Blue Ribbon Review of
Ocean Observatories Initiative Scientific Objectives and Network Design: A Closer Look

Summary of Panel Discussion

Introduction

A Blue Ribbon panel was assembled by the National Science Foundation (NSF) to provide a non-advocate review and constructive criticism of *Ocean Observatories Initiative (OOI) Scientific Objectives and Network Design: A Closer Look* (hereafter "the document"). The document is the latest in a long series of planning efforts, dating back to 1988, prepared to articulate the scientific vision for OOI, which will be funded via the NSF's Major Research Equipment and Facilities Construction (MREFC) Account, for the creation of a new research and education infrastructure to promote understanding of the ocean, seafloor and sub-seabed processes, and their relationships to the Earth system. A predecessor report, *OOI Scientific Objectives and Network Design* (July 2006), also prepared by the OOI Project Team, was previously reviewed by a separate panel of experts in August 2006, and a copy of their review was provided to the current panel members. The July 2006 *OOI Scientific Objectives and Network Design* report was revised in response to the recommendations of the August 2006 Blue Ribbon Review and to a "rescoping" that was necessary after better definition of capital cost estimates and projected costs for operations, maintenance, and management. A major responsibility of the current Blue Ribbon Panel review was to evaluate whether the revised science prospectus remains a visionary program that is worthy of MREFC investment.

The panelists were asked to review the document and to assess the following:

- whether the questions posed in the document are of high priority for advancing ocean science research and understanding;

- whether the network infrastructure planned for the OOI will enable the ocean science community to answer the oceanographic questions posed in the OOI Science Plan; and

- whether all scales of OOI infrastructure are being fully utilized, where appropriate, to answer the questions outlined.

The review consisted of the following components: (1) independent, anonymous mail review by each panel member, (2) a one-day meeting in Washington, D.C. (22 October 2007), that included presentations by NSF program officials and a 2-hour question and answer session with leading members of the OOI Project Team, (3) a half-day discussion and writing session held near NSF the following day, and (4) a teleconference on 2 November 2007 to finalize recommendations.

This report summarizes the panel discussion, including recommendations regarding the OOI research program and suggestions for improving the OOI document.

Overall Assessment

The panel endorses the OOI as a worthy investment that when implemented fully will advance the understanding of ocean and Earth processes. The panel makes this endorsement with the understanding that building and operating the OOI infrastructure will likely impact the level of funding available from NSF for Principal Investigator-led science projects in the core research programs. It is therefore critical that the ocean science community and NSF remain convinced that the OOI will be "transformational" in the scientific discoveries it will engender. We believe that the OOI will meet this expectation. Nearly two decades of community effort have created a remarkable opportunity that will allow us to address broad and compelling interdisciplinary scientific questions that cannot be adequately investigated with current methodologies. However, the capabilities in the present OOI design must be preserved in any future modifications to the project, and diligent and open management of the program must be sustained.

To ensure that the transformational aspects of the OOI are preserved, the panel recommends that NSF take the following steps:

1. Form an external OOI scientific oversight committee (OOI-SOC) to assess progress periodically, evaluate the impact of proposed changes in infrastructure on the achievement of program goals, and recommend changes in direction and reallocation of resources as appropriate. This committee should be composed of informed but non-conflicted members of the ocean science, engineering, and education communities. Representatives from other major ocean science planning activities might also be included.

2. Charge the OOI-SOC to establish the relative priority of the "key science questions" that have guided OOI development. This prioritization must be consistent with the community planning process that led to the OOI and with commitments to, and opportunities for collaboration with, other federal agencies and international partners. To assure continued support by the oceanographic community, this task must be conducted openly and the outcome thoroughly justified.

3. Charge the OOI-SOC to develop a "science performance floor" that each component of OOI must accomplish for the project to be viewed as a successful return on NSF investment. This performance floor should guide all future trades among capabilities, schedules, and costs.

4. Develop a risk-management strategy, with a commitment of OOI funds, to deal with sensor availability and performance. Such sensor-related issues as the development of new sensors meeting long-term stability and performance characteristics requirements and the mitigation of sensor biofouling during deployments should receive enhanced attention.

5. Ensure prompt and open access to all data from the OOI infrastructure. Further, the OOI should implement an information technology development plan that screens prototypes through demonstrations and evaluation activities with end user groups to ensure that the project's cyberinfrastructure effectively serves the ocean science research and education communities and public awareness audiences.

6. Develop the education and public outreach components of the OOI through open competition.

7. Exercise careful program oversight and wise program management to allow for potential shifting of resources among implementing organizations as needs are identified through periodic external review of the OOI.

