# Review Report

**of the**

# NSF Conceptual Design Review Panel

**for the**

# Ocean Observatories Initiative

**Performed for the**
**National Science Foundation**

**Conducted at the Monterey Bay Aquarium Research Institute in Moss Landing, CA**
**August 14 – 17, 2006**

**Date of this Report**
**September 8, 2006**

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## Table of Contents



## Appendices

## Executive Summary

The Conceptual Design Review of the Ocean Observatories Initiative (OOI) was conducted by a review panel of experts on behalf of the National Science Foundation on August 14 – 17, 2006 at the Monterey Bay Aquarium Research Institute in Moss Landing, CA. The focus of this review was on the scope and system level implementation plans for the OOI, the proposed budget, the proposed schedule and milestones, the organizational structure and management plan, the technical readiness of the project, and an early look at the proposed operating budget along with likely education and outreach activities to be funded separately. The NSF charge to the review panel is provided in Appendix A of this report. Members of the OOI CDR Review Panel and the observers from the NSF are listed in Appendix B. Appendix C is the agenda for the review.

Written material was provided by the OOI team and by the NSF to the Panel electronically in advance of the meeting. The available documents were examined, oral presentations were heard and subgroups of the Panel met with appropriate members of the OOI team to explore details of the project. The format of the review followed the one used during recent reviews with short overview sessions followed by expanded breakout sessions with individual groups for in-depth discussions. This arrangement provides a very effective format for the review of the project. Based on these evaluations, the Panel discussed its findings in executive session and generated written summary conclusions and observations.

The structure of the OOI project is complicated with the Joint Oceanographic Institutions (JOI) as the overall management organization for the project. The Ocean Research Interactive Networks (ORION) is within JOI and has guided and will continue to guide the scientific mission of the OOI project. OOI itself consists of four separate Implementing Organizations (IOs) as subcontractors for the construction and operation of the project. Both ORION and OOI report in parallel to the president of JOI.

The conceptual design of the project has matured greatly during the past six months and is now a project with clear goals and a reasonable preliminary budget and proposed schedule. The next step is to refine the conceptual design to the preliminary design stage to present for a preliminary design review along with a bottoms-up baseline cost estimate. The project is ready to move to that stage and what follows is a detailed assessment of the conceptual design along with recommendations and comments that will help the proponents prepare for a successful preliminary design review.

### Project

1. OOI will transform the way oceanography research is carried out. Research on all scales will provide a transformational view of the 70 % of the earth's surface that is the last frontier.

2. Many people have worked hard to bring OOI to its present stage of conceptual design. The conceptual design is credible and provides a good starting point as the project proceeds towards the preliminary design review (PDR). However, there is a significant variation of the state of readiness for a preliminary design review among the four areas of the project with one area nearly ready for a preliminary design review.

3. NSF/JOI should evaluate the schedule for the PDR to allow the maximum preparation time for the newly selected IOs. JOI should consider providing funds for the PDR preparation volunteers.

4. The question of the ownership of the physical assets of the project along with who bears the associated liability needs to be resolved soon. This will certainly impact the bidding process for the IOs and could adversely affect the issuance of cable landing and environmental permits.

5. The process for allocation of contingency along with the division between centrally held contingency and contingency assigned to the IOs needs to be settled before the preliminary design review.

6. Because of potential outside funding of some of the instrumentation, it may be beneficial to review the balance of core instrumentation and core infrastructure. There may be variation in the potential for these funds across the IOs and a more flexible policy may enable greater scientific reach.

7. An aggressive public relations campaign should be mounted by JOI and the NSF to entrain the broader community (scientists, engineers, reviewers, news media, and the general public) so that they will understand and take advantage of the OOI.

8. The Panel recommends additional investment, both by the NSF through an increased OTIC budget and by directing some of the R&D funds associated with the MREC, in emerging technologies for sensor and mobile platforms (including profiling platforms, gliders, and AUV's) that will significantly augment the capabilities of all three observatories. This should also include the development of technologies that will insure data quality while minimizing O&M costs. This investment will enable the realization of the full potential of ORION.

9. NSF should partner with other federal and non-governmental agencies – NASA, ONR, NOAA, the Navy, DOE, etc. – to leverage the use of OOI facilities and bring more funds to the table for infrastructure and instrumentation. The nature of the OOI lends itself to uses outside of the traditional oceanographic community. Partnership with other federal agencies should be explored to help offset the O&M costs associated with the OOI. An OOI level Concept of Operations (CONOPS) should be generated and could be used to help define the O&M staffing for each of the IOs.

10. Sufficient funding should be maintained to account for changing ship day-rates. All three observatories require ships to deploy and maintain their systems. OOI requirements need to be considered as a high priority within UNOLS scheduling.

**Management**

1. JOI should reorganize its management of the OOI project to place it within ORION, reporting to the ORION Director.

2. JOI should get highly qualified IOs in place and functioning as soon as possible, and ensure that their key personnel participate fully in developing the PDR, the cost estimate, schedule, and the review and revision of the top-level management plans, risk analysis, etc.

3. The Panel recommends that lower level technical interfaces between the IOs, and in particular between the CI IO and the other IOs, be specified and cultivated.

4. The Panel encourages JOI, ORION, and all stakeholders to take advantage of the opportunity provided through OOI to broaden participation in oceanography, especially with respect to traditionally (and persistently) under-represented groups.

5. The project team should thoroughly review all the project plans, system descriptions, and WBS prepared during the past four months, and revise them as needed to describe the specific processes, approaches, and plans appropriate to OOI. The IOs should participate in this review and revision. NSF and ORION should develop a clear description of project completion as soon as possible.

6. Given the unusual history and situation of OOI, NSF should consider tailoring its processes so that NSB approval can be obtained based on the essential elements of the baseline allowing demonstration of readiness to use MREFC funding on the current schedule (April 2007).

7. JOI should consider implementing one of the more capable project scheduling systems, and should do so without delay. It may be helpful to contact other scientific projects of similar complexity and magnitude to take advantage of their experience and insights in making this selection. Select and implement performance measurement system applications as soon as possible.

8. A bottoms-up evaluation of contingency needs should be done for the PDR as part of the bottoms-up cost estimate.

9. JOI should work with the NSF to define and document a workable process and dollar thresholds for approving subcontracts. Rules can be established for different kinds of purchases, e.g., catalog items, that would require no or less stringent review.

10. JOI should prepare and maintain a procurement plan forecasting the number and size of procurements. Based on this plan, different thresholds for approval of subcontracts might be considered for the MREFC funded effort. The effort on the procurement plan should be started and shared with the NSF as soon as possible to facilitate NSF planning.

11. NSF should make its environmental determination as soon as possible, and put in place the mechanism and timetable for completing the appropriate environmental analysis and public review.

12. JOI should obtain and have available on an as-needed basis, specialized legal advice on the Law of the Sea with respect to rights of cables, and on applicable regulations, permitting, rights of way and contract, in order to ensure that both JOI and the NSF are properly protected.

13. JOI should reconsider its decision not to have in-house Quality Management staff. While the project office is responsible for QA, it is inappropriate for the primary QA requirement to be in the hands of a member of the project office such as the Project Director. QA needs to have a ultimate reporting channel above the Project Team – e.g. to JOI President.

14. JOI should be proactive about its safety/health culture and expectations and provide clear safety/health guidance to IOs. JOI should consider having a safety/health officer for OOI, and requiring IOs to report any safety/health incidents and injuries to OOI, in addition to their reporting to their own institutions.

15. JOI needs to configure the Systems Engineering function to serve the project's needs. This is a key position for the success of the project and requires a strong full time person. JOI should consider how its Systems Engineer can remain current with the systems engineering issues as they evolve within and among the IOs.

16. The commercial/legal and technical significance of Acceptance must be defined as well as a mechanism for resolving disputes.

17. JOI should figure out how to set up and fund a core Education and Public Awareness (EPA) program management structure that enables the national office to manage a highly-leveraged system and produce a coherent, coordinated program that will have a significant impact. The Panel considers a reasonable target would include a staff of 2.5 FTE and a budget of ~1-2% of the total NSF annual operating budget for OOI.

18. EPA Committee should revise the strategic plan based on the most recent understanding of allowable MREFC costs to support EPA planning and capital investment.

19. The EPA Committee should look beyond the current list of potential collaborators to exemplars in other scientific disciplines for model programs and best practices.

**Coastal Scale Observatory**

1. The Panel recommends a phased deployment for the Pioneer Array at five year intervals with competitive review of science initiatives for each deployment. Each new deployment should address scientific issues of concern throughout the nation's coastal research community.

2. A more thorough review of resource requirements for the Pioneer system as part of the preparation for the preliminary design review could be beneficial. Since this array will be utilized for different problems and locations, it is essential that a systematic approach be utilized to ensure that the facility will meet the needs of new experiments. This systems analysis should also inform the risk assessment for component failures.

3. The Panel recommends that the justification for the California moorings be carefully reviewed. It may be that these resources would be better utilized by redirecting them for additional key technologies, including sensors and mobile platforms, in the other arrays.

4. The Panel recommends that a long-term agreement be developed with the U.S. Navy and perhaps other agencies to assure access to the Navy's TACTS towers currently housing the SEACOOS sensors that are critical to the CSO.

5. The Panel recommends that the team complete the "traceability" exercise prescribed by the Blue Ribbon Panel. This matrix should map the key (relevant) science questions to the proposed core infrastructure. The scientific themes should be those defined in the science plan and then expand on these themes to emphasize particular opportunities in the coastal region observatories.

6. The Panel feels that the O&M costs must be continually reexamined to assure consistency with expected performance of a large variety of instruments in a complex configuration and difficult environment. The CSO has particular challenges in this regard due to the variety of instruments, locations and platforms for this program. It is the understanding of the Panel that additional work is required to complete the O&M budget estimates.

7. The Panel recommends the development of a timeline for network development and deployment, defining the capabilities achieved at key milestones in the implementation. Define the "critical path" for implementation, identifying important precedence relations among implementation steps.

**Regional Cabled Observatory**

1. The RCO Team should include the prioritization of the plate scale science drivers they used to develop the present Conceptual Network Design. This information will provide the RCO IO with the tools to manage budget and RCO scope. In particular, it can be used for any necessary de-scoping or up-scoping due to costs and budget.

2. A plan needs to be developed to insure that the needed ships are available to perform the required RCO work.

3. The NSF/JOI/IO project structure and OOI concept of operations (CONOPS) should be structured to maintain the existing USN/NSF process or clearly define a new structure for dealing with national security related issues.

4. The RCO IO should keep the scientific research community involved in the evolution of the RCO project in case hard decisions need to be made on the scope of the RCO infrastructure.

5. The RCO project execution plan should identify resources, perhaps through a special NSF solicitation, to entrain and grow the RCO user community

**Global Scale Observatory**

1. Both OOI and the Integrated Ocean Observing System (IOOS) have much to gain by sharing data and both need to establish a common strategy for combining OOI and IOOS data streams. This task needs to be included in the conceptual/preliminary design process.

2. Implementation of the Southern Ocean site should take into account the balance between science achieved and cost. Options should be considered for this site in the Preliminary Design – including the one as presently envisioned with the spar buoy, and other options possibly utilizing lower cost, lower capability wave following buoys. Selection of the most appropriate option can be made after a buoy design study is completed and a more reliable cost estimate is available.

3. Advances in sensor technology, especially in hostile environments, is critical to achieving the long range science goals of the OOI. Additionally, alternative approaches to diesel fuel generators, particularly at the Southern Ocean site, might provide significant advantages. For example, wind power, wave power, ocean current power might be considered. Alternative sensor and infrastructure technologies could reduce operations and maintenance costs over the long term. Other alternative logistics planning could also reduce O&M costs.

4. The preliminary design should evaluate adding meso-scale arrays at additional global sites rather than the single site presently envisioned.

5. Optimal phasing of the global spend plan needs to be examined in light of the need for prototyping and the testing of challenging new technology systems, and considering that good progress with the Global Observatory can be achieved early-on by rapid deployment of some of the simpler systems.

6. Existing sensor development programs within NSF, e.g., OTIC, should encourage power generation and sensor development for hostile environments, and the OOI

management structure should be proactive in finding and adopting successful new technologies.

**Cyber Infrastructure**

1. The CI IO plan while relatively new compared to the other components of the OOI plan appears to be very well thought out and incorporates modern techniques to achieve a robust and scalable architecture for the data acquisition and interactive control of the sensing systems.

2. The significantly higher estimated cost of the CI IO presented to the Panel needs to be reconciled with the cost assigned to CI in total project cost overview

3. The projected schedule and staffing levels for the construction and operation of the cyber infrastructure for OOI appear to be realistic and probably are adequate to achieve the goals.

4. The cyber infrastructure should ensure that a subset of the OOI data stream is maintained with WMO/IOC formats and standards for international distribution to operational (and research) institutions.

5. The Panel suggests strongly that processes be designed before the PDR that will integrate domain scientists and marine observatory personnel into the detailed design process on an ongoing basis and throughout the project's lifetime. It is essential that domain scientists and observatory technical staff be embedded in the CI IO planning process; and similarly it is essential that CI planners be embedded in the higher level OOI organization, so that there is sufficient understanding of the CI and its design process at all levels. Integration of this sort is essential.

6. To the extent there are weaknesses in the current CI IO plan, the corresponding funding, staffing, and scheduling estimates are also in question. The OOI planning group can and should design processes to address these concerns in time for the PDR, and to make appropriate adjustments to their cost estimates.

7. In preparation for the PDR, the CI IO planning group should work directly with the IOs to clarify design, implementation, operation, and financial responsibility for all CI and embedded CI components of the OOI. An additional level of detail will be needed with respect to instrument control and QA/QC in order to be able to properly evaluate the plan and readiness.

8. The plan should address what functionality will be implemented as part of the early implementation of the OOI, and what functions might be added later. For example, while basic measurement collection will clearly be part of the base operation of each of the IOs, some instrument control and actuation will be needed early-on. Similarly, some of the sensor types planned for the long term are not yet available. Which specific sensor types will be included in the original construction phase?

9. A cross observatory concept of operations needs to be developed so that the effectiveness of the proposed cyber-infrastructure can be evaluated. For the PDR, the plan and/or associated reports should make clear how the CI IO will integrate the domain scientists and will help lead the cultural shift in the way ocean science is conducted. One approach could be to show the connection with the education and public awareness components within the three observatories.

10. A user and role analysis should be conducted to ensure effective implementation of the essential cyber infrastructure.

11. Protocols for how to bring in experiments and manage experiments as well as bringing sensors on-line in new or exceptional situations, needs to be added as an explicit item in the CI IO design.

12. The interaction and interfaces that depend on the knowledge infrastructure should be clearly defined with an example. Instrument and data calibration issues are a good example of how the process could work.

13. Given the concern that the oversight organization must be capable of analyzing and responding to proposals for the CI IO, a qualified person needs to be identified for this task.

