributed evenly over the first 5 years, the mooring components will be acquired and the moorings constructed and deployed. The capital cost per year is simply the total cost of 13 moorings divided by 5 years. No attempt is made here to be more specific as to phasing.
- In all years, the previously deployed moorings will be operated and maintained. With Year 6, all moorings are in place and the budget is strictly for O&M.
- O&M replacement equipment cost in Year x = 10% of total preceding installed equipment cost. The salary of the project group remains constant.
- Travel is $100K/yr.
- Supplies and services (e.g., machine shop, calibration, rentals, warehouse lease, miscellaneous) is 10% of equipment costs.

The concept of a project group is crucial to provide the necessary continuity and breadth of expertise. It may be that this group will be part of some larger ORION RCO engineering effort.

The mix of personnel may well vary over time (e.g., relatively more technician time in the later stages), but the total level of effort is reasonable for the task based on previous experience at APL with large projects. We assume a low level of continual Non Recurring Engineering (NRE) Development costs included here to cover start up and the continual re-engineering necessary as parts become obsolete and requirements change. Sea pay is not explicitly accounted for; one can regard full time support as 11 months + 1 month for sea time. We have not explicitly tried to distinguish between fabrication and non-fabrication budgeting here (At APL-UW, this might reduce labor cost by 17%). We have assumed no sales tax on equipment (permissible in the state of Washington if retained longer than 5 years).

Ship and ROV time was estimated as follows (Table BJ1). Nominal distance between the 12 sites and Seattle is 3000 km, or 6 days transit. Two days are added for weather/contingency (8 days). In Year 1 all the bottom sensor suites are deployed, requiring 1 day each for a total of 8+12=20 days. In Year 2, 3 moorings are installed, each taking 3 days; the other 9 sites are visited for servicing the bottom packages (each 1 day), with 1 extra day for change out, with a total of 8+9+9+1=27 days. In Year 3, the next 3 moorings are installed, and the other 9 sites visited (1 day each), with 3 days allowed for a mooring change out, 8+9+9+3=29 days. This is repeated in Years 4 and 5. In Year 6 with no new installations and just service, 8+12+3=23 days are required. ROV time is just ship time minus the 8 transit/weather days each year. Actual ship and ROV costs are not included in this budget.

Table BJ1. Ship and ROV time

Days	Y1	Y2	Y3	Y4	Y5	Y6
Ship time	20	27	29	29	29	23
ROV time	12	19	21	21	21	15

The first year is ambitious. It assumes that the project group is assembled and operational (people, documentation procedures, laboratory, assembly, and warehouse space, etc.), that previous projects have provided good documentation so that the (relatively simple) bottom package can be rapidly fabricated and deployed and that the acquisition of parts for the first 3 moorings can proceed, and that between now and the time this project begins, this technology (e-o-m moorings and profilers) has been rigorously tested and infant mortality design flaws eliminated. It is imperative that experience be obtained using one of the observatory testbed facilities, MARS and the Canadian component of the RCO, NEPTUNE Phase 1. Thus, a 1 October 2007 start date is in fact not unreasonable, even if the US OOI RCO component is not installed before 2010.

The number of spares one keeps on hand (and has to purchase and maintain) [KD1]will crucially depend on the reliability, survivability, and overall robustness of the equipment (e.g., acoustic sensors vs. "wet" chemistry and biology; biofouling); extra up-front effort and on-going attention in these areas will be well worth the cost. The operational aspects of how to actually service and calibrate sensors on an annual basis without simply having a complete second set for each must be worked out. The scenario described above of one long service cruise is likely overly simple; rather, the servicing probably would take place 1 mooring at a time, interspersed with other RCO tasks. This would provide time to calibrate/repair/turn-around sensors and equipment before the next cruise. Exactly how much servicing and calibration can be done in place with an ROV (or ultimately an AUV) must be addressed.

Detailed spreadsheets describing the sensors and the mooring are attached. Table BJ2 shows the high level summary of the equipment costs of a single mooring sensor system. These costs assume the presence of a RCO node within 2 km of the mooring site (i.e., we require the RCO to provide an appropriate "extension cord" if a primary node is not nearby). There are 60 sensors called for on each mooring with, an average cost of $25K. Sensors are 64% of the total cost, the mooring infrastructure equipment cost is 36% of the total.

Table BJ2. Summary equipment costs for mooring infrastructure and sensors

Mooring infrastructure + sensor cost	
	Cost $K
Fixed mooring infrastructure	587
Profiling infrastructure	269
All infrastructure	856
Fixed sensors	1,117
Profiling sensors	406
All Sensors	1,524
Total	2,379

The overall summary budget is given below on the next page. The average cost per year is ~$9M; the O&M cost in Year 6 is $5M.

The last year (Year 6) in the budget has only "wet" O&M costs. The expectation is that the project would continue for the duration of the ORION program (>25 y). This field effort must reside within a larger effort that includes overall coordination, and the science effort (see Project Management section). Our estimate of the various necessary tasks is given in Table BJ3. Most of these costs are labor (e.g., Senior scientist, junior scientist, post-docs, students, project manager, data manager, programmer, administration, etc.). This estimate is clearly very rough, and does not take into account the many synergistic and parallel activities that conceivably could reduce this cost; it assumes this is a quasi-stand-alone project – emphatically not the desire!