In the remainder of the report, these and other recommendations are highlighted in bold italics.

Panel Recommendations

We here expand on the above assessment and recommendations, and we summarize the panel's discussion of a number of specific scientific, technical, educational, and managerial aspects of the OOI.

In general, the authors of the 2007 version of *Ocean Observatories Initiative (OOI) Scientific Objectives and Network Design: A Closer Look* have been broadly responsive to the recommendations made by the Blue Ribbon Review Panel that reviewed an earlier version of this document in August 2006. In particular, the list of the science questions that motivate the OOI concept is better conceived, and considerable work has gone into the development of traceability matrices that delineate how those questions lead to infrastructure and measurement requirements. A timeline for the development, installation, and operation of the different OOI components now appears in the document, and the sense is clearly conveyed that the network will continue to evolve and improve after the installation period. As recommended in 2006, the OOI infrastructure now includes mobile assets such as gliders and autonomous underwater vehicles (AUVs) that will provide important information on scales of horizontal heterogeneity and their governing processes. There is a strong cyberinfrastructure component to OOI that was less clearly articulated in the earlier version of the document. Cost estimates are much better developed than one year earlier, and there is a healthy recognition of the need to identify a contingency for each budget line that varies as a fraction of the estimated cost in proportion to risk, as well as a 3% program reserve held by NSF.

Management and Oversight

The panel was not persuaded that there is an effective management structure yet in place, not merely to manage the technical aspects of the challenges to infrastructure development and operation, but more importantly to ensure that the scientific return from that infrastructure is broadly maximized. That the project management is in a state of flux is hinted by the fact that the document includes no list of authors. During discussion with representatives of the OOI Project Team, it became clear that the document was prepared primarily by members of the JOI staff, who extracted material from a variety of sources. This approach contributed to the unevenness of the document.

The panel understands that management team capabilities will be assessed at the OOI Preliminary Design Review (PDR), to be held in December, but we take this opportunity to offer our comments and suggestions on management issues.

The planning committee process that JOI used to develop the Conceptual Design of the OOI was suspended in April 2007 to avoid conflicts of interest. JOI's competitive process then led to a significant percentage of the former advisory committee members now serving on the project team as subcontractors. Since there is considerable latitude for modification of the plans (e.g., selection of moorings or adoption of new sensors), and trade-offs will impact not only subcontractor budgets and technical interests but also the achievement of program science objectives, close supervision of the project should be provided to ensure transparency and to encourage continued support of the program by the oceanographic community. ***The panel recommends that NSF form an OOI external scientific oversight committee (OOI-SOC) to assess progress periodically, evaluate the impact of proposed changes in infrastructure on the achievement of program goals, and recommend changes in direction and reallocation of resources as appropriate. This committee should be composed of informed but non-conflicted members of the***

ocean science, engineering, and education communities. Representatives from other major ocean science planning activities might also be included. The establishment and effective operation of this committee is vital to the success of the OOI, with respect both to the fulfillment of the project's scientific mission and to the building of community confidence in the open operation of the OOI program.

The document states that the new JOI Division of the Consortium for Ocean Leadership serves as the OOI Project Manager. Three subcontractors, termed Implementing Organizations (IOs), have been selected. A consortium led by the Woods Hole Oceanographic Institution (WHOI) will build the Global and Coastal Nodes, the University of Washington (UW) will build the Regional-Scale Nodes (RSN), and the University of California, San Diego (UCSD), will lead the development of the project's Cyberinfrastructure. According to the document, these institutions will form an "integrated project team to implement the facility on behalf of the community." More details, however, are warranted. It is conventional in projects of this scale, for instance, that contractors designate "key personnel" and summaries of their relevant experience to provide evidence that they are competent to deliver the services they propose. This document should specify the experience levels of the key contractor personnel to provide assurance to the community that the work will be completed on schedule and within budget. Moreover, technical and scientific synergies, and any cost savings, that result from managing all of the observatory networks under a single program should be described. Opportunities for moving funds among network development projects if technical challenges or cost growths differ should also be described. ***The panel recommends that NSF exercise careful program oversight and wise program management to allow for potential shifting of resources among implementing organizations as needs are identified through periodic external review of the OOI.***

Priority of Science Questions Addressed by OOI

The panel is of the view that the 10 key science questions that have guided the design of the OOI are fundamental, broad, and amenable to progress toward answers with new measurement programs.