14. CI has a large role to play with the outreach and education program. Some of the CI IO budget might be used to enable "grids for kids", or some equivalent, to allow students access to the data sets and possibly some instrument access to capture the excitement of oceanography research.

**Operation and Maintenance**

1. ORION should develop early in the project an overarching O&M plan that integrates activities from all the observatories into a consolidated “ORION Observatory” plan that allows the overall observatory to:

- Access economies of scale in acquisitions,
- Minimize O&M costs over the lifetime of the observatory via consolidated spares management,
- Enable the IOs to understand and plan for their responsibilities,
- Establish a governance environment that addresses planning and execution needs on a continuing basis and provides a mechanism to develop and spread “Best Practices” across all observatories.
- Include positions for an observatory scientist and education manager in the annual

operations budget.

2. The ORION Observatory (JOI, Implementing Organizations) should work directly with the Vessel Facility program managers at NSF, ONR, and NOAA and the UNOLS Office in defining and refining UNOLS ship time and costs as the OOI project moves from Conceptual to Preliminary Design.

3. Project Managers from all IOs should work closely to coordinate Operations and Maintenance where possible to ensure cost savings.

4. The Operations and Maintenance budget needs to include appropriate FTEs if the plan is to include 24/7/365 operations; this appears to be a shortfall in current planning.

## 1. Introduction

The Oceanographic Observatories Initiative (OOI) is a proposal to instrument the world's oceans on a scale that will provide transformational insight into the workings of this last frontier. The oceans cover more than 70% of the earth's surface and contain more than 98% of the earth's water yet remain poorly understood. The oceans are one of the major drivers of the earth's weather and play a significant role in the use and storage of carbon dioxide thought to be a major contributor to global warming.

The project was proposed in the late 1990's and was approved as a MREFC project by the National Science Board in 2000 for a total cost of $309.5M in then year dollars. Initial funding for the project is included in the President's Budget in the amount of 13.5 M$ which is currently before Congress. Since 2000 the project has evolved significantly from the initial concept. During the past 18 months many people have worked very hard to develop the current project conceptual design. Many hard choices had to be made with respect to observational techniques and to project scope. The project naturally divides into four components, three observatories that work at differing scales and a cyber-infrastructure that connects and serves them all. The operation and maintenance budget of the completed project must fit within the annual projected budget of the NSF's Division of Geosciences. The four components of the project consist of the three observatories, Coastal, Regional Cabled, and Global and the Computing Infrastructure that enables the real-time control and data collection from the instruments deployed in the observatories. While not part of the construction project except for a modest component having to do with education of the project participants, the project provides an outstanding opportunity for education and public awareness of oceanographic science and forefront technology.

Through a process that involved very significant volunteer help from the oceanographic community, the conceptual design of the project has matured greatly during the past six months and is now a project with clear goals and a reasonable preliminary budget and proposed schedule. The next steps will be to refine the conceptual design to the preliminary design stage for presentation at a preliminary design review along with a bottoms-up baseline cost estimate. The Panel concluded that the project is ready to move to that stage and what follows is a detailed assessment of the conceptual design along with recommendations and comments to help achieve a successful preliminary design review.

## 2. Project Management and Support

### Project Organizational Structure

### Findings

The Joint Oceanographic Institutions (JOI) is responsible for managing the construction, operation, and maintenance of OOI. Within JOI, the Ocean Research Interactive Observatory Networks (ORION) has been coordinating, leading, and responding to the scientific community planning for OOI and the formulation of its science user requirements. The OOI project within JOI is outside of ORION and is responsible for managing the construction of OOI. Thus, both the OOI Project Director (Stu Williams) and the ORION Director (Kendra Daly) report in parallel to the President of JOI (Steve Bohlen), who reports to the JOI Board of Governors. The plans are to contract the implementation of OOI via sub awards to four Implementing Organizations (IOs), which would each be responsible for the day-to-day activities associated with building and later operating and maintaining their portion of the OOI network infrastructure. The IOs will be academic institutions, academic/industry partnerships, or nonprofit oceanographic research centers, selected by a competitive bid process. The JOI Director of Operations (Carol Kokinda) will provide contracting support as contracting officer (CO).

JOI plans to set up and manage an OOI Management Team comprised of the project managers from each IO, the OSC Committee Chair, the ORION Program Director, and the OOI Project Director, who will be the team leader. This team will be the focal point for all strategic planning, will interface with the science community, and will approve all project changes, procurement plans, and observatory designs. In a similar vein, it is envisioned that system engineers from each IO, led by the system engineer from JOI, will meet regularly to coordinate trade studies, share lessons learned, and negotiate appropriate interface specifications and documentation between OOI elements. Within the Project Office are JOI employees, who will serve as the contracting officer's technical representatives (COTR) to provide oversight and liaison with each IO. Currently Jet Propulsion Laboratory (JPL) is on contract to provide systems engineering support. The Project Director reports that other specialized support to the project (safety, QA, environmental, legal, etc.) may be hired or contracted. CORE education and public awareness staff is in the ORION office.

**Comments**

JOI has a successful track record managing oceanographic research endeavors, notably the Ocean Drilling Program, that are larger and more complex than can be managed by individual institutions or small collaborations of institutions. The organizational structure proposed for OOI, using IOs, is quite similar to the approach used for ocean drilling. However, the OOI is quite different from the Ocean Drilling Program scientifically, technically, and sociologically. The desire to maximize the scientific potential of the installed hardware and systems and to turn instruments over to operation as soon as they are installed and functioning drives a need to integrate and optimize planning across the entire OOI (including the transition to operations and maintenance) and to stay closely connected with and responsive to the scientific community throughout the duration of construction. From this perspective the Panel is puzzled and concerned that the OOI Project Office is not located within the ORION organization, which interacts extensively with the scientific community and will be responsible for operations and maintenance.

The organization will be incomplete until the IOs are selected and get up to speed, and the Panel was not provided with sufficient information to assess the likelihood that these selections would result in a team of strong, qualified, and committed IOs. The chief scientists and engineers for the IOs are key positions for the project overall. Active and engaged systems engineering and integration interacting with and crossing all the IOs on a day-to-day basis will be essential, and the planning for this function is at best vague. The Panel considers multi-level communications between the IOs and between each IO and JOI to be essential to developing a unified system. The decision to utilize multiple IOs has benefits, but also presents the risk of segmentation of the project.

**Recommendations**

1. JOI should reorganize its management of OOI to place the Project within ORION, reporting to the ORION Director.

2. The Project Execution Plan (PEP) should more clearly and explicitly describe the OOI organization, advisory structures, the role and functioning of systems engineering, and the responsibilities and relationships of key personnel/positions in JOI and the IOs.

3. JOI should get highly qualified IOs in place and functioning as soon as possible, and ensure that their key personnel participate fully in developing the PDR, the cost estimate, schedule, and the review and revision of the top-level management plans, risk analysis, etc.

4. The Panel recommends that lower level technical interfaces between the IOs, and in particular between the CI IO and the other IOs, be specified and cultivated.

Internal and Institutional Oversight, Advisory Committees, and Plans for Building and Maintaining Effective Relations with the Research Community that will use the OOI to Conduct Research

**Findings**

JOI is a consortium of 31 oceanographic institutions, which currently manages a research and research infrastructure portfolio of about $110 million per year. Its President (Steve Bohlen) reports to a Board of Governors, which sets policy and provides oversight of contracts and program plans. The Panel informed that JOI is in full compliance with the Sarbanes-Oxley Act and is moving toward compliance with DCAA. JOI's major activities are governed by contracts or cooperative agreements with the sponsors, and these specify annual review processes tailored to the scope. An extensive advisory structure, involving over 80 community members, reports to the ORION Director. This structure has specialized committees (Sensors, Engineering, Cyber-infrastructure (CI), EPA) reporting to the Science and Technical Advisory Committee (STAC), which reports both to the ORION Director and the Observatory Steering Committee, which advises the ORION Director. ORION coordinates numerous workshops and maintains liaison with other NSF observatories and with international partners. These structures and relations are expected to continue and evolve through the construction and into the operation and research phase of OOI.

**Comments**

The existing and planned governance and advisory arrangements along with plans for effective relations with the research community appear to be reasonable and appropriate. The oceanographic community, which has been engaged in developing the OOI concept and science user requirements, represents many disciplines crossing oceanography and beyond. However, the demographic diversity of this community in terms of participation of members of minority groups is quite limited. As OOI is implemented and comes into operation, the mode of oceanographic research will broaden and the population of oceanographers should grow. The community's success over the past 20 to 30 years in increasing the number and advancement of women in the field has been remarkable, and the Panel hopes that the community can build on this success to include more underrepresented minorities and persons with disabilities.

**Recommendation**

The Panel encourages JOI, ORION, and all stakeholders to take advantage of the opportunity provided through OOI to broaden participation in oceanography, especially with respect to traditionally (and persistently) under-represented groups.

**Systems Integration, Testing, Acceptance, Commissioning, and Operational Readiness Criteria for all Components of the OOI**

**Findings**

Systems engineers from each IO will meet regularly with JOI's System Engineer to negotiate and document appropriate interface specifications between OOI elements. A Test Plan will be developed that documents the approach for testing of the OOI. The responsibility for testing will reside with the IOs. The systems engineers at each IO, in conjunction with JOI's system engineer (supported by JOI's systems engineering consultant), will be responsible for verification and validation. Each IO, in conjunction with the OOI Project Office, will identify and correct any physical, documentation, or performance deficiencies before presenting the system to the OOI Project Office for Acceptance. The Project Office has responsibility for accepting the observatories.

JOI currently has the Jet Propulsion Laboratory (JPL), a federally funded research and development center, under contract to support the system engineering efforts.

**Comments**

Both the Project Development Plan (PDP) and the PEP make reference to JOI's Systems Engineer. However no position with that title is found in Appendix A of the PDP. One of the JOI Program engineers is tasked with "Responsible for the management of the RCO IO and the systems engineering process for JOI. In addition he acts as COTR for the RCO, serves on technical evaluation teams for the Proposals, authors the PEP and PDP, writes the SOW for the CSO and GSO (in the absence of the second Program

Engineer), serves as OOI Risk Manager, and provides back-up to the OOI Director when required". This work load seems unrealistically large for one person.

The Project Director stated that JOI would only be involved in those system engineering issues that rise to the level of affecting an IO to IO interface. However it will be hard to adjudicate between the IOs unless the JOI's systems engineer and systems engineering consultant have detailed knowledge of the lower level design issues. In addition, the proposed procedure does not contemplate disagreements or failure. A complete procedure has to include remedies for worst cases. For instance, if the two IOs cannot agree on the best path, how is the issue decided? If the decision has cost implications, who bears the costs? JOI has suggested that it would resolve disagreements between IOs. As the project proceeds, both time and cooperation will be of the essence in making these decisions, and the concept of how this will happen should be clarified with IO involvement before the PDR.

The test plan for final acceptance is similarly incomplete. What is the definition of project complete? What is the requirement for acceptance of a component, subsystem, or node? What is the significance of Acceptance? Is it the end of the IO's implementation contract, or the point of title transfer, or the point at which the IO begins to assign the residual contractual responsibilities, or some other thing? What if the criteria for Acceptance are not, or cannot, be achieved? What if the IO and JOI (and perhaps a subcontractor or user) disagree about the results of the Acceptance Tests?

No indication has been provided on the qualifications or the tasking of the JPL Systems engineering group assigned to this project. While JPL is a very capable organization, the OOI seems out of its normal scope of business. No evidence was provided of JPL team experience in deepwater marine projects, in long-haul optical transmission or in complex IP systems.

**Recommendations**

1. JOI needs to configure the Systems Engineering function to serve the project's needs. This is a key position for the success of the project and requires a strong, full-time person to oversee and manage the systems integration issues across the IOs and the work being undertaken by JPL.

2. The qualifications and tasking of the JPL team to provide specific systems engineering support should be aligned with the project needs.

3. JOI must insure that its Systems Engineer remain current with the systems engineering issues as they evolve within and among the IOs.

4. On issues as contractually sensitive as disagreements between IOs and the definition of Acceptance, the PEP must be specific about where JOI anticipates that the responsibilities will lie and how disagreements will be resolved. While the approach may

change following negotiation with each IO, the Panel considers it essential for the PEP to include a practical approach to managing these issues.

5. The commercial/legal and technical significance of Acceptance must be defined. At a high level, the technical goals for Acceptance should be laid out.

**OOI Project Management Systems (General)**

**Findings**

The OOI was initially approved by the NSB as an MREFC in 2000, before the NSF's project approval and management processes developed the formality they have today. The FY 2007 Appropriations Bill currently proceeding through Congress includes MREFC funds for OOI, which cannot be used until after the project receives the go-ahead from the National Science Board (NSB). In preparation for this approval, the project has prepared many of the documents describing project management systems and plans and is undergoing this CDR review in August 2006. The Preliminary Design Review (PDR) is planned for spring 2007 as a pre-requisite to NSB approval to use the FY 2007 MREFC funds. JOI will be making major sub-awards to the IOs early in FY 2007 after competitive acquisition processes (one to select each IO). JOI indicates that it plans to hold similar reviews (e.g., preliminary and final design reviews) with the IO sub awardees, but these cannot happen before the PDR next spring.

**Comments**

Because this project consists of many "nodes" of oceanographic instrumentation, sensors, and infrastructure (much like some already deployed in specific locations or for small experiments), it is not as monolithic as many complex projects funded through MREFC. Thus, the overall risk of complete project failure is extremely low, and, in fact useful progress could be made today with minimal risk, if MREFC funds were available. However, managing the acquisition, deployment, and transition into operations of these systems in a way that maximizes their scientific capability for the anticipated facility lifetime of 30 years will be a significant project management challenge that needs a level of project management formality and systems. Although the project documentation for OOI is more extensive than is typical at the CDR stage, due to the history and the likely availability of FY2007 MREFC funds, the project is in an awkward position and must rush to prepare for and pass a PDR, currently scheduled for April 2007.

While the "plan" seems to be comprehensive and a lot has been accomplished within the past few months, there remains a lot to be defined and accomplished before next spring. New financial systems are being or have just been installed. Earned Value and Document Management systems and software are yet to be defined, selected, and installed. Processes like change control and subcontracts planning have details that must be addressed.

**Recommendations**

1. The project team should thoroughly review all the project plans, system descriptions, and the WBS prepared during the past four months, and revise them as needed to describe the specific processes, approaches, and plans appropriate to OOI. The IOs should participate in this review and revision.

2. Given the unusual history and situation of OOI, NSF should consider tailoring its processes so that NSB approval to proceed with the MREFC can be obtained on the current schedule (April/May 2007), based on validation of the essential elements of the baselines.