Table BJ3. Overall, long-term annual project costs

	$M
Project management (science and engr)	1,200
Field/instrumentation/operations and maintenance	5,388
Data quality control and handling	800
Data analysis	1,200
Modeling	1,300
Data assimilation	1,600
Integration and synthesis	1,650
Total	13,138

Overall, the costs estimates given here are in line with the "big picture" rule of thumb. As an example, the science costs associated with a research ship are 2 to 3 times the annual operating cost of the ship; for a large ship (~270 ft) that cost $80M to build and costs $6-7M/y (doesn't include technicians or submersibles) to operate, this implies $14M to $21M of science per year. These costs correspond to the estimates for this project.

APL- UW Estimated Budget

An Interdisciplinary Ocean Observatory Linking Ocean Dynamics, Climate, and Ecosystem Response from Basin to Regional Scales

Principal Investigator: Senior Scientist
Project Time Period: 1 October 2007 to 30 September 2012

		YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	TOTAL
A. Salaries [1, 2]	mths/year							
Senior Scientists	6	68,309	71,042	73,883	76,839	79,912	83,109	**453,094**
Jr. Scientists	12	75,417	78,433	81,571	84,833	88,227	91,756	**500,237**
Sr. Engineers	24	222,818	231,731	241,000	250,640	260,665	271,092	**1,477,946**
Jr. Engineers	24	153,828	159,982	166,381	173,036	179,958	187,156	**1,020,341**
Technicians	24	129,068	134,231	139,600	145,184	150,991	157,031	**856,106**
Coordinator/Admin	2	14,922	15,519	16,140	16,785	17,457	18,155	**98,977**
Subtotal Salaries		664,362	690,937	718,574	747,317	777,210	808,298	**4,406,699**
B. Employee Benefits [3]								
Employee Benefits (22.0%)		146,160	152,006	158,086	164,410	170,986	177,826	**969,474**
Leave Allowance (24.9%)		165,426	172,043	178,925	186,082	193,525	201,266	**1,097,268**
Subtotal Benefits		311,586	324,049	337,011	350,492	364,512	379,092	**2,066,742**
C. Equipment								
Mooring Equipment		6,186,000	6,186,000	6,186,000	6,186,000	6,186,000	0	**30,930,000**
Mooring O&M		0	619,000	1,237,000	1,856,000	2,474,000	3,093,000	**9,279,000**
Subtotal Equipment		6,186,000	6,805,000	7,423,000	8,042,000	8,660,000	3,093,000	**40,209,000**
D. Travel [4]		100,000	100,000	100,000	100,000	100,000	100,000	**600,000**
E. Other Direct Costs								
Services		289,000	318,000	346,000	375,000	404,000	144,000	**1,876,000**
Supplies		289,000	318,000	346,000	375,000	404,000	144,000	**1,876,000**
Graduate Operating Fees		0	0	0	0	0	0	**0**
Subtotal Other Direct Costs		578,000	636,000	692,000	750,000	808,000	288,000	**3,752,000**
F. Prorated Direct Costs [5] (47.8% of salaries)		317,565	330,268	343,479	357,218	371,506	386,367	**2,106,402**
G. TOTAL DIRECT COSTS		8,157,514	8,886,254	9,614,064	10,347,027	11,081,228	5,054,757	**53,140,844**
H. Facilities & Admin Costs [5] (17% of G less Equip, Grad Op Fees, & Subcontract amounts above $25K)		335,157	353,813	372,481	391,855	411,609	333,499	**2,198,413**
I. Total Direct + Indirect Costs		8,492,671	9,240,067	9,986,545	10,738,881	11,492,837	5,388,256	**55,339,257**
J. TOTAL		**$8,492,671**	**$9,240,067**	**$9,986,545**	**$10,738,881**	**$11,492,837**	**$5,388,256**	**55,339,257**

NOTES (APPLY TO INDIVIDUAL YR BUDGET SHEETS)

1 The amount budgeted for administrative, clerical, or secretarial support will cover services directly related to the grant/contract. APL-UW is considered a major project, and thus such charges are in full compliance with OMB Circular A-21, Section F.6.b. Reference 30 Sept. 1994 letter (ser 4330/247) from June Hawley, Administrative Contracting Officer, Office of Naval Research, Seattle Regional Office, to William Bakamis, APL-UW General Manager, Business and Fina
University of Washington uses a 4% cost of living increase each year.