That said, it is also clear to the panel that the key science questions vary in their breadth and reach. There is no sense from the document, or from the question and answer period that the panel held with representatives of the OOI Project Team, that any of the 10 are viewed by the project as of greater primacy than any of the others, that any are better addressed by an OOI approach, or that any are more likely to be answered in the near-term (next 5-10 years) than over a longer time frame (decades or longer). Some discussion in the document of the questions among the ten that anchor the OOI most firmly would be helpful. The panel of course recognizes that scientific progress cannot be predicted over timescales as long as the anticipated lifetime of the OOI, but we were disappointed that the document in its present form offers no scientific, logistical, or managerial priorities to the programmatic goals. Such priorities are essential when any rescoping or realignment of resources is required.

Therefore, ***the panel recommends that NSF charge the OOI-SOC to establish the relative priority of the "key science questions" that have guided OOI development. This prioritization must be consistent with the community planning process that led to the OOI and with commitments to, and opportunities for collaboration with, other federal agencies and international partners. To assure continued support by the oceanographic community, this task must be conducted openly and the outcome thoroughly justified.***

Ability of OOI to Answer Questions Posed

The rescoping of OOI that has been carried out in response to growth in capital costs and operations and management (O&M) costs has had a large impact on the ambitions of the initiative across the different scales of networks. The reduction in numbers of sites occupied and in the diversity and areal coverage of instruments that can be operated at each site, compared with descriptions of the OOI program even one year ago, is substantial. What is not clear from the document, however, is how the reduced capabilities have affected the ability to address the scientific questions that motivate the initiative. If there is a "science performance floor" to OOI, it is not described in the document. Nor is it apparent if and how such a floor guided the many scientific and technical trades that were explored as the various networks were rescoped. Therefore, ***the panel recommends that NSF charge the OOI-SOC to develop a "science performance floor" that each component of OOI must accomplish for the project to be viewed as a successful return on NSF investment. This performance floor should guide all future trades among capabilities, schedules, and costs.***

The panel wishes to highlight a number of specific areas for which we are concerned that OOI could achieve less than optimum scientific return, within the constraints of capital and recurring costs, without additional attention.

Global-Scale Nodes and Platforms

As described in the document, Global-Scale Nodes (GSN) occupy four sites. Two sites are at high latitudes in the Pacific: at Ocean Station Papa (50°N) in the Gulf of Alaska and in the Southern Ocean to the west of Chile (55°S). A third node is located in the north Atlantic to the east of Greenland in the Irminger Sea (60°N). The mid-Atlantic node is located on the Mid-Atlantic Ridge at 23°N. Each node is envisioned as a cluster of moorings that provide unparalleled vertical resolution of the surface and bottom boundary layers as well as the water column. Flanking moorings and gliders will provide some observations of horizontal gradients, although the plan is vague about the details of this design. The mid-Atlantic node will feature a novel buoy design, the Extended Draft Platform (EDP), designed to allow a 100-fold increase in power and data rates to the bottom of the ocean.

The panel finds the plan deficient, however, in two important ways. First, it is unclear what science questions are supported by the EDP. The design and development of this mooring will be costly, and there is little justification given in the document for why it is necessary, or why it is superior to an event-driven sampling strategy. Moreover, the investment in the design of this platform clashes with the lack of support for instrument technology development, arguably a more significant limitation to the achievement of OOI goals. There appears to be uncertainty as to whether the EDP mooring will be used at other sites as well. There is a consequent uncertainty in the program budget, yet a trade-off between the number of nodes and the cost and capability of each seems to have been made. If there are funds available for more EDPs, then the option of expanding the number of nodes to extend strategic coverage, or of enhancements to instrumentation at the given nodes, should also be considered.

More significantly, there is no justification given in the document for the specific choice of sites beyond a general interest in air-sea CO_2 exchange at high latitudes. There are some obvious arguments for station Papa, and the mid-Atlantic node is likely linked to other global geophysical monitoring programs, although such links are not made in the document. There are now reasonably capable biogeochemical moorings in place at station Papa and in the Irminger Sea, supported by a Canadian and NOAA consortium and by the European carbon cycle programs, respectively. The panel expects that considerable thought has gone into the final choice of the four nodes, including the availability of platforms operated by federal and international partners, and we recommend that greater evidence of that thought be provided in the document.

The need for an Extended Draft Platform at the mid-Atlantic site is not well-articulated or justified on scientific grounds. In three high-latitude sites, a discus buoy design is proposed, with power generating capability and reasonably high bandwidth for data communications. In the fourth site (mid-Atlantic) an EDP is proposed that would clearly generate more power and bandwidth, although as noted above a compelling science driver for this increased capacity is not made in the document. A few potential measurements have been offered (continuous transmission of underwater video, LIDAR for lower atmosphere winds), but the close integration of these measurements with the motivating science drivers is not clear to the panel. If underwater video is required, for example, cannot duty cycles be selected that activate sensors only when needed, perhaps triggered by events? Cannot data transmission be compressed, or other "smart" deployment methods used that do not require continuous full power or bandwidth?