3. NSF and ORION should develop a clear description of project completion as soon as possible.

**Work Breakdown Structure**

**Findings**

A work breakdown structure (WBS) exists to level five for the observatories and for the cyber infrastructure system, which represent most of the costs. Some areas, for example program management and systems engineering, are only known to level three. A rudimentary WBS dictionary is provided in the Project Execution Plan (PEP) down to level three of the WBS. The WBS has been defined by JOI. It may change and be expanded by the IOs when they are selected and awarded subcontracts.

**Comments**

The top level organization of the WBS is logical and reasonable and appears to identify the work to be done. This is a good start, and considerable work on the WBS and a detailed WBS dictionary will be required prior to PDR and much of it must be done by the IOs. JOI intends to prepare a cost book for the PDR with a separate cost sheet for each element and at each level of the WBS. Each cost sheet will include a definition of the work to be performed or item to be provided. This will form the basis of a true WBS dictionary.

**Cost Estimate**

**Findings**

Budgets at level three of the WBS are provided in the PEP. Lower level estimates exist for the sites and infrastructure typically to level five. These level five estimates have been prepared by groups of engineers with experience based on historical prices, quotes and engineering judgment. The basis for the "detailed" costs has not been formally documented or made available to the Panel. Resource loading for the PDR will be done on the basis of IO proposal schedules and cost estimates.

The cyber-infrastructure system presented a cost estimate that was substantially higher than the estimate for that system presented in the total project cost estimate by JOI.

**Comments**

There is a basis for the estimates that is appropriate to the CDR stage. JOI intends to prepare a detailed cost book with a separate page and estimate for each element at each level of the WBS. The cost book will include the basis for each estimate. This represents a lot of effort to be completed in time for the PDR and will require direct involvement by the IOs, who have not yet been selected.

It was not clear to the Panel whether JOI had internally reviewed and scrubbed the estimate presented, or whether any explicit cost-estimating philosophy guided the estimate. Does JOI expect the detailed WBS element estimates to be sufficient to have a high likelihood of completion for that element within the cost, to have 50/50 chance of completing within the cost, or to be so tight that it is credible only if the uncertainties are resolved favorably and the work is managed extremely well? Since the project will be executed by the distributed IOs, it will be especially important to establish a common philosophy, budget transparency, and a contingency management approach that is very tight if the base estimates are generous, but loose if the base estimates are tight.

If the significantly higher cyber-infrastructure system cost estimate remains at the PDR stage, there must be a corresponding reduction in the budgets of the observatories to preserve the total project cost estimate given by JOI.

**Recommendations**

1. JOI should establish a clear cost-estimating philosophy, which establishes the project's expectations for the likelihood that each WBS element can be delivered for the base cost estimate.

2. After each IO is in place and prior to the PDR, JOI should conduct a thorough review and 'scrubbing' of the base cost estimate (using a transparent process, participants from the other IOs, and experts from inside and outside the project, as needed), to ensure that the margins in the estimates for each IO's scope of work are comparable and consistent with the project's cost-estimating philosophy.

3. The basis of estimate for the PDR should be coded in such a way that percentages can be provided, at the IO level and for the project overall, of how much of the estimate is based on catalog prices, vendor quotes, historical costs, engineering judgment, etc. It is also recommended that this system be implemented in such a way that the information can be maintained for subsequent reviews so that the review teams can track the maturation of the cost-at-completion estimates, starting with a relatively large share based on engineering judgment, and evolving towards a mix of completed work and awarded contracts.

4. In its management of the cost estimate, JOI should obtain from cost account managers their professional best judgment of the cost to complete about once or twice per year (and whenever major new information becomes available or significant variances arise). The Panel cautions JOI, the IOs, and the cost account managers not to rely solely or excessively on the algorithmic predictions from the earned value management system when preparing the cost to complete.

5. Sufficient funding should be maintained to account for changing ship day-rates. All three observatories will require ships to deploy and maintain their systems. OOI requirements need to be considered as a high priority within UNOLS scheduling.

6. The Panel recommends further consideration of the following key management topics in order to refine the observatory design process. These include the definition of the key cost-drivers and risks, the bottom-up derivation of costs, the definition of the planned schedule of development and deployment, and the definition of the project management requirements with emphasis on integrated systems design. In addition, the interdependencies among program elements must be identified, including links to cyber infrastructure. Cyber infrastructure needs must be identified and prioritized based on existing experience.

**Project Schedule**

**Findings**

Proposed top level or key milestones are identified in the PEP. No integrated detailed schedule exists. While it is recognized that the schedule may be determined by the funding profile, and that the Cyber Infrastructure System probably represents the critical path, no specific critical path tasks have been identified. Any detail concerning the transition to operations does not exist. There has been no attempt to marry a schedule with the resources required.

JOI previously used CSTI and Microsoft Project with WinSight Reporting and proposes to use the same systems for OOI. JOI showed the Panel examples of reports that can be provided.

**Comments**

Given the nature of this project, the existing schedule documentation is reasonable for the CDR stage. The need for adopting a scheduling package for use throughout the project is high and urgent. A useful critical path, one that would provide focus on potential problems, has not yet been identified. Looking forward, a lot of effort must be completed to prepare a detailed schedule before the PDR, and this will require direct involvement by the IOs yet to be selected. JOI is thinking that the cost book will include basic schedule information that would provide the basis for preparing an integrated schedule as well as the information required to “resource load” the schedule to derive the performance measurement baseline.

The schedule for IO selections ideally should occur well in advance of the PDR. The current schedule is severely compressed in terms of adequate preparation for the PDR. Additionally, only limited funds have been available to date for PDR preparation by the scientists/engineers involved for each component. Most of the work for the CDR was done by volunteers.

While this Panel recognizes that Microsoft Project has some advantages in that it can be easily distributed to and used by Cost Account Managers with minimal training and is relatively inexpensive, it is our view that Microsoft Project does not provide an adequate platform for a project of this size and complexity.

Several of the breakout groups were shown pieces of the schedule that had apparently been prepared using a variety of software applications. Once the project selects and implements its scheduling software, a central "integrated schedule" can be developed and then used for uniform reporting, for critical path analysis, and for modeling alternate scenarios.

**Recommendations**

1. JOI should consider implementing one of the more capable project scheduling systems, and should do so without delay. It may be helpful to contact other scientific projects of similar complexity and magnitude to take advantage of their experience and insights in making this selection.

2. NSF/JOI should evaluate if the PDR can be held one month later to enable better preparation by the newly selected IOs. JOI should provide funds for the PDR preparation.

**Change Control**

**Findings**

The governing document for change control provided to the Panel is titled "Configuration Management and Change Control Plan for the Ocean Observatories Initiative."

**Comments**

The Panel is interpreting “configuration management” to refer to the fact that “cost, schedule, and technical performance” of the total system is determined by the cooperative agreement negotiated with the NSF and cannot be changed without NSF concurrence. The Panel has not evaluated “Engineering Configuration Management” concerned with, for example, what hardware is located where and tracking and documenting how individual circuit boards may have been modified in the field.

The "Configuration Management and Change Control Plan for the Ocean Observatories Initiative" is an adequate first draft. There are some issues that should be tailored to OOI. For example, the specific responsibilities of members of each change board should be identified (who has ultimate approval authority and what are the roles of the other members?). The membership of the change boards as defined seems reasonable but should be expanded to insure appropriate visibility and scrutiny of proposed changes across the project, even by representatives of systems not likely to be affected (both to make sure that this is the case, and to enhance communication). Adjustment of the membership to ensure availability of the requisite expertise may be necessary on a case-by-case basis.

The Panel is concerned with some aspects of the "Configuration Management and Change Control Plan" namely assuring that subtle potential impacts of proposed changes on other systems are not missed, assuring that safety, environmental, and quality impacts of changes are assessed, and optimizing use for the project overall of funds saved as a result of a change (which should not necessarily be a windfall to be used by the system where the savings occured).

**Recommendations**

1. Revise the Configuration Management and Change Control Plan to address the issues noted above.

2. Implement a change log that tracks the status of each change and documents the effect of approved changes on the baselines and contingency.

**Performance Measurement System (Earned Value Management System)**

**Findings**

JOI understands the purpose and methods of modern performance measurement systems as implemented for large science projects and has experience with EVMS. Selection of performance measurement tools for OOI has not yet been finalized. JOI previously used CSTI and Microsoft Project with WinSight Reporting and showed the Panel examples of reports from the drilling program (IODP). The JOI project team for earned value system and reporting for OOI currently consists of one person. JOI recognizes that additional personnel will be needed and is willing to use contract personnel if necessary to address immediate short-term needs.

**Comments**

The project is at a reasonable point for the CDR, and in many ways it is ahead of other projects at this stage. The EVMS reporting systems presented seem to have the necessary capability and flexibility to support a project of this complexity. JOI is designing the EVMS with the intention that it will be the primary customer for the earned value reports, and the Panel applauds this choice. The reports will provide information useful for monitoring and managing the IOs and for reporting to the NSF. Making the systems useful for the IOs should also be a goal. A lot of effort must be completed prior to the PDR and this effort will require direct involvement by the IOs. The EVMS and its reports can contribute meaningfully to overall project communication and visibility among all the participating organizations and the user community.

**Recommendations**

1. Select and implement performance measurement system applications as soon as possible.

2. Recommendations regarding the selection of a capable scheduling application are included above.

**Accounting and Financial Tracking**

**Findings**

JOI is installing a financial system that will support project accounting, and the intention is to integrate the financial systems of the IOs, to allow direct 'upload' of their accounting data.

**Comments**

The system is likely to be adequate, but the integration cannot be demonstrated until the IOs are selected.

**Document Management System**

**Findings**

The current document management system used at JOI is OPTIX. The individuals interviewed were not completely satisfied with the capabilities provided by OPTIX based on feedback that they had from the Texas A&M University IO for ocean drilling.

The selected document management system will be web based. The selected document management system will have work flow capability to facilitate electronic approval. JOI has not completely thought through the kinds of documents that will be collected and saved in a document management system. However they indicated that the system will be used to archive project management documents, subcontract documents, interface control documents, etc. It was not apparent whether the documentation needs of the IOs for Engineering Configuration Management had been considered.

**Comments**

JOI's document management experience gives a base to build on, and the project's document development to date shows an awareness of document management and control that is more sophisticated than one often sees at CDR. Clearly, some document management system will have to be selected soon, and the direct involvement of the IOs in document management will be essential.

**Recommendation**

Automated document management systems should be evaluated, selected, and implemented quickly.

**Contingency**

**Findings**

Contingency needs were estimated top down, not derived bottoms-up. The amount in the estimate is about 21 percent. It appears that the cost estimates are "best estimate" since they were done by groups of engineers and scientists assembled for the purpose, and not by potential cost account managers who will ultimately be responsible for meeting the budgets and could be expected to provide 90-percent success-rate estimates. The Panel does not know how much, if any, contingency might be hidden in the individual estimates.

**Comments**

Normal contingency for a project of this complexity at this phase as a percentage of the total cost estimate would be in the high 20s. However, the project consists of a large number of separately functioning "nodes" and instruments, and the failure (or inability to complete) a few of them does not necessarily result in failure of the project. Thus, the project could be managed as a "fixed cost" endeavor, with scope increasing/decreasing to fit within the budget. In fact, the idea of being able to use unspent contingency to increase scientific capability (scope) near the end of the project can provide a powerful incentive to the IOs to be very cost conscious and to minimize their requests for contingency to accomplish the approved scope. See also the comments and recommendations, above, regarding the cost estimate.

**Recommendations**

1. A bottom-up evaluation of contingency needs should be done for the PDR as part of the bottom-up cost estimate. JOI should be aware of "contingency" included in the base estimate.

2. The vast majority of the contingency should be held and managed at the central project level (JOI) and not allocated to the individual IOs. If JOI chooses to pre-allocate some contingency to be managed by each IO, it should make sure that there is no hidden contingency in the IO's cost estimate, ensure that contingency management by the IO is

transparent to JOI, and the IO should be required to report contingency balances and use in the monthly progress reports. In addition, robust mechanisms must be in place for reclaiming contingency from the IOs to the central contingency pool (as well as for flowing the other way).

**Risk Management**

**Findings**

Risk analysis and documentation is advanced beyond what one would expect in a CDR. A formal risk management program will be implemented for the OOI as described in JOI's document, Risk Management Plan for the Ocean Observatories Initiative (OOI). This risk management plan follows a traditional risk management approach of identifying potential risks, applying a severity ranking, analyzing potential cost impacts, and developing mitigation strategies. The identified risks to the OOI project are documented in the OOI Network Risk Register. The risks identified in the risk log are not directly reflected in the contingency needs estimates, which were done top down. The Risk Management Plan is not tied into the EVMS or the Plan of Work.

**Comments**

The OOI is a project with many unusual risks when compared to conventional capital projects. However, the vast majority of these risks will not lead to overall project failure, because of the nodal and network nature of the infrastructure. There will be cases where risk management considerations are the major decision driver.

The OOI Risk Management Plan is a valuable tool. However it needs to be supplemented with a reporting system that will tie the pressing risks in with the plan of work and the EVMS. This could be a manual report, or a software system. Moreover, the Panel came up with many significant project risks not included in the Network Risk Register. Both the Project Office and senior management need to be aware of the risks, their implications and the options available for risk mitigation. Some of these risks can be mitigated by contract, depending on the contractual regime selected for the OOI. The risks may be seen as sufficiently significant that they drive senior management to limit the contractual options available to the project office. The risks associated with predictable normal variations in material costs or uncertainties related to engineering judgment (for example "CDR estimates based on smaller systems") should be identified on the cost sheets and handled through the bottoms up contingency estimating methods. The risk log should be used to track items typically outside the contingency needs estimates on the cost sheets, for example what happens if environmental permitting is bogged down or an accident occurs and the investigation halts progress for a period of time. This Panel is concerned that contingency needs will be over stated by inclusion on the cost sheet contingency calculation as well as via top level adjustments made to address items in the risk register.

**Recommendations**

1. The bottom-up contingency calculations may be modified if it is deemed necessary to reflect risks that are not included in the cost estimate contingency calculation.

2. For PDR the risks related to engineering estimates or material costs should be dealt with in the cost sheets and the contingency estimates rather than on the risk register. Those risk register items that are also reflected in contingency estimates on cost sheets should be carefully identified.

**Acquisition Plans, Subcontracting Strategy and Awards Associated with each Level 2 WBS Element**

**Findings**

JOI has considerable experience managing IOs and subcontracts, and proposes to use the same approach with OOI. The process as described is consistent with how the R&RA funded effort requires NSF approval for subcontracts/sub awards larger than $100,000. JOI does not yet have a procurement plan for OOI, and could not tell the Panel how many contracts of what size would be processed during the project, but the consensus is that the number will be sizeable.