10. APPENDIX

Table A. Location of proposed sites, justification, and science objectives	
Sites	Observations
1, 11, 12, 8, and 9	Resolution of N/S fluctuations in the WWD and its bifurcation; comparison of different ecosystems (subarctic and subtropical gyres).
1, 11 and 2, 10	Biophysical variability in WWD advected towards coast; delineate variability of mass and biogenic fluxes in the N/S divergence.
1-2; 3,10,4; 5, 6,7	Comparison of onshelf/slope/offshelf processes and fluxes at locations of different upwelling and mean current regimes.
2 and 10	Located in a highly dynamic and ecologically diverse region of the NE Pacific; will provide insights into climate-scale (seasonal-to-interannual and interdecadal time scale) impacts on regional physics and ecology.
4 and 7	Provide estimates of along-shelf variability in biophysical fields. Despite the coarse spatial scale, co-variability (or lack thereof) between extended time series observations in these two locations would provide improved tests of various hypotheses relating ocean productivity to the success of commercially important fisheries
4	Major site for larval retention, harmful algal blooms, and source of deepwater renewal for large areas of inner coastal waters
7	Site for questions related to upwelling-driven production, physical-biological retention mechanisms, cross-shelf transport of organisms and particulate flux, fisheries, and marine mammals and bird dynamics
7-5	Enable sampling of biophysical processes from the exceptionally productive upwelling zone (over the shelf) to the nutrient-poor, subtropical waters west of the shelf break. Sustained observations of the upper water column (mixed layer/euphotic zone) will provide insights into climate-scale (seasonal to interannual and interdecadal time scales) impacts on regional physics and ecology
3 and 12	Located at major hydrothermal vents (Endeavor Ridge and Axial Volcano) along the Juan de Fuca Ridge, that will be intensively studied by the geophysical community. Water column observations will provide measurements of along-ridge flows; transport of vent larvae, and measurements of mega-plumes.
2, 10, 6 (shelf break), 12 (ridge), 5, 8, and 9 (across transform fault	Provide data on boundary mixing that may be critical to understanding the maintenance of the observed abyssal stratification. Diapycnal mixing near the seafloor helps transport mixed water, nutrients, etc. from coastal margins into the interior ocean. Continuous, high-frequency (subtidal time scale) and spatially distributed sampling across the complex bottom topography of the shelf-break, ridge and transform fault will provide information necessary to quantify the statistics of bottom-water mixing that vary on a broad spectrum of time scales (shorter than tidal to seasonal and interannual).

Table B. Coordinates and depth for proposed water-column sites*			
Site name	Position (approximate) Latitude	Longitude	Water depth (m)
1	50°N	131°W	2990
2	49°40'N	128°10'W	1900
3	47°40'W	128°20'W	2590
4	47°55'W	125°10'W	160
5	44°39'N	124°40'W	2840
6	44°39'N	125°30'W	2990
7	44°39'N	127°50'W	110
8	43°20'N	128°20'W	2850
9	42°30'N	128°55'W	3240
10	48°15'N	126°50'W	2600
11	48°10'N	131°W	3230
12	45°50'N	129°30'W	1970
*Deployment for all sites is 30 years; revisits during deployment are assumed to be once per year.			

TABLE C: COSTING Detailed single mooring: components and sensors				
	Qty	Cost	Cost	Modules
		unit	Total	cost
Cables and connectors				
Media Converters	6	8,000	48,000	
Extension Cable	3000	12	36,000	
ROV Connectors	4	4,500	18,000	
Mooring Cable	3000	25	75,000	
Swivel/Sliprings	2	12,000	24,000	
Terminations	4	12,000	48,000	
Total				249,000
Float				
Foam	1	30,000	30,000	
Structure	1	25,000	25,000	
Total				55,000
Mooring				
Anchor	1	5,000	5,000	
Releases	2	17,500	35,000	
Total				40,000
Winch system on subsurface float				
Basic System	1	75,000	75,000	
Miscel	1	3,000	3,000	
Total				78,000
MMP (2)				
Basic System	2	75,000	150,000	
Modifications	2	5,000	10,000	
Inductive Data Transfer	2	3,000	6,000	
MMP Inductive Power (2)				
DC-HFAC	2	3,000	6,000	
HFAC-DC	2	2,000	4,000	
Battery Charger	2	1,200	2,400	
Battery Pack	16	165	2,640	
Coupler	2	5,000	10,000	
Total				191,040
Secondary Node - In-line mooring				
Frame	1	5,000	5,000	
Pressure Housing	1	10,000	10,000	
ROV Mate Receptacles	3	8,000	24,000	
Enet Switch	2	1,000	2,000	
DC-DC Conv	1	1,000	1,000	
GFM	1	1,000	1,000	
Load Switching	1	1,000	1,000	
Timing	1	1,000	1,000	
Total				45,000
Secondary Node - Seafloor				
Frame	1	5,000	5,000	
Pressure Housing	1	10,000	10,000	
ROV Mate Receptacles	5	8,000	40,000	
Enet Switch	2	1,000	2,000	
DC-DC Conv	1	1,000	1,000	
GFM	1	1,000	1,000	
Load Switching	1	1,000	1,000	
Timing	1	1,000	1,000	
Total				61,000
Secondary Node - Float				
Pressure Housing	1	10,000	10,000	
ROV Mate Receptacles	5	8,000	40,000	
Enet Switch	2	1,000	2,000	
DC-DC Conv	1	1,000	1,000	
GFM	1	1,000	1,000	
Load Switching	1	1,000	1,000	
Timing	1	1,000	1,000	
Total				56,000

Detailed single mooring: components and sensors				
	Qty	**Cost unit**	**Cost Total**	**Modules cost**
SIIM - Float				
Frame	1	5,000	5,000	
Pressure Housing	1	10,000	10,000	
Dry Mate Connectors	8	200	1,600	
ROV Cable	1	4,500	4,500	
Enet Switch	1	1,000	1,000	
I/O Board	1	1,000	1,000	
Xports	8	100	800	
DC-DC Conv	1	1,000	1,000	
Video Server	2	500	1,000	
Timing	1	1,000	1,000	
Total				26,900
SIIM - In-line mooring				
Frame	1	5,000	5,000	
Pressure Housing	1	10,000	10,000	
Dry Mate Connectors	8	200	1,600	
ROV Cable	1	4,500	4,500	
Enet Switch	1	1,000	1,000	
I/O Board	1	1,000	1,000	
Xports	8	100	800	
DC-DC Conv	1	1,000	1,000	
Video Server	2	500	1,000	
Timing	1	1,000	1,000	
Total				26,900
SIIM - Seafloor secondary node				
Frame	1	5,000	5,000	
Pressure Housing	1	10,000	10,000	
Dry Mate Connectors	8	200	1,600	
ROV Cable	1	4,500	4,500	
Enet Switch	1	1,000	1,000	
I/O Board	1	1,000	1,000	
Xports	8	100	800	
DC-DC Conv	1	1,000	1,000	
Video Server	2	500	1,000	
Timing	1	1,000	1,000	
Total				26,900