Nor is it clear what trade-offs would accompany investment in one very large such platform versus more discus buoys that also generate their own power, but less of it. Our understanding is that approximately $3.5-4.5M in NSF money would be required to match the $8M equivalent equipment donation from industry for an EDP. Apparently the cost of a discus buoy is ~ $2M. Hence, comparing initial platform costs, approximately double the number of sites could perhaps be occupied with a discus buoy design rather than an EDP design. Selection of the EDP platform may thus offer additional power capability, but at the same time it limits the spatial extent of the open-ocean element of OOI. As many issues in water column oceanography would benefit from occupation of more sites, this trade-off is of some consequence. Whatever discussions of this trade-off were held among OOI planners, particularly during project rescoping, the comparative advantages of fewer nodes with an EDP platform versus more nodes with less capable platforms is not articulated in the document.

An additional issue raised with respect to very large moored devices is the observer effect associated with their presence in the ocean. The device itself may modify the local winds and fluid flow. Mobile marine organisms are likely to be attracted to the structure in the open ocean. To some extent such issues arise with any moored device, but the subject is compounded with a structure that would emerge more than 10 m above the sea surface with a relatively large surface and deep subsurface penetration. It may be possible to compensate for some of these problems, but they require objective evaluation.

At this juncture, we do not yet see truly compelling science drivers for EDP capacity, and we see distinct advantages to increasing the spatial coverage of key areas of the open ocean with deployment of more discus buoys.

Gliders and AUVs

Water column scientists, in particular, require spatial context. It is vitally important that the three-dimensional fields around point-source moorings be resolved. We are very pleased to see that mobile assets such as gliders and autonomous underwater vehicles are called for repeatedly throughout this document and are mentioned explicitly in 9 out of 10 of the key science questions. We note, however, that it is not clear the extent to which resources are being made available to support the glider and AUV developments and enhancements that will be required to support them fully. Gliders and AUVs have already proven themselves as excellent tools for ocean science research, but the very long-term deployments expected in some remote open ocean regions are going to require re-engineering and design modifications for expanded capacity. By not addressing these issues, the document appears to be overly optimistic.

Coastal-Scale Endurance Array

For the Endurance Arrays to be deployed off the Pacific Northwest, it is unclear whether the number of mooring locations is being (or has already been) winnowed to the point of ineffectiveness of the science. These arrays are charged with several objectives, including assessing climate variability, responses of ecosystem structure, spatial variability of shelf-slope exchanges of carbon and other elements, and the effects of hypoxia on the coastal ocean. They are also supposed to form the basis of a comparison with the Mid-Atlantic Bight site. As the west coast site is largely structured in a two-dimensional manner, with very strong cross-shore gradients and weak alongshore gradients, there is a reasonable justification for the linear cross-shore orientation of the proposed moorings. The Endurance Array mooring plan in the document suggests that there will be a line of five moorings off Newport and 2-3 moorings in a contrasting coastal site off Washington. The five moorings off Newport will be complemented by Node 1 of the Regional-Scale Nodes, which will help measure some of the open ocean drivers. As depicted graphically, this plan is reasonable.

Yet the text of the document identifies a triage plan for mooring deployment, implying that not all of these moorings may actually be put into place. A 150-m site off Washington is not even illustrated in the schematic diagram in the document, and its absence reduces the Washington site to only two moorings. Such an outcome arouses concern, because this part of the ocean is strongly spatially structured with sharp cross-shore gradients and dynamic frontal systems that move over time. The ability to resolve onshore-offshore flows demands a complete measurement array. Moreover, much of the forcing in this part of the ocean operates on a large spatial scale. Previous results in this area have shown that local winds do not explain local upwelling; rather regional and larger-scale winds must be measured. Changes in source waters from North Pacific drift and Subarctic Pacific as well as more southern parts of the California Current are important to understanding the local dynamics in the Pacific northwest. Hypoxia can be influenced by waters of remote origins. While mobile assets such as gliders can assist with some of the spatial context, they cannot solve the whole problem. It is important that the mooring design be as complete as possible in order to resolve the cross-shore changes in key processes, their lateral migrations, and effects on the biota. ***The panel recommends that the science goals and the design of the Endurance Array be clarified to assure the community that significant science discoveries will occur and that the planned infrastructure is truly "transformational."***

Coastal-Scale Pioneer Array

The Pioneer Array concept is intended to allow it to be moved periodically (at approximately 3-to-4-year intervals) to other regions of ocean. The document, however, focuses only on applications at one site in the northeast. Broad support for this capability would increase if it were made clear how the scientific priority for the next site will be established, the site competed, and the infrastructure transferred. One or two specific examples of future Pioneer Array deployments might clarify how logistics and operations of the array will be sustained at a location distant from its operators.