The acquisition process foreseen is that JOI will make sub awards to competitively selected IOs, and that most of the subcontracts to construct the OOI will be generated by the IOs. JOI is preparing and issuing RFPs to select IOs now, and they should all be in place by early 2007. The primary responsibility of each IO is to provide for the design, development, construction, and operation of the observatory component for which it is responsible. The IOs will be reimbursed for their costs, and will be bound to a specific set of deliverables. Whenever an IO is ready to place a subcontract that is larger than $100,000, the documentation will be elevated to JOI. After review and approval, JOI will elevate it to the NSF for final review and approval. Assuming that everything goes smoothly, this process is likely to add weeks to the procurement process.

**Comments**

The Panel had difficulty understanding the exact responsibilities and liabilities of the IOs. Some potential bidders for IO sub awards were present at the review, and expressed surprise that the IO would be anything other than a construction manager. The Panel does not consider that the RFP document is sufficiently clear on this important matter. Lack of clarity may cause problems and introduce schedule risk.

Currently JOI and NSF have a good working relationship in contracting. However, the NSF has limited resources for reviewing subcontracts. Some of these subcontracts will be significant.

**Recommendations**

1. The relationship between the NSF, and JOI and its subcontractors (the IOs), should be carefully and clearly defined.

2. The Panel recommends that a clarification be issued to make the RFPs specific as to the expectations, risks and responsibilities to be transferred from JOI to the IOs.

3. JOI should work with the NSF to define and document a workable process and dollar thresholds for approving subcontracts. Assuming JOI has a federally approved procurement system, "rules" can be established to streamline the processing of some kinds of purchases, e.g., catalog items, that would require no or less stringent review.

4 JOI should prepare and maintain a procurement plan forecasting the number and size of procurements. Based on this plan, different thresholds might be considered for the MREFC funded effort. The effort on the procurement plan should be started and shared with the NSF as soon as possible to facilitate NSF planning.

5. The detailed project schedule should include sufficient time to review and process/award subcontracts.

**Quality Control and Quality Assurance Plans for Components of the OOI**

**Findings**

The PEP states that critical suppliers or further sub-recipients under this contract must be ISO 9001 compliant. The responsibility and guidance for the overall quality assurance of the OOI will be coordinated through the OOI Project Director. The quality assurance and quality control function for the OOI will be primarily implemented by the IO organizations. Use of COTS (Commercial, Off the Shelf) technology and technology solutions and proven open source code will be adopted to minimize both risk and cost with the hardware and software systems.

JOI proposes to not have a staff Quality Manager, but to use an external consultant (to be selected).

**Comments**

ISO 9001 is a series of documents that define requirements for a Quality Management System. It is not a Quality Management System in and of itself. ISO 9001 companies produce consistent quality products, not necessarily high quality products. The level of quality is defined in each company's Quality Plan. The mixture of academic and industry resources and suppliers proposed for the OOI requires that JOI implement a high level project quality plan to guide the IOs. This Quality Plan would recognize the different quality goals for different parts of the OOI.

Use of COTS equipment is a valuable risk mitigation decision, but presents its own quality management issues. High quality COTS equipment used in novel situations can react in unexpected and damaging ways. QA on COTS equipment is as or more challenging than QA on custom built.

Software quality control is a significant issue that is not addressed in the documentation provided.

JOI should reconsider its decision not to have in-house Quality Management staff. While the project office is responsible for QA, it is inappropriate for the primary QA requirement to be in the hands of a member of the project office such as the Project Director. QA needs to have an ultimate reporting channel above the Project Team – e.g. to JOI President.

**Recommendation**

JOI should appoint an in house Quality Manager. The Quality Manager must have an ultimate reporting channel above the Project Team – e.g. to the JOI President.

**Environmental Assessments and Permitting Related to Implementation of the OOI**

**Findings**

NSF is responsible for all decisions with respect to applying the National Environmental Policy Act (NEPA) to the OOI project. NSF is in the process of determining what level of environmental assessment will be required for the project. JOI, on behalf of NSF, has contracted with a consultant (SRI International) to review strategy options for complying with NEPA and other environmental regulations applicable to the proposed OOI. SRI has produced a report titled “Environmental Requirements Applicable to the Proposed National Science Foundation Ocean Observatories Initiative”.

Once the decision is made, the appropriate environmental analyses and documentation must be completed and made available for public comment. On this basis, a final environmental decision will be made, and assuming it is favorable to OOI proceeding, the IOs will proceed with their scopes of work, in compliance with the environmental requirements. The IOs will be responsible for obtaining any site specific permits, marine permits and landing licenses required to accomplish their part of OOI.

**Comments**

Until NSF makes its determination, environmental documentation requirements and schedule for OOI cannot be known. The relationship between the NSF, and JOI and its subcontractors, the IOs, with respect to the preparation of the environmental assessments, site specific environmental reports and permit applications needs to be carefully and clearly defined in order to ensure that all relevant federal and international regulations are properly applied to the project. Satisfying the environmental requirements must continue to be a priority throughout the period of deployment and operation.

**Recommendations**

1. NSF should make its environmental determination as soon as possible, and put in place the mechanism and timetable for completing the appropriate environmental analysis, documentation, and public review.

2. Someone in JOI should be designated to be responsible for management of the environmental consultant(s), review of the environmental reports and associated work. This work is not currently identified in the PDP Appendix A. The responsible person will need to have experience in permitting linear and discrete marine projects landing in the U.S., and be able to dedicate sufficient time to this work.

3. JOI should budget for, obtain, and have available on an as-needed basis, specialized legal advice on the Law of the Sea with respect to rights of cables, and on applicable regulations, permitting, rights of way and contract, in order to ensure that both JOI and the NSF are properly protected.

**Systems Integration, Testing, Acceptance, Commissioning, and Operational Readiness Criteria for all Components of the OOI**

**Comment**

Systems integration of all OOI components is lacking. Each component (CSO, GSO, RCO, CI) is currently working independently. There is also a lack of definition of responsibilities (physical and logical) between the CI and each component. For example, what software is each IO expected to develop that is specific to their infrastructure and instruments?

**Recommendation**

The OOI needs a systems integrator that works closely with all IOs to ensure efficiency, collaboration, and consistency where possible.

**Plans for Transitioning OOI Assets to Operational Status**

**Comment**

The Panel could not determine if partnerships with other government agencies had been considered to help offset the O&M costs of the OOI.

The Panel evaluated the Operations and Maintenance plans and budget for the IOs. The overall concept of operation (CONOPS) for the OOI and the associated CONOPS for the each of the IOs is not clearly defined. The expectations of the science community suggest a responsive 24/7/365 operation of the IOs. The current O&M staffing levels do not support this type of operational mode. The Panel was unable to get a clear picture of the linkages between the O&M staffing across the various IOs.

**Recommendation**

1. The nature of the OOI lends itself to uses outside of the traditional science community. Partnership with other federal agencies should be explored to help offset the O&M associated with the OOI. These partnerships would also bring more resources for the science experiments and technology development for the OOI.

2. An OOI level CONOPS should be generated and used to help define the O&M staffing for each of the IOs.

3. The Observatories Operations and Maintenance budget needs to include adequate FTEs to meet the requirements established for 24/7/365 operations. Project Managers from all IOs should work closely to coordinate Operations and Maintenance where possible to ensure cost savings.

**Health and Safety**

**Findings**

The OOI project and each IO will comply with all applicable Health and safety policies and requirements of the NSF and those of the cognizant IO's organization. In conjunction with the IOs, the ORION Program Office will coordinate safety audits of OOI installations including any ground stations and ship-borne facilities.

**Comments**

Given that the IOs will be academic institutions, without the type of safety policies that JOI may have seen in the offshore drilling industry, the Panel recommends that JOI give serious consideration to establishing specific guidelines for the IOs with respect to safety programs. JOI will need ongoing support to assist the IOs in implementing safety programs. These safety programs should specifically address 10 KV DC power safety, vessel personnel safety and vessel safety, as well as more conventional requirements. Some of these safety requirements may affect system design details.

**Recommendations**

1. JOI should be proactive about its safety/health culture and expectations and provide clear safety/health guidance to IOs.

2. JOI should consider having a safety/health officer for OOI.

3. JOI should require IOs to report to ORION any safety/health incidents and injuries occurring during the conduct of OOI, in addition to their reporting to their own institutions.

## 3. Coastal Scale Observatory

### Introduction

The Panel's evaluation of the proposed scientific programs and supporting technology research for the Coastal Scale Observatory (CSO) with an emphasis on the investment of funds that could provide a transformative capability through new science programs and new technology enablers is provided in this section.

Overall, the Panel feels that the proposed CSO will achieve the goal of providing transformative science through the investment of NSF funds. The proposed scientific programs enabled by the CSO would support major advances in the fundamental understanding of coastal oceans and their related physical, chemical, biological, and ecological processes, and will support education programs that will broaden participation in ocean research. The CSO has identified three major complementary locations and scientific themes and have proposed unique technological capabilities to study these regions. The CSO would be a major contribution to the ocean sciences scientific community, stimulating exciting new science and fundamentally advancing the technology base for research in these fields.

In the summary below, comments on the conceptual design of the CSO as presented in the CND document for review is supplemented by detailed discussions with research team members at the CDR review. Several clear principles have guided the evaluation and comments. First, the design of the CSO should be governed by the opportunity for transformational science and technology. Second, the investment in focused capabilities with clear scientific merit is more important than wider geographic distribution of assets. Third, the OOI is conceived as a network of observing systems supporting interactive scientific experiments, and does not simply provide a passive monitoring function. To be successful, the OOI must support interactive experiments linked to key scientific themes.

The CSO includes three major components, and it is important to clearly define the scientific and technological importance of each of these components. For each of the three subprojects, the key elements that will enable transformational science, consistent with the OOI Science Plan, and the key elements that will contribute transformational technology, creating an infrastructure that will directly support the planned science contributions should be clearly presented in the preliminary design.

### CSO Component 1: Pioneer Arrays

### Findings

The OOI will build the Pioneer Array providing the oceanographic community for the first time a sustainable multi-disciplinary integrated network capable of resolving multiple spatial scales with sufficient fidelity to resolve critical processes in the coastal ocean. The arrays will be relocatable and sufficiently flexible to study a range of processes in the coastal ocean. The arrays will enable the development of robust numerical models with predictive skills that will provide insight into the minimum requirements for any operational ocean observing and prediction systems. This interactive adaptable ocean sampling network will transform process studies in the ocean and will springboard development of transformational new technologies.

The principal science drivers of the initial deployment of the Pioneer Array are the interaction between the continental shelf and shelf slope. This is an extremely important region where there is significant exchange of heat, salt, nutrients and biology. These dynamics make these areas biologically productive and impact the fluxes of material between the coastal and deep ocean. This region is a highly dynamic, influenced on the inshore by rivers, on the surface by weather, and on the offshore side by deep ocean circulation.

**Comments**

A significant transformative aspect of the pioneer array is its ability to resolve energetic meso-scale to submeso-scale structures for extended periods so that many events can be captured. Resolving many events is especially significant for the multidisciplinary aspects, where biological processes are being studied.

The Pioneer project is designed to provide capability that may be deployed to other settings where high resolution, three dimensional sampling is essential – for example, harmful algal blooms, or river plumes. Systematic deployment of successive realizations of the array should be considered.

The Pioneer project has great potential for evolution of new science as capabilities are added using multi-component integration and new sensor and communications technologies. Extrapolation of the current design and anticipation of future technology requirements will be important. These new capabilities will have implications for power, communications, and computational capabilities of the system.

**Recommendations**

1. The Panel recommends a phased deployment for the Pioneer Array at five year intervals with competitive review of science initiatives for each deployment. Each new deployment should address priority scientific missions to address issues of concern throughout the nation's coastal research community..

2. A more thorough review of resource requirements for the Pioneer system as part of the preparation for the preliminary design review could be beneficial. Since this array will be utilized for different problems and locations, it is essential that a systematic approach be utilized to ensure that the facility will meet the needs of new experiments. This systems analysis should also inform the risk assessment for component failures.

**CSO Component 2: West Coast Endurance Array**

**Findings**

The OOI proposes to build two Endurance arrays which will provide both long term time series measurements on the scale of a large marine ecosystem and the power and data bandwidth that are critical to conducting interactive experiments and quantifying biotic responses at multiple trophic levels using state-of-the-art sensors. The time series will be anchored by cross-shelf arrays of highly capable profiling moorings which are complemented by either the adjacent RCO (West Coast Array) or large towers (South Atlantic Bight Array) that are ideal for offshore CODAR and multi-elevation air-sea measurements during extreme weather events. The time series sites will provide vertically resolved measurements in the water column and sufficient surface expression to allow for air-sea flux experiments. The fixed point mooring arrays will be complemented with long duration gliders providing sustained spatial time series to complement the high frequency sampling at the moorings and towers. The spatial time series will enable transformative research by the oceanographic community to address large-scale questions regarding coastal biogeochemistry, climate, and ecosystem dynamics.

The assets in the West Coast Endurance Array are concentrated on the Central Oregon and Central Washington mooring lines. The purposes of these lines are to contrast shelf and slope processes in regions that are influenced in different ways by the outflow from a large river and to contrast processes in a region of smooth topography (i.e., the Washington shelf) and a region with a topographic bank (i.e., Heceta Bank on the Oregon shelf). The assets on the Washington and Oregon lines will include highly capable installations with full-depth profiling, surface expressions for atmospheric measurements, and benthic nodes for intensive near-bottom measurements, in addition to less capable installations without benthic nodes at the 50 and 150 m isobaths. The shelf and slope moorings on the Washington and Oregon lines will be complemented by off-shore infrastructure associated with the RCO thus allowing potentially transformational studies of interactions between deep ocean and coastal processes. The CND also proposes to use some of its resources to support moorings off central California and in the Southern California Bight to sample different biogeographical regimes and to provide spatial measurements of northward-propagating signals originating in the tropical Pacific.

**Comment**

The Panel was impressed with the design of the Pacific Northwest (PNW) portion of the West Coast Array and to extent to which it is integrated with and leverages the RCO to its west, the global moorings to the southwest and northwest in the subtropical Pacific and north Pacific, the Canadian Neptune moorings to the north, and the NSF supported freshwater and terrestrial programs to the east. However, the Panel agrees with the Blue Ribbon Panel that the scientific justification for the California moorings should be carefully reviewed based on their contribution to the scientific mission of this observatory and the need for additional resources to fully realize the potential of the PNW array. Extensive experience in these California sites has created a valuable range of expertise, and it would be important to integrate these capabilities into the design and operation of the other arrays.

**Recommendations**

The Panel recommends that the justification for the California moorings be carefully reviewed. It may be that these resources would be better utilized by redirecting them for additional key technologies, including sensors and mobile platforms, in the other arrays.