Detailed single mooring: components and sensors				
	Qty	Cost unit	Cost Total	Modules cost
Sensors - winched float				
ADCP RDI 150 kHz	0	37,500		
ADCP RDI 75 kHz	0	50,000		
CTDO2 Seabird 52MP/43F	2	12,000	24,000	
NO3 analyzer Satlantic ISUS	1	25,000	25,000	
Camera DSP&L LED Multi SEACAM 2055	0	3,055		
Horiz electric field/Pressure/Inverted echosounder HPIES	0	30,000		
Acoustic current meter	1	10,000	10,000	
300 kHz 5-Beam vertical beam ADCP (VADCP)	0	65,000		
Broadband Hydrophone	0	10,000		
Tomography transceiver - Webb Research 250 Hz sweeper/STAR	0	250,000		
Acoustic modem/navigation Benthos	0	9,188		
PAR	0	10,000		
3 wave Fluorometer sensor Wet Labs	1	5,800	5,800	
Combo backscattering meter and fluorometer WetLabs eco-bb2f	1	4,600	4,600	
Transmissometer, 25 cm, 660 nm, 6000 meter WetLabs Cstar	0	3,900		
Zooplankton/fish/squid acoustics (TAPS)	0	100,000		
zooplankton imaging systems (SIPPER, holography)	0	65,000		
Hyperspectral WetLabs SAFire saf-16-25	1	30,000	30,000	
pH	1	10,000	10,000	
pCO2 Sunburst SAMI-15000	0	18,500		
PO4	0	10,000		
Iron	0	10,000		
Flow cytometry	0	20,000		
Molecular ESP	0	60,000		
Video camera	0	4,000		
Fish and Zooplankton 38 KHz Simrad ER 60	0	51,370		
broadband hydrophone array	0	50,000		
100 kHz slant beam sonar	0	100,000		
acoustic resonator	1	50,000	50,000	
Total				159,400
Sensors - subsurface float				
ADCP RDI 150 kHz	0	37,500		
ADCP RDI 75 kHz	0	50,000		
CTDO2 Seabird 52MP/43F	2	12,000	24,000	
NO3 analyzer Satlantic ISUS	1	25,000	25,000	
Camera DSP&L LED Multi SEACAM 2055	1	3,055	3,055	
Horiz electric field/Pressure/Inverted echosounder HPIES	0	30,000		
Acoustic current meter	0	10,000		
300 kHz 5-Beam vertical beam ADCP (VADCP)	1	65,000	65,000	
Broadband Hydrophone	0	10,000		
Tomography transceiver - Webb Research 250 Hz sweeper/STAR	0	250,000		
Acoustic modem/navigation Benthos	1	9,188	9,188	
PAR	0	10,000		
3 wave Fluorometer sensor Wet Labs	1	5,800	5,800	
Combo backscattering meter and fluorometer WetLabs eco-bb2f	1	4,600	4,600	
Transmissometer, 25 cm, 660 nm, 6000 meter WetLabs Cstar	0	3,900		
Zooplankton/fish/squid acoustics (TAPS)	1	100,000	100,000	
zooplankton imaging systems (SIPPER, holography)	0	65,000		
Hyperspectral WetLabs SAFire saf-16-25	1	30,000	30,000	
pH	1	10,000	10,000	
pCO2 Sunburst SAMI-15000	1	18,500	18,500	
PO4	0	10,000		
Iron	0	10,000		
Flow cytometry	0	20,000		
Molecular ESP	0	60,000		
Video camera	0	4,000		
Fish and Zooplankton 38 KHz Simrad ER 60	1	51,370	51,370	
broadband hydrophone array	1	50,000	50,000	
100 kHz slant beam sonar	1	100,000	100,000	
acoustic resonator	0	50,000		
Total				496,513