Connections among Scales of OOI Infrastructure

There is not a strong sense of connectivity among the three elements of the OOI in the current document, and this lack of strong interdependence was perceived as a weakness by the panel. It would not be clear to many readers why the OOI should be considered one system, rather than three disparate systems. Some of the reasons for connectivity are very briefly articulated in the Appendices, but they are not strongly identified elsewhere. For example, Appendix A-7 (Climate Variability and Ecosystems) makes the case that the Global mooring at "Station Papa represents the 'upstream' end of the start of the California Current," while the water column moorings on the Regional-Scale Nodes "could provide important regional continuity linking Station Papa and the Endurance Array." The scientific case for the OOI design would be strengthened by a clearer articulation of the synergies among the three systems with respect to the science questions that motivate OOI.

Sensors

The ability to answer the science questions identified in the document is critically dependent on the availability of sensors for a variety of properties. In some cases, these sensors are robust and routinely available (e.g., CTD, ADCP, seismometers) and are well suited for extended deployments. However, many of the sensors indicated in the document may not exist (e.g., dissolved Fe sensor), may exist only as one-of-a-kind prototypes supported by specialized engineering teams (e.g., in situ DNA analyzers, flow cytometers), may exist as industrial prototypes that have not routinely demonstrated long-term stability (e.g., phosphate wet chemical analyzers, mass spectrometers), may exist but clearly do not have the performance characteristics needed (e.g., pH electrodes), or are routinely available but are subject to rapid biofouling (e.g., transmissometers, fluorometers). Many of the core sensors identified in the document (Appendix B) fall in these categories. Further, the case examples of transformative capabilities that focus on ecosystem processes all depend on these sensors. During our question and answer discussion, the OOI Project Team representatives did not identify this issue as high-risk. This posture constitutes a weakness of the document. Sensor-related issues should receive much more explicit discussion than is presently included.

Meeting the objectives of the OOI will require long-term data sets that are of climate quality, i.e., the data must be of consistent quality over decadal time periods and not temporally biased with large data gaps or uneven temporal coverage. This requirement demands sensors that have well-documented, long-term stability, or capabilities for self calibration, or which receive external calibration from ship visits at frequencies higher than the expected rates of sensor change due to fouling or instrumental drift. The response from the Project Team representatives to questions from the panel was that the project would initially collect short time series of data with all sensors operating. While this is a practical, short-term response, it does not solve the longer-term issue and it does not constitute an advance toward the overarching goals of the OOI. Development of sensor suites that generate climate-quality data will require an explicit effort. The document should acknowledge this key requirement and give an overview of the steps that will be taken to ensure that it will be met.

Indeed, many of the sensors discussed in the document simply do not exist in a form that is available for routine use. Although the document notes that many of the sensors do exist as prototypes, the success rate for transition of instruments from this stage to routine operation can be low. In some cases, there are fundamental reasons why the technology in prototype instruments will be inherently unreliable. In other cases, the instruments may be so complicated that substantial engineering is still required. Use of industrial partners to complete the engineering is not always feasible because the markets are small, particularly if high power and bandwidth are required. While oceanographic engineering skills are available at many institutions, the requirements for hardening sensors lie in the industrial engineering and software user interface areas, specialized topics that are not always available in oceanographic institutions. As a result, development of new sensors remains a high-risk activity.

Even after instruments are brought to a state of high reliability, their routine use may be compromised by biofouling problems. Extensive efforts to develop effective antifouling strategies have been successful in a few cases. Biofouling may also be ameliorated by parking instruments in profiling moorings at depth. However, instruments such as transmissometers, which are mentioned throughout the document appendices as on the Core Instrument list, remain difficult to use for long periods of time in the euphotic zone. Even when parked at 300 m depth in the open ocean, fouling of the optics becomes an issue in documented cases.