**CSO Component 3: East Coast Endurance Array**

**Findings**

The proposed East Coast Endurance Array is located in the South Atlantic Bight, a region characterized by a broad, shallow continental shelf with intense interactions between the seafloor and water column, direct forcing by a strong western boundary current (the Gulf Stream) and frequent, high-energy atmospheric events such as hurricanes. The proposed East Coast Endurance Array benefits from the existing array of surface piercing towers (owned by the US Navy) that provide unmatched all-weather mid- and outer-shelf access to the air-sea interface and water column. The main new element of the East Coast Endurance Array is a cable extending from shore to a medium voltage inner-shelf benthic node and then to a dry node on a mid-shelf tower and finally to a dry node at a shelf break tower. Two additional un-cabled towers (R4 and R8) will be instrumented with high frequency (HF) radars, provided with power and two-way communications to measure along-shore spatial variation in surface currents over the outer shelf and slope. Observations from an array of gliders will be used to further quantify spatial variability.

**Comments**

The success of this proposed effort is contingent on the availability of these Navy owned towers over the 25 year life of the ORION program. Although these towers are already being utilized as part of the regional IOOS observing system (thus creating an excellent opportunity to leverage costs with NOAA), continued Navy use (thus availability) of the fixed towers is uncertain at this time.

**Recommendation**

The Panel recommends that an agreement be developed with the U.S. Navy and potentially NOAA to provide use of these towers over an extended time period to support the resources required for this observatory.

**CSO Science and Technology Issues**

**Findings**

The CSO incorporates a wide variety of technologies and an integrated view of systems design will be essential to successful development of this facility.

### Comments

The Panel feels that there are requirements for additional investment in key technologies that would strengthen the scientific value of the three components. These include new sensor technologies, including biological and chemical sensors that are based on emerging technologies and will significantly expand the scope of these networks in the future. The Panel is concerned that the core sensing capability included in the basic observatory design may not be sufficient for many important scientific missions that were defined in the ORION plan. In addition, new mobile platform technologies, including both gliders and AUV's, can significantly expand the opportunity for sampling with high spatial and temporal resolution, as well as significantly improve the interactive and adaptive capabilities of the observatories.

The observatory technology can be a driving force for new technologies and cyber infrastructure, but only if the initial systems are designed to allow their incorporation. As a result, there is a need to extrapolate the implementation of the technologies in the observatories and consider the opportunity for long-term evolution and accommodation of new capabilities. These would include adaptive sampling, mobile platforms (see Blue Ribbon Panel report) and the development of new sensors.

Integrated design of the observatories and the enabling cyber infrastructure is essential for the success of the project. These observatories encompass a complex hierarchy of subsystems, and the design of the network will require formal design methodology to establish definition and evaluation of key functional modules and interfaces among them, including both hardware and software components. These integration issues are intimately connected with the design of the cyber infrastructure architecture.

The CSO observatories place special emphasis on interactive and adaptive systems and these will present cyber infrastructure requirements in order to facilitate these real-time interactive capabilities. Mobile platforms and advanced instrumentation will often have on-board computational and data storage capabilities that provide both on-board real-time information for control and decisions, as well as the buffering of data within the large architecture.

### Recommendations

1. The Panel recommends careful consideration of how technologies in the programs will integrate together, within each of the three component observatories, within the CSO as a whole, across the entire OOI network, and finally integration with other entities and facilities, e.g. IOOS, MARS and others.

2. The involvement of domain scientists with extensive experience in field experiments, data acquisition, and analysis will be essential for the effective development of the cyber infrastructure systems. There are existing examples of cyber infrastructure implementations within currently deployed facilities, and this experience should be captured in this development process. Integration of sensor technologies among platforms will be a critical aspect of the design process.

3. The Panel recommends that the team complete the "traceability" exercise prescribed by the Blue Ribbon Panel. The proposed core infrastructure must support full exploration of the key (relevant) science questions defined in the science plan. It can then be expanded to emphasize particular scientific opportunities in the coastal region observatories.

**CSO Budget and Schedule**

**Findings**

The CND provides a broad overview of the budgetary plans for construction and the expected O&M expenses for the CSO. Significant additional refinement of the budget is needed to provide a more accurate depiction of the implementation schedule and accurate budgetary projections.

**Comments**

There is no specific schedule for network development and deployment that define the capabilities achieved at key milestones in the implementation.

For each of the three component observatories the budget implications of the refocused observatory plans should be examined. Analysis of each component and evaluation of its ability to achieve significant scientific capability, enabling observations and scientific exploration in a manner that would not be possible using conventional approaches and tools is required.

As discussed above, the Panel feels that the scientific justification of the California moorings should be reexamined, and potentially those funds could be considered for reinvestment in other areas, particularly for additional technology needs.

The Panel feels that the O&M costs should be continually reexamined to assure consistency with expected performance of a large variety of instruments in a complex configuration and difficult environment. The CSO has particular challenges in this regard due to the variety of instruments, locations and platforms for this program. It is the understanding of the Panel that additional work is required to complete the O&M budget estimates.

The current budget does not adequately provide for the scientific oversight of operations, and the management and staff positions required for this responsibility are not adequately described.

For each of the three components of the CSO, the schedule implications of the refocused observatory plans should be considered.

The spending schedule described in the CND is unrealistic and is unlikely to serve the needs of the project.

The simultaneous development of all three observatory components seems unwise for both technical and management reasons. Instead, it may be appropriate to initiate a multiphase development of the key components to take advantage of lessons learned and to better take advantage of technological advances in measuring devices.

**Recommendations**

1. The Panel recommends the development of a timeline for network development and deployment, defining the capabilities achieved at key milestones in the implementation. Define the "critical path" for implementation, identifying important precedence relations among implementation steps.

2. The Panel recommends additional investment in emerging technologies for sensor and mobile platforms (including profiling platforms, gliders, and AUV's) that will significantly enhance the capabilities of all three coastal observatory components.

3. The Panel recommends that the O&M cost structure be thoroughly reviewed to include all necessary elements. Concerns were expressed about a number of areas including operations and replacement costs for the mobile assets, ship time for the Pioneer and East Coast array, and the operation and maintenance team for the Pioneer and East Coast.

4. The Panel recommends that lead project scientists and supporting staff should be present in each of the observatory components to provide oversight of the scientific programs to ensure that the facility adequately supports the overall science goals of the program and ensure that the observatory provides the quality assurance for data. These positions have not been specifically included in the current CND CSO budget. It is important that NSF recognize the need for these positions and provide budgetary support if possible. There may also be alternative mechanisms through the IO support/match that could provide these capabilities.

4. The Panel recommends that multiphase development of the three components of the observatory. The first phase would include:

a.) The Pioneer array providing early access to these emerging capabilities. Early deployment also anticipates the need for a second phase implementation in another setting, and

b.) The Washington line of the West Coast array. A second phase of deployment would emphasize the Oregon line of the West Coast array, which depends on linkage to the RCO. A third phase of deployment might focus on the East Coast array, where negotiations for use of towers and related resources may require additional time.

5. The Panel recommends that the schedule of fund allocations be reexamined. The research team should examine the refocused design of the component observatories and propose a spending schedule that would maximize the availability of scientific resources as early as possible.

6. The Panel recommends that NSF carefully consider the need to announce competitive program funds in a timely manner that will encourage wide community participation in the observatory utilization. Innovative approaches to encourage wide community participation and broadening of the access to data from groups other than traditional field oceanographers.

**CSO Management and Planning**

**Findings**

The management structure is superficially presented in the CND. There is little detailed information regarding the particular management requirements for the CSO case that includes multiple sites and a diverse set of instruments and users.

**Comments**

The IO management structure will impact the CSO plans and the special needs of the multiple subprograms, locations, and sub-communities. CSO will have more diverse locations, technologies, and user groups than the other observatories, and these needs should be carefully considered in the selection of the IO.

Part of the CSO in the West Coast array requires connection to the RCO. This connection will require particular care with respect to management and technical coordination.

Because of the distributed nature of the coastal observatories, the education and outreach capabilities provide an excellent opportunity for engaging local institutions. These efforts are well underway and coordinated by other groups. Cooperation of institutions in each region will be important as well as the inclusion of undergraduate non-major institutions. Training of future generations familiar with these observatories, and crossover of ocean sciences and engineering disciplines are also important aspects.

Broad access to data streams and visualization techniques will enable their use in education and outreach efforts. Broad access enhances diverse participation.

**Recommendations**

1. The Panel agrees that the CSO will require a separate IO (not combined with GSO) and should have clear experience in managing complex distributed projects in different geographical locations. While a consortium approach may provide this diversity, the availability of clear consistent formal management experience is of primary importance.

2. The Panel recommends cooperative management of the connections between RCO and CSO for the West Coast array.

## 4. Regional Cabled Observatory

### Scientific and Operational Requirements

**Findings**

The RCO CND has been through a number of iterations since the Jan 2004 ORION Science Workshop. These changes have lead to a reduction in the scope of the proposed RCO to meet the expected funding levels. It was clear to the Panel that these reductions in scope had been undertaken with the participation of the planned user community and that the present conceptual design is currently the minimum required to satisfy the ten regional plate scale science drivers.

**Comments**

The RCO team should be commended on their ability to involve the community and to make difficult decisions for the benefit of developing an RCO that maintains a plate scale infrastructure and the opportunity for transformational science.

The Panel noted that the prioritization of the ten regional plate scale science drivers in relation to the design was not documented in the Conceptual Network Design. A ranking of the science drivers based on the transformational nature of the science would be a useful management tool to allow the RCO IO to manage budget and RCO scope.

**Recommendation**

The RCO Team should include the prioritization of the plate scale science drivers they used to meet the present Conceptual Network Design. This information will provide the RCO IO with the tools to manage budget and RCO scope. In particular, it can be used for any necessary de-scoping or up-scoping due to costs and budget.

### RCO WBS, Acquisition Plans, and Budget

**Findings**

The project Work Breakdown Structure (WBS) and WBS dictionary that defines the scope of WBS elements was presented

The project's acquisition plans including their subcontracting strategy and awards strategy associated with each level 2 WBS elements were also presented.

The project budget by WBS element and the basis of estimate for the budget components was presented.

**Comments**

The Panel notes the discussions over the balance between infrastructure and core instruments. The RSO user community appears to support the notion of limiting core instruments to maximize the funds available for the core infrastructure. It was not clear to the Panel what the policy requirements are that drove the allocations between core infrastructure and core instruments.

**Recommendation**

The balance of core instrumentation and core infrastructure should be reviewed for each of the components (RCO, GSO, CSO) of the OOI. Each component should not have to be treated the same but rather should depend on the schedule of when the facility is to be put in the water, what technology is available, and if other funding sources are available for instrumentation. MREFC funds are one-time opportunities for facilities construction so this element should be optimized. Additionally, the NSF should consider allocating R&RA funds specifically for OOI-related science and technology development to ensure the success of the $309.5M MREFC funds invested by the NSF.

**RCO Areas of Uncertainly, Project Risk Analysis, and Methodology**

**Comments**

The Panel was concerned that the issues of the ownership and the associated liability for the RCO infrastructure have not been resolved. The ultimate resolution of these issues will have a direct impact on the respondents to the RFPs for the RCO IO. The ability of the IOs to contract with industry and commence environmental permits may also hinge on the resolution of this issue.

The Panel was concerned that the current risk register for the RCO does not address the risks associated with the in-water power system. While development by MARS and NEPTUNE-Canada provides some risk mitigation, it is important to realize that (1) this power system represents a significant engineering challenge, and (2) the cost and schedule impact of random failures as well as systematic failures is very large. Examples to consider include H20 and the MARS development process. In the case of H20, the power supply was reliable in the laboratory but persistent failures occurred when the system was integrated (at-sea) with the actual in-water infrastructure. MARS continues to struggle with this problem. The power-supply risk must be considered significant until a system of multiple power supplies have been working in the water with real science loads and real power-feed transmission-line dynamics for a significant period of time.

Having the CI IO not an integral part of each component (RCO, GSO, CSO) adds complexity and risk to the OOI but in turn offers the opportunity for an integrated OOI.

There is currently no ship(s) allocated for the RCO. The RCO installation will require 280 days of ship time and the operations and maintenance is estimated to require 170 days of ship time per year (158 with ROV).

**Recommendations**

1. The issue of who will own the infrastructure and assume the associated liability must be determined before the selection of the RCO IO.

2. The RCO Risk Register should be amended to include the risks associated with the power system.

3. A plan needs to be developed to insure that the needed ships are available to perform the required RCO work.

**Contingency**

The RCO has included contingency in their budgets for the MREFC and Operations and Maintenance. The RCO IO will need to issue an RFP to industry for a large subcontract to build and install the RCO infrastructure. The RCO IO will be responsible for this subcontract and needs contingency funds to adequately manage the project.

**Recommendation**

It may be advantageous for the IOs to have some modest contingency funds in addition to the centrally managed contingency funds that they can manage directly as needed for their elements of the project.

**RCO Work Package Prioritization, Scope Contingency and Project Organizational Structure**

**Comments**

The Panel was unclear on a number of the project organization structures and relationships, between the various IOs, between the system engineering function at JOI and the various IOs, between Stage I (NEPTUNE Canada) and Stage II of the RCO.

The RCO CND includes a cable that is used jointly by both the RCO and CSO. The responsibilities and funding for this jointly used portion of the facility need to be clearly defined.

The RCO generates a number of issues related to national security. Currently these are addressed at the USN/NSF level through an MOU and associated meetings. The project organizational structure and the operational structure of the resulting RCO must ensure that this “Department to Department” structure remains intact or that a structure agreeable to the USN is clearly defined.

A change in the economic environment for the telecomm industry may significantly increase the cost of cable for the RCO at the time supplies are purchased. If so, the RSO infrastructure may need to be de-scoped to remain within budget.

It should be noted that there was not an existing RCO user community at the start of the OOI. The “disruptive technology” nature of the RCO will require continued effort on the part of the RCO team to generate, nurture and grow a healthy and supportive user community.

It is recognized that an OOI community is relatively new and that the IOs, JOI, and NSF need to ready the community – scientists, engineers, reviewers, and the general public – for multi-observatory science and technology development as well as education.

There appears to be little if any outreach by NSF to other funding agencies to leverage the OOI facilities.

**Recommendations**

1. The organizational structure for the OOI including the relationships between NSF, JOI and the IOs should be clearly defined before the award of the IOs. In addition, a strong project manager that is intimately knowledgeable about all OOI components needs to lead the overall OI project management. This project manager would work closely with all IO project managers. The relationship, communications, and responsibilities between Stage I and Stage II of the RCO need to be clearly defined.

2. The RCO/CSO interface agreement should include a clear division of the build and O&M responsibilities and funding sources for the shared cable.

3. The NSF/JOI/IO project structure and OOI Concept of Operations (CONOPS) should be structured to maintain the existing USN/NSF process or clearly define a new structure for dealing with national security related issues.

4. The RSO IO should keep the scientific research community involved in the evolution of the RSO project in case hard decisions need to be made on the RCO infrastructure scope.

