II. Introduction

"A program of sustained observations is a requirement for understanding oceanographic processes."

Ocean Sciences at the New Millennium, 2001

For centuries, oceanographers have relied on data and observations about the ocean and seafloor below gathered from ships during cruises of limited duration. This expeditionary research approach has resulted in major advances in understanding global ocean circulation, the energy associated with mesoscale circulation, plate tectonics, global ocean productivity, and climate-ocean coupling. These and many other successes have provided exciting glimpses into Earth and ocean processes and have contributed fundamental knowledge for understanding Earth. New enabling technologies now offer the oceanographic community the opportunity to revolutionize the study of the oceans by providing interactive sampling capabilities spanning temporal and spatial scales not effectively captured using ships. To realize the potential of these new observational opportunities, community efforts in the United States (Table 1) have consistently noted that it is critical to develop, deploy, and maintain a permanent, instrumented presence in the ocean; to collect sustained, spatially resolved time-series measurements; and to deliver data back to scientists on land in real time. This sustained presence will complement traditional ship-based research, permitting integrated and adaptive sampling of the world's oceans.

ORION is more than a research program. It is a transformation step, providing scientists, educators, and the general public interactive and continuous access to the oceans. This access will revolutionize our understanding of the ocean and the seafloor below by providing the biological, chemical, physical, and geological information needed to develop a dynamic, three-dimensional understanding of water-column constituents, physical oceanographic parameters, and ecosystems; Earth structure; and fluid and material fluxes within sediments and oceanic crust. ORION data collected at high sampling rates over many years using a variety of sensors on fixed and mobile platforms deployed in key oceanic regions, combined with remote-sensing information, will provide the integrated, time-dependent, scalable picture of the oceans required to distinguish long-term trends or short-term perturbations due to natural phenomena, as well as human-induced changes in the oceans.

The ORION program consists of four main instrumentation components, three of which will be built using Ocean Observatories Initiative (OOI) infrastructure funds from the National Science Foundation's Major Research Equipment and Facilities (MREFC) account.

1. Relocatable deep-sea moored buoys will contribute to studies of the ocean's role in global climate and will help support observations of the structure and dynamics of Earth's interior. These buoys will be sufficiently robust to be able to be deployed in harsh environments such as the Southern Ocean. Moored observatories consist of surface systems that provide central power generation, and data communication by a satellite or radio link to shore. The moored buoys support water-column sensor systems for physical, biological, and chemical studies; seafloor geophysical sensors; and sophisticated flux measurements that quantify the ocean-atmosphere exchange.
2. The regional cabled network will consist of interconnected monitoring sites located on the seafloor. These will span regional-scale (10-1000 km) geological and oceanographic features of a crustal plate. This observatory component will use undersea electro-optical cables connected

Table 1. Some of the many workshops and/or reports that have called for sustained ocean observations. All propose building permanent observing capabilities in the world's oceans.	
Workshop and/or Report Title	**Year**
International Conference on the Ocean Observing System for Climate	1999
Developing Submergence Science in the Next Decade (DESCEND)	1999
Symposium on Seafloor Science	2000
Ocean Sciences at the New Millennium	2001
Integrated and Sustained Ocean Observing System Workshop	2002
Office of Naval Research/Marine Technology Society Buoy Workshop	2002
Scientific Cabled Observatories for Time-Series (SCOTS)	2002
Coastal Ocean Processes and Observatories: Advancing Coastal Research	2002
Autonomous and Lagrangian Platforms and Sensors (ALPS)	2003
Implementation Plan for the DEOS Global Network of Moored-Buoy Observatories	2003
NEPTUNE Pacific Northwest Workshop	2003
Biological and Chemical Instrumentation in the Ocean	2003
Links between OOI and IODP Workshop	2003
REgional Cabled Observatory Network (of Networks) (RECONN)	2003
Technical Issues Related to Cable Re-use	2003
Coastal Observatory Research Arrays (CORA): A Framework for Implementation Planning	2003
Ocean Research Interactive Observatory Networks (ORION)	2004

to shore to supply power, communications, data relay, and command and control capabilities to scientific instruments connected to nodes along the cabled system. These nodes will be designed to interface with moored systems and dynamic observing platforms, such as autonomous underwater vehicles, or floats designed to sample the water column.