These issues suggest that sensor availability remains a high-risk area that has important implications to the success of the OOI. A risk management strategy to deal with sensor availability should be developed by NSF and the project. Funding mechanisms for sensor development, technological support, and recruitment of the community into the overall sensor discussion should be developed within the OOI budget. ***The panel recommends that the OOI Project Team develop a risk management strategy, with a commitment of OOI funds, to deal with sensor availability and performance. Such sensor-related issues as the development of new sensors meeting long-term stability and performance characteristics requirements and the mitigation of sensor biofouling during deployments should receive enhanced attention.***

Gas Hydrates and Hypoxia on Continental Shelves

The panel expresses concern regarding the limited justification and explanation of the location of the sites selected for study of gas hydrates (Question A-6) and hypoxia on continental shelves (Question A-9). An outline of the rationale for these choices would strengthen the document. For example, "dead zones" along the Atlantic and Gulf coasts have been documented to occur repetitively during the last four decades. Gas hydrates also occur in locations where both biogenic gas hydrates and thermogenic hydrates are found, including mounds of hydrates visible on the seafloor with their associated and scientifically fascinating chemosynthetic communities.

Cyberinfrastructure

The document appropriately acknowledges the centrality of the importance of cyberinfrastructure (CI), from both the scientific and public utility points of view. However, the relevant portion of the document paints with too broad a brush. The plan would be much improved if specific deliverables were listed and a schedule provided.

The document would benefit from a concise account of how system design will address the issues of data acquisition, quality assurance and control, incorporation of data into accessible relational databases, development of user interfaces, access to those data, interoperability with other databases, and interaction with different user groups for development of data visualization tools. Long-term custody and care of the data should also be addressed. Although the panel understands that a detailed discussion of these components is beyond the scope of this review, the document nonetheless misses an opportunity to reassure interested readers that these matters are appreciated and are actively under discussion. Moreover, given the acknowledged centrality of cyberinfrastructure and data usage for science, education, and outreach, the document should illustrate that the needs of these different communities will be addressed.

In summary, without cyberinfrastructure that is developed in close connection with diverse user groups, the program effectively will not function because it will be invisible or it will become lost in the firehose of internet-accessible datasets. The panel was concerned that not enough specific attention to this important subject is evident in the document. ***The panel recommends that NSF ensure prompt and open access to all data from the OOI infrastructure. Further, we recommend that the OOI implement an information technology development plan that screens prototypes through demonstrations and evaluation activities with end user groups to ensure that the project's cyberinfrastructure effectively serves the ocean science research and education communities and public awareness audiences.***

Inclusion and Community Access

The proponents of OOI are to be congratulated for their multiple successes in garnering support for this program, through many workshops, planning meetings, requests for applications, and other mechanisms. However, as the Project Team representatives acknowledged during their discussion with the panel, engendering support for a project is fundamentally different in many ways from overseeing an active program that continues to enjoy support, or ideally, grows the support to be even larger.

To this end, the document does not adequately describe how a very broad community will be able to participate in the OOI. An overall "build it and they will come" approach is not sufficient. The document states "In principle, anyone – scientist, engineer, or educator – will have access to two-way interactivity, command and control, and resources (a common term for entities such as instruments, near-real-time data…and so on.)". The panel agrees with this statement, given the leading phrase "In principle…" But what of practice? As with cyberinfrastructure, the panel acknowledges that management details will be addressed very soon, but the issue goes beyond management, because broad and interdisciplinary collaboration is at the very core of the success of a long-standing OOI. The first five years of the program will be critical in this regard. Should the community perceive that this huge investment has resulted only in expanding access to the ocean for a few large oceanographic institutions, then support for the operation and maintenance of the program would be substantially diminished.

In short, the "ownership" should evolve from the IO leads to the entire community. In this sense, the goal of being "transformative" applies not only to the hardware of the network itself, but philosophically.

One parallel with which the panel is familiar is scientific ocean drilling, which has operated as a community enterprise for 40 years, the envisioned time frame of OOI. Although initiation of the Deep Sea Drilling Program (DSDP) preceded the professional careers of many of the panelists, one could imagine how the DSDP could have been susceptible at its outset to criticisms from the community that it was just the pet program of a few interested investigators to drill into the crust and mantle. At the initiation of DSDP, the overwhelming contributions to climate change, plate tectonics (beyond the dating of crust), gas hydrates, and other discoveries of the past 35 years were not foreseeable. In this sense, the OOI proponents are correct in their goal of setting up the facility and letting it evolve without trying to predict the future or be constrained by these predictions. Yet the proponents have not provided an adequate plan – or framework of a plan – toward enabling community access, from which will inevitably derive most of the new ideas and developments.

Specific questions are many, and include: How will new technologies be selected for installation? The document includes a scenario under which an individual scientist who develops a sensor can gain access to a node for testing, evaluation, and eventual installation. If a proposal to add a new sensor is declined, however, how will the proposer be reassured that the declination is being made strictly on scientific and technical grounds? What active recruitment of early-career scientists will occur, for example, through fellowship programs or speaker programs? How will an absence of conflict of interest be assured in program oversight and advisory committees?