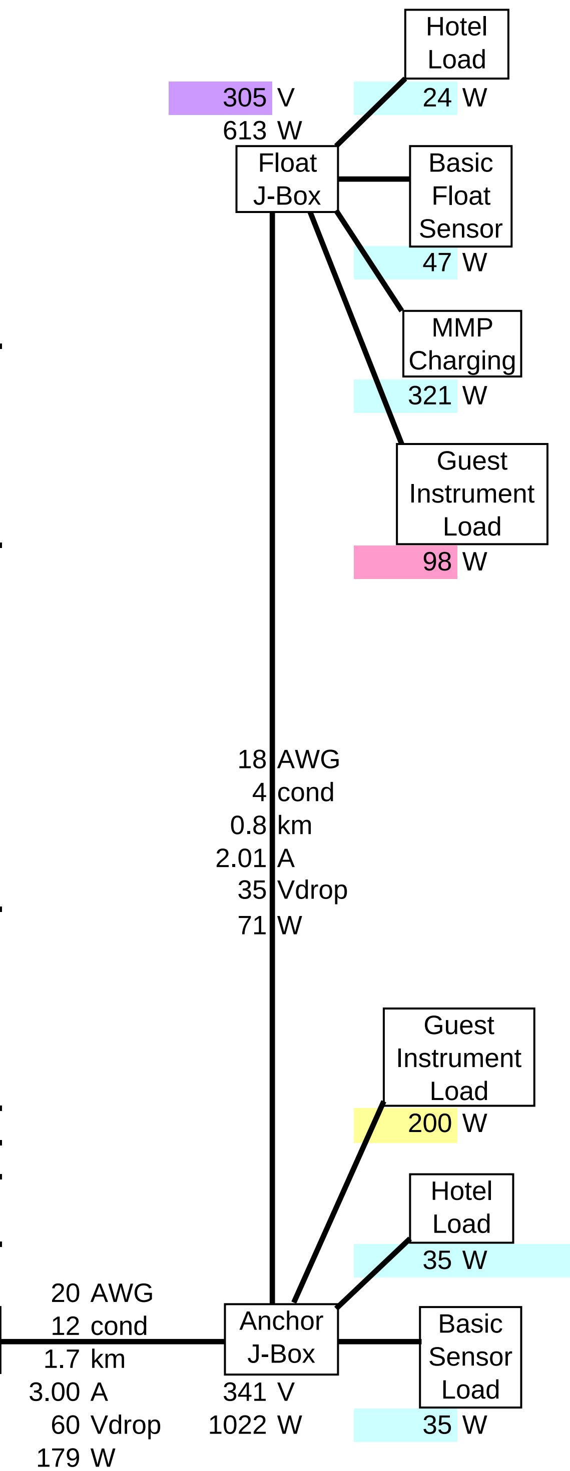
Detailed single mooring: components and sensors				
	Qty	Cost	Cost	Modules
		unit	Total	cost
Sensors - 200-600m profiler				
ADCP RDI 150 kHz	0	37,500		
ADCP RDI 75 kHz	0	50,000		
CTDO2 Seabird 52MP/43F	2	12,000	24,000	
NO3 analyzer Satlantic ISUS	0	25,000		
Camera DSP&L LED Multi SEACAM 2055	0	3,055		
Horiz electric field/Pressure/Inverted echosounder HPIES	0	30,000		
Acoustic current meter	1	10,000	10,000	
300 kHz 5-Beam vertical beam ADCP (VADCP)	0	65,000		
Broadband Hydrophone	1	10,000	10,000	
Tomography transceiver - Webb Research 250 Hz sweeper/STAR	0	250,000		
Acoustic modem/navigation Benthos	0	9,188		
PAR	0	10,000		
3 wave Fluorometer sensor Wet Labs	1	5,800	5,800	
Combo backscattering meter and fluorometer WetLabs eco-bb2f	1	4,600	4,600	
Transmissometer, 25 cm, 660 nm, 6000 meter WetLabs Cstar	0	3,900		
Zooplankton/fish/squid acoustics (TAPS)	0	100,000		
zooplankton imaging systems (SIPPER, holography)	0	65,000		
Hyperspectral WetLabs SAFire saf-16-25	0	30,000		
pH	1	10,000	10,000	
pCO2 Sunburst SAMI-15000	1	18,500	18,500	
PO4	0	10,000		
Iron	0	10,000		
Flow cytometry	0	20,000		
Molecular ESP	0	60,000		
Video camera	0	4,000		
Fish and Zooplankton 38 KHz Simrad ER 60	0	51,370		
broadband hydrophone array	0	50,000		
100 kHz slant beam sonar	0	100,000		
acoustic resonator	0	50,000		
Total				82,900
Sensors - 600 m fixed				
ADCP RDI 150 kHz	0	37,500		
ADCP RDI 75 kHz	0	50,000		
CTDO2 Seabird 52MP/43F	2	12,000	24,000	
NO3 analyzer Satlantic ISUS	0	25,000		
Camera DSP&L LED Multi SEACAM 2055	1	3,055	3,055	
Horiz electric field/Pressure/Inverted echosounder HPIES	0	30,000		
Acoustic current meter	0	10,000		
300 kHz 5-Beam vertical beam ADCP (VADCP)	0	65,000		
Broadband Hydrophone	0	10,000		
Tomography transceiver - Webb Research 250 Hz sweeper/STAR	1	250,000	250,000	
Acoustic modem/navigation Benthos	0	9,188		
PAR	0	10,000		
3 wave Fluorometer sensor Wet Labs	1	5,800	5,800	
Combo backscattering meter and fluorometer WetLabs eco-bb2f	1	4,600	4,600	
Transmissometer, 25 cm, 660 nm, 6000 meter WetLabs Cstar	0	3,900		
Zooplankton/fish/squid acoustics (TAPS)	0	100,000		
zooplankton imaging systems (SIPPER, holography)	0	65,000		
Hyperspectral WetLabs SAFire saf-16-25	0	30,000		
pH	1	10,000	10,000	
pCO2 Sunburst SAMI-15000	1	18,500	18,500	
PO4	0	10,000		
Iron	0	10,000		
Flow cytometry	0	20,000		
Molecular ESP	0	60,000		
Video camera	0	4,000		
Fish and Zooplankton 38 KHz Simrad ER 60	2	51,370	102,740	
broadband hydrophone array	0	50,000		
100 kHz slant beam sonar	0	100,000		
acoustic resonator	0	50,000		
Total				418,695