3. A network of coastal observatories consisting of long-term arrays spanning continental shelves, augmented with re-locatable instrument arrays, will provide critical measurements to understand along- and cross-shelf transport and transformation processes, to quantify the importance of episodic events in structuring shelf ecosystems (e.g., harmful algal blooms, storm surge, coastal erosion), to improve the accuracy of regional shelf forecast models, and to assess the impact of anthropogenic inputs to and through the coastal zone. Coastal observatories will gather data using moored buoys, shore-based radar, and seafloor cables.

The fourth critical ORION instrumentation component includes deployment of a diverse group of instruments on mobile platforms to provide the spatial context around the fixed time-series point measurements. These mobile assets include fleets of autonomous drifters and vehicles. Spatial data collected by *in situ* ORION assets will be merged with existing and emerging remote-sensing techniques. ORION's success will be measured by how well data from these diverse interactive observational capabilities, and data returned from them, can be integrated into a fully four-dimensional picture of the ocean system.

The 2004 ORION Workshop

Many of the technical elements of proposed observatories have been highlighted at workshops focused around specific technologies. For example, the Scientific Cabled Ocean Time Series (SCOTS) workshop focused on scientific issues that could be addressed using seafloor cable networks (Glenn and Dickey, 2003), while the Autonomous and Lagrangian Platform and Sensors (ALPS) workshop focused on the utility of mobile vehicles and drifters (Rudnick and Perry, 2003). Although these focused planning efforts were needed to identify critical technical and scientific issues, and to exchange ideas within specific communities, they did not allow for effective communication of information across groups, or for coordination of a large-scale strategy for ocean observatories. This compartmentalization was also mirrored in the scientific planning efforts, with different workshops focusing on different spatial scales (e.g., global, regional, coastal).

As a first step in defining the ORION scientific, technological, and educational priorities, the Dynamics of Earth and Ocean Systems (DEOS) Steering Committee, with support from the National Science Foundation (NSF), convened an open community workshop in early January 2004 in San Juan, Puerto Rico. Over 300 scientists, engineers, educators, and science managers from eight countries attended the meeting (Appendix 1). Compared with past workshops, participants were not constrained by a specific scientific focus (e.g., solid Earth, air-sea fluxes, or marine food webs), geographical footprint (e.g., coastal, regional, or global), or observational platform (e.g., cables or autonomous underwater vehicles). Prior to the workshop, participants had web access (still available at www.orionprogram.org under "San Juan Workshop") to the agenda (Appendix 2), background information papers, and an evolving list of scientific questions that would be discussed by various groups during the workshop.

The first day of the ORION workshop was devoted to science, technology, and education overview talks, a poster session (Appendix 3), and a panel discussion of broader ocean-observing activities with representatives from the National Science Foundation, the National Oceanic and Atmospheric Administration, the Office of Naval Research, Ocean.US, and the National Aeronautics and Space Administration.

The remainder of the workshop focused on highly interactive small-group discussions of science, technology, engineering, and education and outreach. The relatively large (>35 participants) technology and education and outreach groups had dual tasks: to send pairs of educators or engineers to join and participate in science small-group discussions, and to periodically reconvene to tackle technology or education and outreach issues that arose during the scientific discussions. The goal was to weave technology and educational opportunities into the initial observatory network design.

The smaller scientific working groups, all with fewer than 30 participants, met to discuss how access to two-way communication, sustained data recording, and power could be used to tackle questions related to Earth structure, plate dynamics, fluid-rock interactions, air-sea fluxes, biogeochemical cycles from rivers to the continental slope, benthic water-column coupling, global ocean circulation and climate, global biogeochemistry, small-scale mixing and nearshore processes, marine food webs, impact of humans on marine ecosystems, and marine ecology. The groups were encouraged to mix and evolve the scientific focus as desired. These groups were asked to identify, among other items: (1) the most exciting research opportunities that could be provided by ORION but could not be addressed using traditional assets and techniques, (2) the spatial and temporal scales required, (3) the priority measurements and parameters needed, (4) the education and outreach opportunities, and (5) a time line for addressing the question or experiment (Appendix 4).

This report summarizes working group deliberations. In some cases, working group materials have been combined to reduce redundancy.