Partnerships

The document addresses the potential for many partnerships with other NSF programs, other federal agencies, and international collaborators. The panel encourages the pursuit of additional partnerships with other major U.S. ocean science planning activities, such as the Ocean Carbon and Biogeochemistry program and the RIDGE 2000 program. These programs are planning large activities for the next decades, and the OOI should be proactive in entraining these programs in the development of the OOI science plans. The document would be much stronger if it provided a directed discussion of how the OOI will develop cooperative agreements with these programs to ensure that they are active supporters and users of the OOI infrastructure.

Satellite and other platforms for remote sensing will be vital complements to the OOI by expanding the spatial footprint and synoptic perspective of ocean measurements, yet there is scarcely any mention of the importance of remote sensing tools in the present document. Especially in light of the uncertainty of future NASA science missions related to ocean observations, a clear statement from the ocean sciences community of the pressing need for satellite remote sensing tools in partnership with OOI is essential.

International partnerships are also of great importance, in order to maximize the return from the U.S. investment in OOI. The panel understands that European colleagues have a mooring in the Irminger Sea and Canadian colleagues maintain a research mooring at Ocean Station Papa, among other internationally occupied sites. It is important that justifications for site selection by U.S. OOI assets be made clearly. When there is geographic overlap with existing programs, the novel aspects of a U.S. presence should be clearly identified.

Broader Impacts of OOI

The full integration of education and outreach has been an OOI goal from the inception of the project. The first community workshop document identified two goals related to broader impacts: (1) increasing participation in science and technology careers, in particular, in ocean sciences; and (2) increasing awareness, understanding, and appreciation of the oceans' role in the Earth system (Schofield, O. and M. Tivey, ORION – Ocean Research Interactive Observatory Networks – A report of the workshop held January 4-8 in San Juan, Puerto Rico, 140 pp., http://www.neptune.washington.edu/documents/WORKSH/orion_pr_report.pdf, 2005). The last sentence of that document states "The program will invigorate the public's ability to share in discoveries, insights, and excitement about understanding the ocean." Clearly there is widespread support across the project of education and outreach, including training the future OOI workforce.

The present document, however, exhibits a lack of understanding of the education and public outreach enterprise and makes overly ambitious claims. The most specific descriptions offered about education are "Use-Case Scenarios." These examples are meant to illustrate the utility of OOI data and resources beyond marine science investigators (i.e., the stated primary audience for the document); however, the gap between the current state of network design and these scenarios is huge. These idealistic scenarios overlook the considerable efforts that will be required to develop "user friendly tools" and train non-OOI investigators to use the data streams. This is disconcerting given that an ORION-supported Education and Public Awareness Committee addressed this issue in a recently produced *Strategic & Implementation Plan* (Matsumoto, G., Education and Public Awareness Strategic & Implementation Plan, 48 pp., 2007, http://www.mbari.org/education/epac.htm).

OOI has the potential to develop data visualization products that are not only based on effective pedagogical practice but also help to advance understanding of this area of educational research. In the area of ocean data visualization, OOI can be truly transformational. The OOI Project Team should embrace the investment in the infrastructure needed to serve education and public awareness audiences, including building and testing learning prototypes that use OOI data and analysis tools. Given the broad expertise needed to carry out these endeavors – and to ensure broad impact – OOI should form effective education and public outreach partnerships well beyond the oceanographic community. Other than COSEE-NOW (Centers for Ocean Sciences Education Excellence-Networked Ocean World), the formal and informal education partnerships given in this document are merely a "laundry list" of possibilities.

Given the stated importance of education, outreach, and training to the long-term success of OOI, achieving national impact is at risk without a sustained and cohesive education management infrastructure. Table 1 in the document indicates that education may not be a stand-alone element but instead embedded within in the OOI Project Office. This organizational approach should be reconciled with recommendations of the *Strategic & Implementation Plan*, which outlines processes for "developing the management infrastructure necessary to sustain a coordinated and coherent education program that is aligned with the science and technology research objectives" of the OOI program. Given that other key elements of the OOI are being funded independently through JOI's competitive process, ***the panel recommends that NSF develop the education and public outreach components of the OOI through open competition.*** Moreover, mirroring the concern expressed about science oversight, ***the panel recommends that OOI form an external advisory committee for education composed of informed, yet non-conflicted and non-advocate, members of the ocean science education community.***

The decades-long investment requires that OOI build a system that can be used by tomorrow's workforce (e.g., community colleges, pre-college audiences) and informal audiences (e.g., museums, aquariums, media). Likewise, the stated goal of increasing interdisciplinary research compels OOI to build a system that can be readily used by scientists from other related fields. The panel encourages the OOI Project Team to work with NSF to ensure that MREFC funds can and will be used for essential infrastructure needed to build the capacity for engaging these non-traditional users. Such an allocation of resources will better position OOI to grow and maintain the program, fostering a community that values OOI's assets. Such a goal is a major undertaking but, if achieved, could help justify long-term financial support for OOI.