Detailed single mooring: components and sensors				
	Qty	Cost unit	Cost Total	Modules cost
Sensors - 600-3000m profiler				
ADCP RDI 150 kHz	0	37,500		
ADCP RDI 75 kHz	0	50,000		
CTDO2 Seabird 52MP/43F	2	12,000	24,000	
NO3 analyzer Satlantic ISUS	0	25,000		
Camera DSP&L LED Multi SEACAM 2055	0	3,055		
Horiz electric field/Pressure/Inverted echosounder HPIES	0	30,000		
Acoustic current meter	1	10,000	10,000	
300 kHz 5-Beam vertical beam ADCP (VADCP)	0	65,000		
Broadband Hydrophone	1	10,000	10,000	
Tomography transceiver - Webb Research 250 Hz sweeper/STAR	0	250,000		
Acoustic modem/navigation Benthos	0	9,188		
PAR	0	10,000		
3 wave Fluorometer sensor Wet Labs	1	5,800	5,800	
Combo backscattering meter and fluorometer WetLabs eco-bb2f	1	4,600	4,600	
Transmissometer, 25 cm, 660 nm, 6000 meter WetLabs Cstar	0	3,900		
Zooplankton/fish/squid acoustics (TAPS)	1	100,000	100,000	
zooplankton imaging systems (SIPPER, holography)	0	65,000		
Hyperspectral WetLabs SAFire saf-16-25	0	30,000		
pH	1	10,000	10,000	
pCO2 Sunburst SAMI-15000	0	18,500		
PO4	0	10,000		
Iron	0	10,000		
Flow cytometry	0	20,000		
Molecular ESP	0	60,000		
Video camera	0	4,000		
Fish and Zooplankton 38 KHz Simrad ER 60	0	51,370		
broadband hydrophone array	0	50,000		
100 kHz slant beam sonar	0	100,000		
acoustic resonator	0	50,000		
Total				164,400
Sensors - bottom				
ADCP RDI 150 kHz	0	37,500		
ADCP RDI 75 kHz	1	50,000	50,000	
CTDO2 Seabird 52MP/43F	2	12,000	24,000	
NO3 analyzer Satlantic ISUS	0	25,000		
Camera DSP&L LED Multi SEACAM 2055	1	3,055	3,055	
Horiz electric field/Pressure/Inverted echosounder HPIES	1	30,000	30,000	
Acoustic current meter	0	10,000		
300 kHz 5-Beam vertical beam ADCP (VADCP)	1	65,000	65,000	
Broadband Hydrophone	1	10,000	10,000	
Tomography transceiver - Webb Research 250 Hz sweeper/STAR	0	250,000		
Acoustic modem/navigation Benthos	1	9,188	9,188	
PAR	0	10,000		
3 wave Fluorometer sensor Wet Labs	1	5,800	5,800	
Combo backscattering meter and fluorometer WetLabs eco-bb2f	1	4,600	4,600	
Transmissometer, 25 cm, 660 nm, 6000 meter WetLabs Cstar	0	3,900		
Zooplankton/fish/squid acoustics (TAPS)	0	100,000		
zooplankton imaging systems (SIPPER, holography)	0	65,000		
Hyperspectral WetLabs SAFire saf-16-25	0	30,000		
pH	0	10,000		
pCO2 Sunburst SAMI-15000	0	18,500		
PO4	0	10,000		
Iron	0	10,000		
Flow cytometry	0	20,000		
Molecular ESP	0	60,000		
Video camera	0	4,000		
Fish and Zooplankton 38 KHz Simrad ER 60	0	51,370		
broadband hydrophone array	0	50,000		
100 kHz slant beam sonar	0	100,000		
acoustic resonator	0	50,000		
Total				201,643