5. The RCO PEP should identify resources to entrain and grow the RCO user community

6. A large public relations campaign should be launched by the NSF to entrain the broader community (scientists, engineers, reviewers, and the general public) so that they will understand it and take advantage of the OOI. NSF should setup OOI-specific review panels to review science and technology development proposals. NSF also needs to fund science and technology developments *before* the OOI is installed so that it is ready for the OOI.

7. The NSF should partner with other federal agencies – NASA, ONR, NOAA, the Navy, DOE, etc. – to leverage the use of OOI facilities and bring more funds to the table for infrastructure and instrumentation.

**RCO Permitting Issues**

**Comment**

The Panel noted that the issue of the ownership of the RCO infrastructure may have a direct impact on the ability of the RCO IO to get the required permits to land the cable.

**Recommendation**

The ownership issue associated with the OOI infrastructure needs to be determined so as not to adversely affect the issuance of cable landing and environmental permits.

## 5. Global Scale Observatory

### Science Requirements and Infrastructure Design

**Findings**

More than fifteen years of community planning have led to creation of the OOI Science Plan to advance our understanding of ocean and Earth processes, and their interactions. This will provide a continuous, interactive presence in the oceans with high temporal resolution, especially to measure episodic events or dynamic systems with small-scale components whose characteristics change over time periods longer than a few months. It includes the needed infrastructure for investigation at the time and length scale(s) of relevance to the science questions under study, including high vertical resolution from the sea surface to the sea floor along with adaptive sampling that allows targeted science campaigns in response to detected episodic events. The deployed systems will have the payload capacity to field diverse, multidisciplinary sensing systems

At the highest level, OOI requirements include interoperability, expandability, upgradeability, and life cycle cost effectiveness. Some of the systems need to occupy sites for twenty-five years. The system design must be open and provide adequate user support services along with supporting event detection and adaptive sampling.

The high level GSO requirements include the provision of the technology needed to enable an international global network of open-ocean observatories to address global-scale science questions. To be effective it must provide two-way communication and near real-time data telemetry from sites in the open ocean; and, where required by the Science User Requirements (SUR), provide power to a seafloor junction box. It must establish and sustain cutting edge, high capability observatories at key sites that in synergy with other sampling methods advance the ocean sciences. To do this, new technology for occupying sites at high latitudes, especially in the Southern Ocean, where few observations are currently available must be developed. This will require powered high-latitude moorings.

The original DEOS Workshops identified areas of scientific interest and advances in research, which could be furthered by global observatory systems. The RFA process identified installation locations for multidisciplinary and high priority science. The D&I Workshop then helped prioritize the installation locations, and instrument suites desired for each location. The CND then captured the highest priority science within budget constraints. The SUR summarizes the high level science requirements and the requirements flow-down from numerous reports and workshops.

**Comments**

The Global team has done a good job in prioritizing the observing system investments relative to the science objectives. Each of the sites has detailed specifications that address the science objectives. The priority scheme documented in the Global CND provides flexibility in system implementation as the budget and actual costs are finalized. There are provisions for both decreased and increased funding levels that are based on clear scientific needs and requirements. The priority scheme provides a good road map for expanding or reducing the scope of the Global Observatory as funding permits.

A high risk is identified with the Southern Ocean spar buoy. The costs estimated for this site (initial cost and O&M costs) could be significantly different from the present estimate due to the developmental aspect of the spar system and the harsh weather conditions at the site. A buoy design study is under consideration for funding by the NSF and the study needs to be completed as soon as possible. However, it may not be completed prior to the OOI Preliminary Design Review. The Southern Ocean A4 site is a high priority site and should be occupied, but the infrastructure cost needs to be weighed against the science objectives for the site and for the entire global observatory. Any buoy design that allows successful occupation of the Southern Ocean A4 site will be transformative.

The Blue Ribbon review recommended that the "OOI CND be enhanced to include the unique capabilities provided by mobile assets and that a resource allocation restructuring is made to accommodate the costs of these AUVs, gliders and other mobile research platforms." This Panel concurs. The preliminary design review may wish to consider the advantages and costs of including gliders or other mobile platforms to enhance the capabilities at other high priority sites in addition to the site presently envision for the Global Pioneer Array.

**Recommendations**

1. Implementation of the Southern Ocean site should take into account the balance between science achieved and cost. If the present cost estimates still represent a high risk at the time of the preliminary design review, the review may wish to consider options for this sight so that selection of the most appropriate option could be made after a more detailed buoy design study is completed.

2. If funding allows, the preliminary design review may wish to consider adding meso scale arrays, including mobile platforms, at other high priority global sites in addition to the single site presently envisioned for the Global Pioneer Array.

**Science User Requirements and the Global Scale Observatory**

**Findings**

The OOI research objectives are closely linked to the science user requirements (SURs) since the OOI research objectives were derived from extensive community involvement. This involvement consisted of the DEOS and D&I Workshops, as well as RFA process. In the end. individual SUR satisfaction will depend on final design and resultant fiscal constraints.

**Comments**

The Global Observatory has been re-scoped. Some of the OOI education and research objectives may not be fully achieved unless all available data are utilized and assimilated into models including data beyond those being collected by the OOI infrastructure per se. The Integrated Ocean Observing System (IOOS), the U.S. contribution to the Global Ocean Observing System (GOOS), is deploying significant global and coastal assets to deliver ocean data in real time. This data can be used in combination with OOI data to advance the science objectives, and to extend the OOI to achieve truly global coverage.

Conversely, the OOI observatories will provide a significant contribution to the sustained Global Ocean Observing System and observations taken at the OOI sites will be important to the operational community as well as the research community.

IOOS can, in essence, provide a fourth (virtual) observatory to the OOI system, at marginal cost to the OOI. Although the Project Execution Plan mentions IOOS, the "plan" for coordinating with IOOS is not clear. Planning for coordinating with IOOS needs to be more prominent and explicit.

"Data vocabulary inter-operability across disciplines" is identified by Cyber Infrastructure as a high risk item for OOI. This same problem is facing IOOS. Many inter-operability problems are common to both OOI and IOOS. OOI and IOOS need to work together on this so that a single interoperability solution is achieved for both and not two separate solutions.

Also, a moderate risk for OOI is "interfacing with external organizations & resources." Not only will OOI researchers gain from the additional observations taken by IOOS, but also the oceanographic and marine meteorology observations taken at the OOI sites will be important to the operational community, if made available in standard international data formats.

The Blue Ribbon review noted: "the statement in the first paragraph that [OOI] will deliver data in near-real time to a scientist's desktop from almost anywhere in the world's oceans is not true. The global component has scaled down tremendously, and there are very large areas that will not be covered." By including IOOS in the OOI architecture, OOI will be able to deliver real-time data from almost anywhere in the world's oceans.

**Recommendations**

1. Both OOI and IOOS have much to gain by sharing data and both need to establish a common strategy for combining OOI and IOOS data streams. This task needs to be included in the conceptual/preliminary design process.

2. The cyber infrastructure should ensure that a subset of the OOI data stream is maintained with WMO/IOC formats and standards for international distribution to operational (and research) institutions.

**GSO Cost and Schedule**

**Findings**

The schedule for the Global Observatory appears to be determined by the funding requirements of the RSO within the overall funding envelope.

The cost estimate is organized and reported by WBS with contingency managed by OOI Project Office. The cost estimate includes core instruments. Cost estimates were developed for each of the nine high-priority global sites, a moveable Pioneer Array, and an acoustic source mooring off Hawaii. The estimates include costs for hard goods, labor, installation and annual maintenance. Capital costs were estimated from hardware lists using published prices or industry cost analogies. Hardware includes buoys, buoy payloads, moorings, subsurface mooring hardware, etc.

Labor costs are estimated from experience with similar systems using standard salary rates. The installation costs are estimates from experience and include crew, mobilization/demobilization, global or intermediate class vessels depending on site location and activities. Annual operations and maintenance costs include operations staff, shore facility support, telemetry charges, and spares.

The annual servicing cruises to support the Global Observatory will significantly impact UNOLS scheduling. The cost estimate details were summarized in Excel tables.

**Comments**

The cost estimates are reasonable, and for the acoustically and EOM cable linked systems the estimates are based on experience and prototypes. The risk associated with the Southern Ocean (A4) site is discussed above. The cost for the enhanced meso scale arrays, suggested above, has not been estimated.

The Global Observatory is particularly dependent on ship support costs. The installation and O&M costs for ship support may be under-budgeted, especially due to increasing oil prices. The cost estimates for ship support of the Global Observatory assume one turn-around cruise per year and assume present day-rates for ship support. The day-rates are highly dependent on oil prices and may fluctuate considerably over the lifetime of the OOI. No emergency maintenance cruises are budgeted. The Global Observatory systems will be designed for one-year unattended operation between maintenance visits. There is, however, the possibility of gaps in the real time transmissions if a system failure occurs between maintenance cruises; all data will be recorded on board for delayed mode recovery.

The present spending profile calls for a major expenditure in year six. It might be more appropriate to flatten the profile over the life of the OOI. This would allow an earlier deployment of the Global Observatory

**Recommendation**

1. Optimal phasing of the Global Observatory spend plan needs to be examined in light of need for prototyping and the testing of challenging new technology systems and considering that good progress with Global Observatory can be achieved early-on by rapid deployment of some of the simpler systems.

2. If installing meso-scale arrays at additional high priority sites is to be considered, the costs need to be estimated.

**GSO R&D Needs**

The GSO uses many elements of well-understood buoy design. However, the GSO buoys will need to be designed to provide an optimum sampling platform for sensors from diverse disciplines, thus requiring attention to flow disturbance, shadowing, RF and engine exhaust contamination, and other issues. Novel engineering designs will be needed to construct the high-latitude powered spar buoys. Significant engineering development will be required along with the consideration of deployment and recovery strategies.

The GSO IO will identify any specific R&D needs and provide a plan for appropriate development and testing along with an engineering risk assessment of expected additional funds required should the technology schedule slip

Sensor technology may also require R&D to handle the long-term, in-situ measurements that the OOI will enable. Sensors will not delay the deployment of the OOI and more capable sensors will be deployed when they have necessary reliability. The R&D for sensors will be accomplished by collaboration with sensor suppliers, by individual PI's, and for the core sensors by the responsible IO as designated in interface agreements. The capabilities that sensors will require include reliability, non-cascading failure modes, low power consumption, ability to hold calibration or self-calibrate, survivability in severe environments, unattended operation, interfaces to the cyber infrastructure along with resistance to or methods to mitigate bio-fouling and the ability to operate unattended for one year. An OOI-wide instrument qualification and acceptance process is envisioned.

Enhanced mobile platform technologies, including AUV's, gliders, and drifters, may require additional R&D to provide a reliable docking system and appropriate endurance. The OOI infrastructure is being designed to provide power and data services to such docking systems should they be developed, however docking systems will not delay deployment of the OOI.

There is a strong community desire for a standardized instrument interface across platforms. R&D efforts are likely required to facilitate development of a standard instrument interface. OOI will leverage the experiences of the MBARI "smart network" sensor puck, NEPTUNE SIIM, and ROADNet project during the interface definition process.

**Comments**

Alternative approaches to diesel fuel generators, particularly at the Southern Ocean site, might provide significant advantages. For example, wind power and wave power might be appropriate. Other alternative sensor and infrastructure technologies could reduce operations and maintenance costs as well. Other alternative logistics planning could also reduce O&M costs. Advances in sensor technology, especially in hostile environments, are critical to achieving the long range science goals of the OOI.

**Recommendation**

Sensor development programs within NSF should encourage power generation and sensor development for hostile environments, and the OOI management structure should be proactive in finding and adopting successful new technologies.

## 6. Cyber Infrastructure

**Findings**

The Cyber Infrastructure (CI) IO will consist of the computational resources (software and hardware) needed to acquire, control, process, archive, and distribute the diversity of streaming data from the Coastal, Regional Cabled, and Global observatories, on a continuous basis and in a manner that enables interactive access and control of the OOI resources. The CI Plan is relatively new compared to the other portions of the OOI and will need further development as the science and operational requirements of the observatories evolve for the PDR. The CI IO schedule is for the most part realistic and attainable. The CI IO staffing level is for the most part adequate. The risk analysis in general is sound. And finally, the CI architecture as described has the potential to address user requirements.

**Comments**

Much of the CI IO plan is well thought out and is both forward thinking and practical. The architecture is sound, based on modern techniques, and ones that will help the OOI to be robust and with the ability to evolve as new needs arise.

CI IO technology and instrument technology in the observatories are rapidly changing with many components now becoming commercially available. As a result a budget and planning review process is necessary to frequently reset the CI IO objectives and organization to take into account the rapidly increasing capabilities both in processing and in data storage and management.

The success of the OOI CI IO will depend on successful implementation and refinement of these processes during the construction phase. There may be a need to adjust staffing to ensure greater domain scientist and IO involvement in design processes. For the OOI as a whole the cross-observatory questions are the least well formulated and detailed. For this reason the Panel anticipates that it will be difficult to specify the CI IO requirements to support this integrated use. The proposed centralized control of observatories is based on assumptions and has the potential to misinterpreted by the CI IO. A careful user and role analysis will be required to avoid difficulties in this area. The current design documentation does not categorize the users nor how the design satisfies the requirements of each type of user.

Protocols on how to bring experiments on-line and manage them as well as to train sensors in a new or exceptional situation needs to be very specific, and needs to involve the related scientific community, engineering and CI.

Surprisingly, this review was the first time CI was discussed in detail with the other components of OOI. The NSF or JOI should consider funding a detailed functional prototype design and development of CI in a process that would engage domain scientists and observatory engineering teams.

The Panel is quite concerned that the oversight organization must be capable of analyzing and responding to proposals for the IO for CI given the current very conceptual view of CI. One potential risk is finding the expertise in the program office to oversee CI IO activities (QA/QC, Instrument control architecture, etc.) and make sure that it fits with the community's science and operational goals.

**Recommendations**

1. The Panel suggests strongly that processes be designed before the PDR that will integrate domain scientists and marine observatory personnel into the detailed design process on an ongoing basis and throughout the projects lifetime. It is essential that domain scientists and observatory technical staff be embedded in the CI IO planning process; and similarly it is essential that CI planners be embedded in the higher level OOI organization, so that there is sufficient understanding of the CI and its design process at all levels. Integration of this sort is essential particularly in order to meet two of the points called out above:

a.) Data management issues related to the collection, quality control, and storage of data from the OOI network: Quality control in particular requires the integration of domain knowledge understanding of instrumentation, measurement, and analysis, combined with knowledge of the techniques applicable to building appropriate tools.

b.) A description of tests planned to ensure that the cyber-infrastructure system meets its desired performance capabilities: Testing and performance are also very sensitive to the manner in which the data will be used. Precision, spatial and temporal resolution, latency, etc., often represent tradeoffs, which should be made in the context of specific science drivers.