Also, as recommended by the previous Blue Ribbon Panel and in accordance with its importance to overall program success, education and public outreach should be better integrated into OOI's science and cyberinfrastructure planning.

Comments on the Document

In the view of the panel, the document does not provide an adequate overview of the OOI. This document should briefly justify and explain the scientific rationale, approach, and site selection for the initiative. The document falls short of this goal, although the panel recognizes that much material on scientific motivation, engineering considerations, and trade-offs are contained in other documents, as well as in detailed proposals submitted by the IOs.

The following comments are presented in the spirit of constructive feedback meant to improve the document so that in its final form it will serve as a compelling introduction to the OOI that can be viewed by the entire oceanographic community.

This document should convey the excitement of OOI and its promise, but in its present form it falls short of doing so.

Sections 1 and 2 provide a helpful introduction to the program and the motivating science. The traceability matrices are critical components of this discussion. However, there is no explicit link between the six "OOI Science Themes" and the 10 "key science questions." Moreover, the intervening text would be improved substantially by concise reference to the relevant science questions and brief summaries of what led to the choice of measurement location and measurement design. This was reasonably well done for some parts of the document (e.g., the RSN), but for others the measurements appear to be engineering-driven rather than science-driven.

Global-Scale Nodes

There is no connection in the discussion of the GSN (section 3.C) to the high-priority questions. Which science question will these platforms address, and how will they address them? Overall, the rationale for the GSN sites needs better explanation, including mention of potential partnerships with other countries where relevant. There is considerable detail on the EDP platform but very little on the two adjacent sub-surface moorings that are 100 km away at each node. What is on these moorings, and what is the rationale for their positioning and sensor suite? How do they enhance the GSN? Clearly there is an attempt to resolve some mesoscale variations at these sites, but this rationale should be elaborated lest the adjacent moorings appear to be afterthoughts in comparison to the main mooring.

Are other countries planning efforts in the Southern Ocean that would complement the OOI Southern Ocean node? As presented in this report, the Southern Ocean node appears to be an outlier. It is not clear why it is located west of Chile — for convenience, to entrain Chileans into OOI, or for a science reason?

Regional-Scale Nodes

In general, the brief summary of the choice of Nodes 1 through 5 in the RSN section provides a good example of the type of explanation needed throughout the document. However, the water column measurements in the RSN are an exception, as there is not a science question underlying the water column measurements. Because the Endurance Array may lose some moorings, might it be preferable to relocate some of the water-column moorings of the RSN to more fully develop the Endurance Array (or other OOI elements)? Such questions could be more explicitly answered after the science priorities and science performance floors are developed.

Coastal-Scale Nodes

The contrasting experimental arrangements offered by the Endurance and Pioneer Arrays need to be better highlighted in the introduction to this section, identifying the strengths and weaknesses of each. Many readers will not know why a 2-D array is planned for one coast and a 3-D array for the other.

There is no discussion of the mutually beneficial observations among OOI, remote sensing tools (supported by NASA and NOAA), or the Integrated Ocean Observing System core variables. All of these can complement OOI and should be mentioned. There are allusions to these linkages, but these need to be made more strongly since they enhance the proposed OOI efforts.

Additional Details

The last sentence of the first paragraph on p. 9 does not make sense.

The last sentence in the presentation of question 7 on p. 15 makes it look as though "we had to find a reason to include the Southern Ocean in this section."

Node 5 of the RSN is not located in the subtropical gyre (p. 30) and also seems incorrectly located to measure flux of carbon from the shelf across the slope to the basin.

The labeling and symbols in Figure 5 need to be larger for clarity.

Horizontal distance scales on Figures 5, 6, 7, and 9 are needed.

A map showing locations of mooring sites potentially complementary to OOI that are planned or under consideration by other countries would be helpful.

Station Papa is incorrectly located on the cover map, though correctly mapped on p. 20.

Section 4C adds little to the report since it is nothing more than a glorified definition of "disruptive technology" and self-promotion of OOI.

In Section 5C, it is not at all clear what constitutes a system-wide acceptance test.

5 November 2007