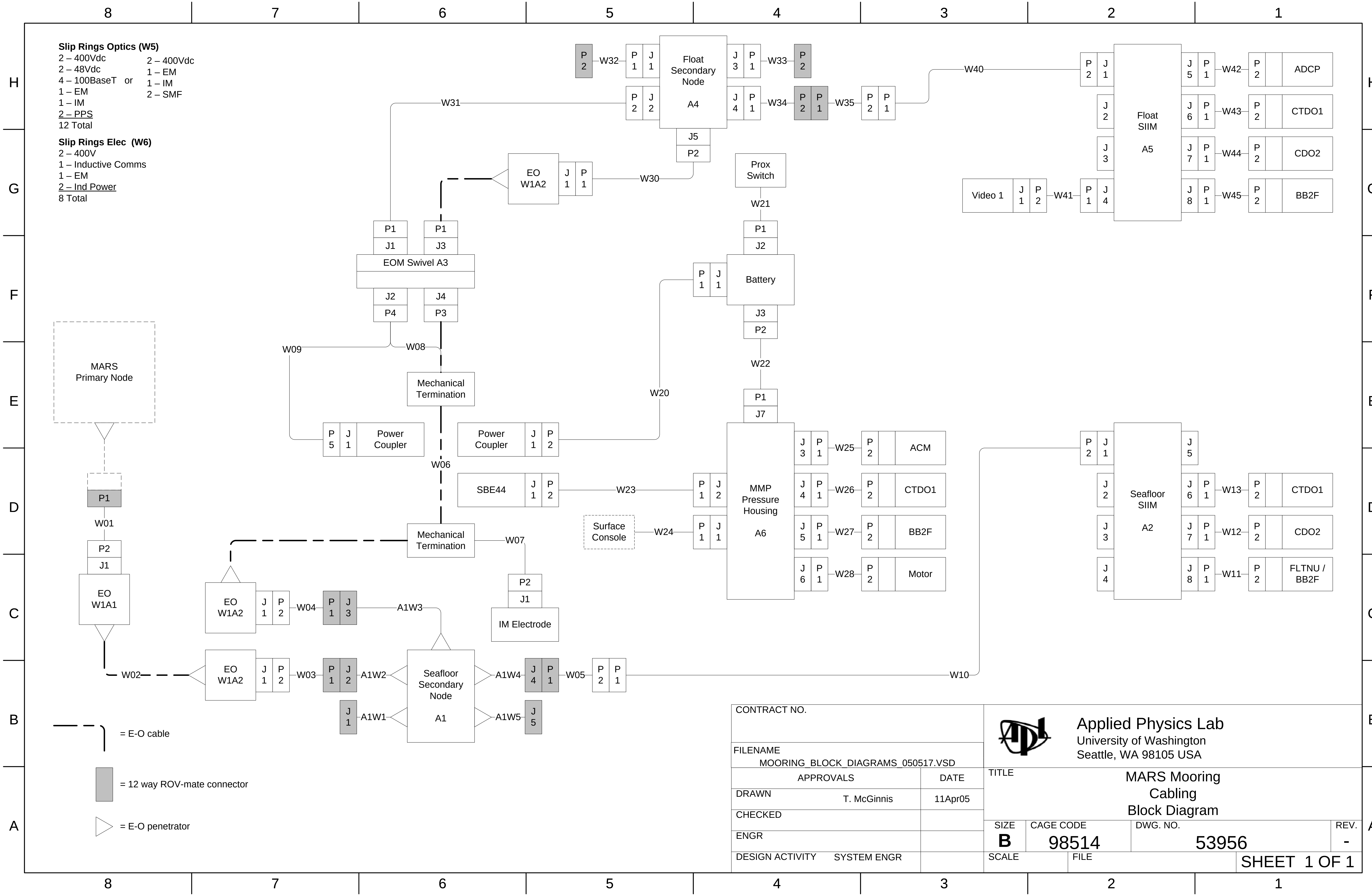
Detailed single mooring: components and sensors				
	Qty	**Cost unit**	**Cost Total**	**Modules cost**
Total				**2,379,291**
Cables and connectors				249,000
Float				55,000
Mooring				40,000
Winch system on subsurface float				78,000
MMP (2)				191,040
Secondary Node - In-line mooring				45,000
Secondary Node - Seafloor				61,000
Secondary Node - Float				56,000
SIIM - Float				26,900
SIIM - In-line mooring				26,900
SIIM - Seafloor secondary node				26,900
Sensors - winched float				159,400
Sensors - subsurface float				496,513
Sensors - 200-600m profiler				82,900
Sensors - 600 m fixed				418,695
Sensors - 600-3000m profiler				164,400
Sensors - bottom				201,643
Total				**2,379,291**
All infrastructure				**855,740**
Fixed mooring infrastructure				**586,700**
Profiling infrastructure				**269,040**
All Sensors	**60**			**1,523,551**
Fixed sensors	**35**			**1,116,851**
Profiling sensors	**25**			**406,700**

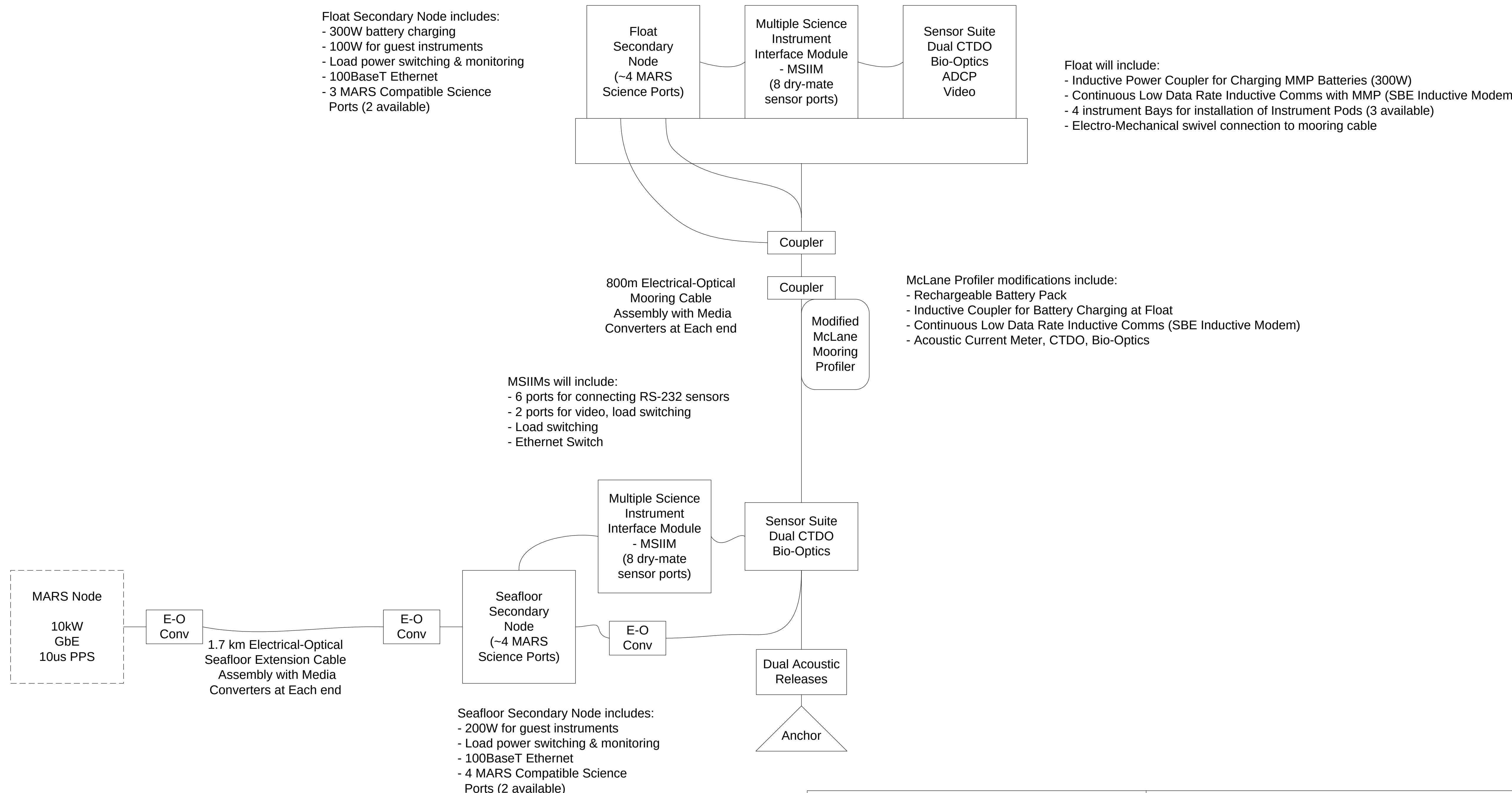
ALOHA/MARS Profiling Mooring Electrical Power Budget