2. To the extent there are weaknesses in the current CI IO plan (see above), the corresponding funding, staffing, and scheduling estimates are also in question. The OOI planning group can and should design processes to address these concerns in time for review at the PDR, and to make appropriate adjustments to their cost estimates.

3. If possible, in preparation for the PDR the CI IO planning group should work directly with the IOs to clarify design, implementation, operation, and financial responsibility for all CI and Embedded CI components of the OOI. An additional level of detail will be needed wrt the Instrument control, QA/QC, (e.g., work items 33-35, 96-109, 136-142) in order to properly evaluate the plan and readiness.

4. The plan should address what functionality will be implemented as part of the very first instantiation of the OOI, and what functions might be added later. For example, while basic measurement collection will clearly be part of the base operation of each of the IOs, at what stage will instrument control and actuation be realized. Similarly, some of the sensor types planned for the long term are not yet available. Which specific sensor types will be included in the original construction phase.

5. The measures of success for supporting cross-observatory investigations should be articulated to an extent that the CI IO will be able to lay out their success criteria as asked by the CDR design. For the PDR, the plan and/or associated reports should make clear

how the CI IO will take action on integrating the domain scientists and slowly triggering cultural shift in the way ocean science is conducted. One approach would be to show the connection with the E&PA components within the 3 observatories.

6. A recommended addition to the risk analysis is the policy governance issues and how the inadequacy of the current state of the art would effect the project execution.

7. The CI IO must interact closely with all other IOs. A user and role analysis should be carried out. Funds should be allocated specifically for FTEs that provide this close coordination.

8. Protocols for how to bring experiments on-line and manage tthem as well as to train sensors in new or exceptional situations, needs to be added as an explicit item in the CI IO design.

9. The interaction and interfaces that depend on the knowledge infrastructure should be concretely defined with an example. The Panel recommends instrument and data calibration issues are a good example to follow up as an example to the process.

10. Given the concern that the oversight organization must be capable of analyzing and responding to proposals for the CI IO, the team responsible for preparing the CI portion of the CDR could be engaged in specifying the qualifications of such a person.

11. CI has a large role to play with the outreach and education program. The Panel recommends that JOI and NSF specify some of the CI IO budget to enable "grids for kids", or some equivalent, to allow students access to the data sets and possibly some instrument access.

## 7. Education and Public Awareness

### Findings

In the MREFC budget, five million dollars has been allocated for education and public awareness (EPA). However, there has been some confusion regarding what those dollars can fund. As a result planning has been divided into developing both strategic and implementation plans. An EPA Committee has met twice and, based on the understanding at that time regarding allowable MREFC EPA costs, drafted a strategic plan that adequately describes educational needs, outlines broad program goals, lists potential partners, and makes recommendations for program management. The management structure includes a national education manager housed within the ORION Project Office; the Education and Communication Committee Office (ECCO), a competitively-bid national facility overseen by the manager; an observatory-based educator suggested as an in-kind contribution; two national councils and an external advisory committee. Without the implementation plan (to be developed this fall), the Panel is unable to comment on program plans, activities, products or the cost and implementation schedule for education and outreach infrastructure.

**Comments**

The nature of this project and the science are particularly compelling to support transformational education programs. Also, it provides an excellent opportunity to make deliberate efforts to increase the diversity of the oceanographic research community. Taking advantage of the observatories and CI infrastructure will enable new, exciting formal and informal activities that bring different audiences into the scientific community. EPA will need staff and resources such as education-specific communication channels and dedicated time on instruments on remote vehicles or moorings.

The strong commitment to education and public awareness that the project espouses does not show up as support for necessary staffing levels or M&S support. It is unrealistic to expect one person in the ORION Program Office to manage a program of the scope proposed. More realistic would be core staffing of 2.5 FTEs, one to handle general program administrative tasks, one to provide program leadership and part-time support staff. To the Panel, the EPA management feels cumbersome, and the risk for failure appears high. Currently, management is located in the Project Office, the ECCO, the science IOs and *hopefully* the CI IO. The director who is located in the Project Office appears to have no real authority to lead and manage the program in part because he or she has no budget. Evidence of the potential problems created by this situation shows up in a strategic plan that is written to be least restrictive, because the program is so highly-leveraged. The director has no say in the knowledge and skills needed for the various education positions. For example, there is no guarantee that the DTAVs hired by the CI IO will be interested in education, and there is no way to ensure that the education management team has the expertise to support formal and informal education and public awareness programs.

EPAC is aware of potential earth-sciences collaborators, including those from education networks with distributed geographic locations, function/thematic education groups and coordinating groups. While developing the implementation plan, it would be wise to look beyond the usual partners to learn from programs where a national office has supported flexible, distributed program implementation. Examples from astronomy (Hands-on Universe) and high-energy physics (QuarkNet) come to mind.

The current strategic plan would be strengthened with a few critical and clarifying elements. Critical to present are an EPA program vision that describes a unique, transformation program of science education and a determination of risks inherent in the highly-leveraged management and funding plans. Also identify the intended contents of the implementation plan components, clarify that the necessary skills and abilities identified in Appendix 5.2 are for the IO education *effort* rather than an *individual* and mention the opportunity EPA programs have to *contribute to* CI design as well as the potential for education to leverage resources from CI.

**Recommendations**

1. JOI should take advantage of this significant investment in oceanographic research capability to make a deliberate effort to increase the diversity of the oceanographic community.

2. JOI should figure out how to set up and fund a core EPA program management structure that enables the national office to manage a highly-leveraged system and produce a coherent, coordinated program that will have a significant impact. The Panel considers a reasonable target would include a staff of 2.5 FTE and a budget of ~1-2% of the total OOI annual operating budget.

3. EPAC should revise the strategic plan based on the most recent understanding of allowable MREFC costs to support EPA planning and capital investment.

4. EPAC should look beyond the current list of potential collaborators to exemplars in other scientific disciplines for model programs and best practices.

## 8. OOI Operation and Maintenance

### Findings

### a. Coastal Scale Observatory

The approach to developing O&M estimates for the West Coast arrays is thorough and complete. The effort includes adequate organization, cost categorization, level of detail associated with cost categories and site revisit assumptions in order to develop a sound estimate. The approach to developing O&M estimates for the South Atlantic Byte and Pioneer arrays are suitable for conceptual review planning, but are less detailed than those used for other portions of the OOI. Again, the estimates are sound with primary risk areas being in the proposed ship time requirements and the number of personnel required to man each facility's operations and maintenance teams; these areas comprise approximately 20% of the annual budget.

The factors used in estimating ship costs for the West Coast arrays are reasonable, but there is risk associated with variability in ship usage rates and fuel costs that could impact cost per day of individual ships and degraded these estimates. The ship costs for SAB and Pioneer arrays were not detailed so assumptions and planning rates are unknown.

There is risk associated with the planned replacement cost budgeted for gliders due to the uncertainty associated with loss rates. The estimate is reasonable, but the loss rate varies significantly and can impact cost associated with this category.

The projected total annual O&M budget (~$15.9M) reflects ballpark historical experience relating annual O&M to total infrastructure costs.

### b. Regional Cabled Observatory

The approach to developing O&M estimates for the Regional Cable Observatory is suitable for conceptual review planning, but less detailed than used for other portions of the OOI. Estimates appear sound with primary risk areas in the areas of instrument maintenance/calibration/replacement and shore station, rights of way rent and backhaul charges. These areas were estimated without supporting details and in total comprise approximately 12% of the annual budget.

Primary risk areas are areas in which there is little data from which to extrapolate since cabled observatories in the deep ocean are relatively new. Much will be learned from MBARI's experience following MARS installation.

The factors used in estimating ship costs, which comprise a 40% of the O&M budget, are thorough and reasonable.

There is risk associated with the planned replacement cost budgeted for gliders due to the uncertainty associated with loss rates. The estimate is reasonable, but the loss rate can vary significantly which can impact cost associated with this category.

The projected total annual O&M budget (~$20.1M) is lower than ballpark historical experience relating annual O&M to total infrastructure costs would indicate.

**c. Global Scale Observatory**

The approach to developing O&M estimates is thorough and complete. The effort includes adequate organization, cost categorization, level of detail associated with cost categories and site revisit assumptions in order to develop a sound estimate. The factors used in estimating cost of replacement parts are reasonable. While the factors used in estimating ship costs are reasonable, there is risk associated with variability in ship usage rates and fuel costs that could impact cost per day of individual ships and degrade these estimates.

There is risk associated with the planned replacement cost budgeted for sensors due to the uncertainty associated with loss of gliders. The estimate is reasonable, but the glider loss rate can vary significantly which can impact cost associated with this category.

The projected total annual O&M budget (~$18M) reflects ballpark historical experience relating annual O&M to total infrastructure costs.

**d. Cyber Infrastructure**

The approach to developing O&M estimates for the cyber infrastructure is reasonably detailed and totally suitable for conceptual review planning. However, the estimate was completed in the final stages of CDR preparation and will be improved with additional vetting from other CI community experts. Estimates appear sound with primary risk areas in hardware and data backbone requirements (which are not included in the estimate). These costs are ballpark estimated to be ~19% of the annual budgeted costs.

Planning rates are based on judgment as to the skill level required to perform each task and on UCSD salary tables. The estimates are felt to be reasonable, but there is some risk associated with ability to obtain required skills at planned salary rates.

The CI approach will scale as additional observatories/nodes/instruments are added to the network; growth of additional personnel to manage the network, man help desks, etc are not included in the estimate; these additional costs are estimated to be minimal.

The Panel does not have experience with which to relate the total annual O&M budget (~$7.9M) to the infrastructure investment, but the manning levels appear reasonable.

**e. Education and Public Awareness (EPA)**

The EPA team continues to receive guidance on activities that can be authorized for use with MREFC funds. The timeliness of this guidance is a hindrance to planning the educational requirements for the facility.

If education is an observatory mission, then EPA activities should be covered in annual observatory operations budgets. These budgets do not need to cover all planned EPAC activities, but should provide a steady funding stream to support core activities because the educational infrastructure cannot subsist on grants nor on goodwill within the IOs.

The EPA team needs to reside within the Observatory's program management team so that it can provide centralized coordination of EPA activities across the observatory. This is the most cost effective manner to ensure all audiences are addressed (e.g., K-12, undergraduate, graduate, museums and news media) and because education is not a major focus of the IOs, whose primary focus must necessarily be on the operations of their facilities.

**Comments**

The OOI lacks an O&M Concept of Operations (CONOPS). Such a document will enable consideration of different manners in which O&M costs may be managed via definition of individual observatories responsibilities and authorities. This will lead to consistency between observatories and higher fidelity of estimated costs associated staffing and maintenance replacements (e.g., centralized or individual observatory spares maintenance, requirement for 24/7 help response desk, etc). CONOPS will enable governance issues to be agreed upon, such as replacement and repair priorities among the individual observatories during periods when there is an O&M shortfall.

There is an opportunity for cost savings in development of centralized O&M management. These include, logistics, use of preferred vendors, contracting for commercial ship time, commonality of sensor design to simplify spares purchase and management, retention of core group of subject matter experts to repair similar instruments.

There is no place nor funding to support an Observatory Scientist – someone who will oversee the observatories performance, QA, note deficiencies or coordinate efforts across the observatories should an episodic event occur.

O&M estimates have been developed on an individual observatory basis (i.e., RCO, GSO, CSO, and CI) and do not include full funding to replace high priority observatory sensors that may be lost due to environmental factors. Should a high priority sensor be lost, ORION may not wish to wait a year or more to replace it as would be required based solely on individual observatory planned revisit schedule.

There is no plan to transition from development to operations. The intersection between development and operations within the observatory's lifecycle needs to be understood so that O&M staffing plan can be developed and executed. This level of planning will not only ensure that the right number of people will be budgeted and hired, but will also enable the CI IO to understand its long-term staffing requirements to enable hiring of people with OOI development experience for O&M activities as most of the CI development team may not be required after the major development effort concludes.

Program level oversight of education and outreach is critical to ensure the observatory is reaching all audiences (K-12, undergraduate, graduate, museums and national news media).

**Recommendations**

1. Develop an overarching O&M plan that integrates activities from all observatories into a consolidated "ORION Observatory" Operations and Maintenance plan that allows the overall observatory to access economies of scale in acquisitions, minimize O&M costs over the lifetime of the observatory via consolidated spares management, enables IOs to understand and plan for their specific responsibilities, establishes a governance environment that addresses planning and execution needs over a continuing basis and provides a mechanism to develop and spread "Best Practices" across all observatories.

2. Include positions for an observatory scientist and education manager in the annual operations budget.

3. The Orion Observatory (JOI, Implementing Organizations) should work directly with the Vessel Facility program managers at NSF, ONR, and NOAA and the UNOLS Office in defining and refining UNOLS ship time and costs as the OOI project moves from Conceptual to Preliminary Design.

## Appendix A. Charge to the OOI CDR Review Panel

# Charge to the Ocean Observatories Initiative Conceptual Design Review Panel

**August 14-17**
**Monterey Bay Aquarium Research Institute**
**Moss Landing, CA**

The NSF requests that the OOI Conceptual Design Review (CDR) Panel review the progress of planning for the Ocean Observatories Initiative (OOI) project. This review will be held at the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, CA from August 14-17, 2006. This location has been chosen to provide panelists with the ability to see, firsthand, state of the art sensors, instrumentation, and platforms that are central to OOI infrastructure planning.

The OOI CDR is intended to review the scope and system level implementation plans for the OOI, including management plans and budgeting, and determine whether all major risks with this project have been identified and whether appropriate initial system development specifications (performance requirements, major system components, and interfaces) have been established for each sub-element of the OOI. The CDR Panel will review elements of the initial OOI Project Execution Plan (PEP) and the project's plans for further development of the OOI to the Preliminary Design phase of project maturity. Following the review, Panelists are asked to write a report describing their findings, an assessment of progress, and recommendations for the future to ensure that this project is constructed on time and within established budgets. The Panel's summary findings will be provided to NSF and to the PI's at the close of the review on August 17th.

NSF asks that the Panel assess the appropriateness of the OOI PEP, and in particular the adequacy of the following essential elements of the OOI Network Design:

- Scientific and operational requirements
- Project Work Breakdown Structure (WBS) and WBS dictionary that defines the scope of WBS elements
- Acquisition plans, subcontracting strategy and awards associated with each level 2 WBS element
- Project budget by WBS element and basis of estimate for budget components
- Project schedule and a plan to estimate resource loading
- Areas of uncertainly, project risk analysis, and methodology
- Contingency budget, method for calculating contingency, NSF management reserve
- Work package prioritization and scope contingency

The Panel is also asked to assess the sufficiency and suitability of the following project implementation activities:

- Project organizational structure
- Processes for OOI documentation management and configuration control
- Project technical and financial status reporting, Project Management Control System, and financial controls

- Internal and institutional oversight, advisory committees, and plans for building and maintaining effective relations with the research community that will use the OOI to conduct research
- Quality Control and Quality Assurance plans for components of the OOI
- Environmental assessments and permitting related to implementation of the OOI
- Systems integration, testing, acceptance, commissioning, and operational readiness criteria for all components of the OOI
- Plans for transitioning OOI assets to operational status
- Estimates for the operations and maintenance phase of the OOI

Once the Panel is established, the OOI Program Manager will work with the Panel to identify in advance specific questions and areas of concern related to the conceptual design of the OOI and its oversight and planning. These questions, in addition to those below, will serve to focus the review on the areas of most critical concern.