MARS Node Voltage	400	vdc
MARS Node Power	1200	watts
Cable Current	3.00	amps
Cable wire gauge	20	AWG
Cable Length	1.7	km
Conductors in leg 1	6	
Conductors in leg 2	6	#
Resistance per conductor	35	ohms/km
Total Cable Resistance	19.8	ohms
Voltage Drop	60	vdc
Cable Power Loss	179	watts
Extension Cable Efficiency	85%	%
Anchor J-Box Voltage	341	vdc
Power to Anchor J-Box	1022	watts
Power to for Anchor Sensors	34.9	watts
Power to Hotel Load	35.4	watts
Power to Guest Instruments	200	
Power from Anchor J-Box	684	watts
Anchor J-Box Voltage	341	
Mooring Cable wire gauge	18	AWG
Mooring Cable Length	0.8	km
Conductors in leg 1	2	
Conductors in leg 2	2	#
Resistance per conductor	22	ohms/km
Total Riser Cable Resistance	18	ohms
Riser Cable Voltage Drop	35	vdc
Riser Cable Power Loss	71	watts
Riser Cable Current	2.01	amps
Riser Cable Efficiency	90%	%
Float Voltage	305	vdc
Power to Float	613	watts
Power to Charge Float Batteries	321	watts
Power to Hotel Load	23.7	
Power to Float Sensors	46.9	
Power available for Guest Instruments	98	watts
Total Power (check)	1200	watts
Converter Efficiency	80%	%
Power to Loads	760	watts
Conversion and Transmission Loss	440	watts
Total Power (check)	1200	watts



MARS Node Power 1200 W
MARS Node Voltage 400 V
MARS Node


Slip Rings Optics (W5)
2 – 400Vdc
2 – 48Vdc
4 – 100BaseT or
1 – EM
1 – IM
2 – PPS
12 Total
2 – 400Vdc
1 – EM
1 – IM
2 – SMF
Slip Rings Elec (W6)
2 – 400V
1 – Inductive Comms
1 – EM
2 – Ind Power
8 Total
Float Secondary Node A4
Float SIIM A5
ADCP
CTDO1
CDO2
BB2F
Video 1
W30
W31
W32
W33
W34
W35
W40
W41
W42
W43
W44
W45
EO W1A2
Prox Switch
W21
Battery
EOM Swivel A3
W08
W09
W20
W22
MARS Primary Node
Mechanical Termination
Power Coupler
MMP Pressure Housing A6
ACM
Motor
SBE44
Surface Console
W23
W24
W25
W26
W27
W28
W06
W07
W01
EO W1A1
IM Electrode
Seafloor SIIM A2
FLTNU / BB2F
W11
W12
W13
W04
A1W3
W02
W03
A1W2
Seafloor Secondary Node A1
A1W4
W05
W10
A1W1
A1W5
= E-O cable
= 12 way ROV-mate connector
= E-O penetrator
CONTRACT NO.
FILENAME
MOORING_BLOCK_DIAGRAMS_050517.VSD
APPROVALS
DATE
DRAWN T. McGinnis 11Apr05
CHECKED
ENGR
DESIGN ACTIVITY SYSTEM ENGR
Applied Physics Lab
University of Washington
Seattle, WA 98105 USA
TITLE
MARS Mooring Cabling Block Diagram
SIZE B
CAGE CODE 98514
DWG. NO. 53956
REV. -
SCALE
FILE
SHEET 1 OF 1



CONTRACT NO.		Applied Physics Lab University of Washington Seattle, WA 98105 USA
APPROVALS	DATE	TITLE MARS Mooring System Block Diagram
DRAWN T. McGinnis	11Apr05	SIZE B · CAGE CODE 98514 · DWG. NO. 53951 · REV. -
CHECKED		SCALE · FILE · SHEET 1 OF 1
ENGR		
DESIGN ACTIVITY · SYSTEM ENGR		