**OOI CDR Schedule:**

All review materials must be made available to NSF for distribution to the review panel by July 17th, 2006. An afternoon on either Day 2 or 3 will be dedicated to demonstrations observatory elements likely to be integral to OOI infrastructure.

Day 1 - Plenary session designed to orient the review panel and NSF staff to progress on high level activities related to OOI science, engineering, and management by the project staff and associated experts. Review of management issues. At the end of the day the panel will present concerns to the project team to be addressed at the start of day 2. After this presentation, the breakout groups will meet with Project leads for Level-2 WBS elements to coordinate for breakout sessions on Day 2.

Day 2 - Break out sessions will review specific OOI WBS elements. At the end of the day the panel will present concerns to the project team to be addressed at the start of day. There will be a site tour of facilities and activities related to OOI on the second day.

Day 3 - Breakout sessions continue in the morning. Meet in plenary at the end of the day to address any lingering questions of the Panel.

Day 4 – Review Panel drafts CDR report and presents a summary of the report findings to the project team at a closeout session.

**The OOI CDR Review report** will respond to each section of the charge. NSF requests that the report be completed in draft form within two weeks following the review and submitted to NSF through the OOI Program Manager.

# Ocean Observatories Initiative
# Questions, Issues, and Concerns

## Conceptual Design Review Panel

**August 14-17**
**Monterey Bay Aquarium Research Institute**
**Moss Landing, CA**

### **Project Management and System Integration Issues** (WBS Elements 1.1, 1.2, 1.7)

- To what extent have the scientific and technical requirements for the OOI been defined, documented, and coordinated with the scientific community? Has the project team appropriately consulted with the user community during development of the conceptual phase plan?
- Does the Work Breakdown Structure (WBS) define the scope of the OOI implementation effort and does the WBS dictionary describe the effort expected for each WBS element?
- Does the WBS identify the costs allocated for each WBS element associated with program management and systems integration and are the bases for these costs clear and reasonable?
- Has a clear schedule been developed for OOI implementation that identifies the critical path for the project as a whole? Does this schedule take into account the phased implementation of OOI components as well as their integration and transition to operations?
- Are the management capabilities and qualifications of senior personnel supervising OOI planning including an evaluation of whether the Project Office team is sufficient to direct the project? Is the project office organizational structure, as well as current and future plans for staffing levels, sufficient to move the project into the Implementation and Operational phases? Are roles and responsibilities between key positions suitably defined? Have key management and staff positions been filled and are sufficient resources assigned to ensure project success?
- Are the responsibilities for the design, implementation, and future operation of the system infrastructure amongst the implementing organizations defined adequately?
- Is the current ORION community advisory structure adequate to continue to provide the ORION Project Office with advice and community input during the implementation and operations phases or are changes needed?
- Is progress being made in the development of a Project Management Control System (PMCS) that will enable development of a resource-loaded schedule by completion of the Preliminary Design Phase? Are appropriate financial tracking and accounting systems currently in place in the ORION Project Office?
- Are plans in place for establishing and maintaining a Document Control System?

- Are appropriate project governance controls being utilized within the ORION Project Office including configuration management and change controls? How will these controls be implemented between the Project Office and the Implementing Organizations?
- Has the approach for systems integration, testing, acceptance, and commissioning of OOI assets been clearly defined?
- Has the project team adequately described strategies that will be used when awarding major procurements, subawards, and subcontracts? Has the ORION Project Office described how it will oversee subcontractor and Implementing Organization activities to ensure that these activities remain within their intended scope and budget as well as to ensure economies of cost and interoperability among all components?
- Has a systematic risk management analysis been performed that identifies high risk and/or long lead time enabling technologies as well as other external factors, such as environmental or regulatory impacts, that may result in significant schedule delays or cost overruns during construction? Has an appropriate response strategy been implemented?
- Has the method used for contingency analysis been clearly defined and are the amounts reasonable for mitigating costs and schedule risks?
- Has scope contingency been identified and what steps have been taken to ensure that the scientific requirements of the OOI will not be compromised if scope contingency is invoked?
- Are procedures for acquiring environmental permits adequate?
- Do international and interagency partnerships exist? What is the nature of these partnerships if they do exist and how will they be managed? How will dissolution of partnerships would the project?
- Is the scope of work, budget, and schedule needed to complete the OOI Preliminary Design and prepare for the Preliminary Design Review adequately documented? Has the project team satisfactorily described the systems integration activities required to develop a preliminary design for the OOI?
- Was the plan for transition and phasing from Implementation to the Maintenance and Operation Phases, including initial estimates for annual operations and maintenance funding, and strategies for ensuring the Implementing Organizations have the capabilities needed to transition from implementation to operation well supported?
- Are estimates for the operations and maintenance costs of the OOI well supported?

## **Global, Regional, and Coastal Components of the OOI** (WBS Elements 1.4, 1.5, 1.6)

The following questions should be addressed for each of the coastal, regional, and global components of the OOI. Particular focus should be paid to whether all major risks have been identified and whether preliminary development specifications produced for each sub-element of the OOI serve the science user requirements.

- Has the project team adequately described and prioritized the high-level quantitative science requirements that motivate and flow down to the overall infrastructure design?
- Are OOI research objectives well linked to science user requirements? Are these user requirements meet by the proposed network design?

- Is the description of infrastructure needed to meet OOI's science objectives adequate, including the system-level design and definition of the functional requirements?
- Has an appropriate schedule for implementation been developed for each of the three scales of the OOI?
- Are cost estimates for infrastructure at each of the OOI scales well justified and do they encompass all aspects of implementation?
- Are there lingering elements of the OOI network that require further engineering development and has as a research and development plan been proposed that provides a roadmap to complete these efforts to ensure all elements of the system will be ready for deployment?
- Are the projected staffing levels for each Implementing Organization (IO) adequate to complete the tasks required to complete the network designs and implement them (this information will be preliminary as the RFP for the IOs will not have been awarded)?

## **OOI Cyberinfrastructure** (WBS Element 1.3)

- Are the conceptual level cost estimates for development and implementation of the OOI data management architecture in preparation for initial acquisition of data adequate?
- Is the schedule for continued development and implementation of the OOI cyberinfrastructure architecture realistic and attainable?
- Are projected staffing levels required to implement the OOI cyberinfrastructure in preparation for initial acquisition of data adequate?
- Will the OOI Cyberinfrastructure Architecture, including the network control facilities, address user requirements? These requirements include:
    - a conceptual level description of the requirements for the OOI Network Management System and an estimate of the resources needed to implement this system;
    - the expected scale of the data management system (how much data being moved, stored, and accessed);
    - inter-operability with other data systems;
    - all aspects of network security including those related to National Security;
    - data management issues related to the collection, quality control, and storage of data from the OOI network;
    - a description of tests planned to ensure that the cyberinfrastructure system meets its desired performance capabilities;
    - the ORION data policy that will guide the collection and use of data from OOI infrastructure.

## Education and Outreach

- What aspects of the OOI network architecture are specifically designed to enable education and outreach?
- What is the cost and implementation schedule for education and outreach infrastructure?

- What are the staffing levels required to implement the Education and Outreach Strategic Plan for the ORION Program including plans to integrate the E&O strategy across all components of the OOI?
- What is the implementation plan for formal and informal education activities (including curriculum development) using data collected from OOI infrastructure that will enable students and teachers to learn from and participate in ORION science?
- What are the plans for general public outreach and activities to enable "citizen science"?
- What are the expected data and visualization products for OOI/ORION education and outreach and how they will be developed and released to the public?
- What education and outreach partnerships exist or will be developed for the ORION Program?

**Appendix B. Members of the OOI CDR Review Panel and NSF Observers**

| | Name | Institution | Expertise |
|---|---|---|---|
| 1 | Altintas, Ilkay | SDSC | CYB |
| 2 | Bardeen, Marjorie | Fermi | PRS |
| 3 | Donaghy, Percy | URI/GSO | CSO |
| 4 | Estrin, Deborah | UCLA | CYB |
| 5 | Gholson, Norm | SAIC | RCO |
| 6 | Glenn, Scott | Rutgers | CSO, O&M |
| 7 | Hartill, Don | Cornell | PRS |
| 8 | Hartline, Beverly | DE State | PRS |
| 9 | Johnson, Mike | NOAA | GLO, O&M |
| 10 | Lindquist, Phil | CalTech | PRS |
| 11 | Luther, Mark | USF | CSO |
| 12 | Meldrum, De De | UW | RCO |
| 13 | Mikhalevsky, Peter | SAIC | GLO, O&M |
| 14 | Dearth, Randy | Boeing | CYB, O&M |
| 15 | Phibbs, Peter | UVic | RCO, PRS |
| 16 | Round, Adrian | UVic/VENUS | CSO, RCO |
| 17 | Sanderson, Art | RPI | CSO |
| 18 | St. Arnaud, Bill | CANARIE | CYB |
| 19 | Suchy, Al | WHOI | CSO, RCO, GLO, O&M |
| 20 | Winokur, Robert | Navy | RCO, O&M |

**Key:**

CSO – Coastal Scale Observatory
RCO – Regional Cabled Observatory
GLO – Global Scale Observatory
PRS – Program Support
CYB – Cyber-infrastructure
O&M – Operations and Maintenance

Review Team

| | | |
|---|---|---|
| **CSO**<br>Percy Donaghy<br>Scott Glenn<br>Mark Luther<br>**Art Sanderson**<br>Al Suchy | **RCO**<br>Norm Gholson<br>De De Meldrum<br>Peter Phibbs<br>**Adrian Round**<br>Al Suchy<br>Robert Winokur | **GLO**<br>**Mike Johnson**<br>Peter Mikhalevsky<br>Al Suchy |
| **CYB**<br>Ilkay Altintas<br>**Deborah Estrin**<br>Randy Dearth<br>Bill St. Arnaud | **O&M**<br>Scott Glenn<br>Peter Mikhalevsky<br>**Randy Dearth**<br>Al Suchy<br>Winokur | **PRS**<br>Marjorie Bardeen<br>Don Hartill<br>**Beverly Hartline**<br>Phil Lindquist<br>Peter Phibbs |

Program Team

| | | |
|---|---|---|
| **CSO**<br>Oscar Schofield<br>Mark Chaffey<br>Doug Luther | **RCO**<br>Deborah Kelley<br>John Delaney<br>Keith Raybould<br>Rosie Lunde | **GLO**<br>Robert Weller<br>Robert Detrick<br>Dan Frye |
| **CYB**<br>Matt Arrott<br>John Gryabeal | **O&M**<br>Kendra Daly<br>Robert Detrick<br>Keith Raybould<br>Dan Frye<br>Mark Chaffey<br>Doug Luther<br>Rosie Lunde | **PRS**<br>Stuart Williams<br>Carol Kokinda |

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# Appendix C. Agenda for the OOI Conceptual Design Review

**ORION Ocean Observatories Initiative (OOI)**
**Conceptual Design Review (CDR)**
August 14th-17th, 2006
Moss Landing, California

**DRAFT AGENDA**
**8/7/06**

<u>August 14th A.M.</u> **Monterey Bay Aquarium Research Institute**

| | | |
|---|---|---|
| 8:00–8:30 | Continental Breakfast | |
| 8:15-9:00 | ***Executive Session I*** | Pacific Forum |
| 9:00–9:15 | Welcome and Introductions (*Coles/Isern*)<br>• Meeting agenda; goals of review | Pacific Forum |
| 9:15–9:30 | OOI History & Organization (*Daly*)<br>• Priority science questions<br>• Observatory elements<br>• Conceptual Network Designs | Pacific Forum |
| 9:30–9:45 | NSF Report (*Isern*)<br>• Funding<br>• MREFC process<br>• "Blue Ribbon" review panel | Pacific Forum |
| 9:45-10:30 | OOI Network Overview (*Williams*)<br>• Implementation Management<br>• JOI Organization<br>• Risk Management | Pacific Forum |
| 10:30–10:45 | *Coffee Break* | |
| 10:45–11:00 | Coastal Scale Observatory (CSO) (*Schofield*)<br>• Science User Requirements<br>• Conceptual Design | Pacific Forum |
| 11:00-11:15 | Regional Cabled Observatory (RCO) (*Kelley*)<br>• Science User Requirements<br>• Conceptual Design | Pacific Forum |
| 11:15-11:30 | Global Scale Observatory (GSO) (*Weller*)<br>• Science User Requirements<br>• Conceptual Design | Pacific Forum |
| 11:30–11:45 | Cyberinfrastruture (*Arrott*)<br>• Requirements<br>• Conceptual Design | Pacific Forum |
| 11:45-12:30 | Program Management (*Lunde*)<br>• Project Baseline<br>• Schedule<br>• Way forward | Pacific Forum |
| 12:30–1:30 | Lunch | |

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**ORION Ocean Observatories Initiative (OOI)**
**Conceptual Design Review (CDR)**
August 14th-17th, 2006
Moss Landing, California

**DRAFT AGENDA**
**8/7/06**

August 14th P.M. **Monterey Bay Aquarium Research Institute**

| | | |
|---|---|---|
| 1:00-1:30 | ***Executive Session II (working lunch)*** | Pacific Forum |

1:30–5:30 Breakout Groups: Session I

- Program Support (*Williams/Kokinda*) — Pacific Forum
  - Management
  - OOI Network
  - Science Requirements (Daly/Detrick/Luther)
  - Education and Outreach (Matsumoto)
  - Safety and Environmental
- Cyberinfrastructure (*Arrott/Graybeal*) — Scientists
  - High level requirements
  - Conceptual Design development
  - Architecture
  - Concept of Operations
- Coastal Scale Observatory (CSO) (*Schofield/Chaffey/Luther*) — Ships View
  - Science requirements development
  - RFA process and results
  - Conceptual Network Design development
- Regional Cable Observatory (RCO) (*Kelley/Delaney/Raybould/Lunde*) — Tank View
  - Science requirements development
  - RFA process and results
  - Conceptual Network Design development
- Global Scale Observatory (GSO) (*Weller/Detrick/Frye*) — Ocean View
  - Science requirements development
  - RFA process and results
  - Conceptual Network Design development

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| 5:30-6:00 | ***Executive Session III*** | Pacific Forum |
| 6:00-7:00 | Social: Atrium of 2nd floor in Building A | |
| 7:00- | Dinner: Phil's Eatery (adjacent to MBARI) | |

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**DRAFT AGENDA**
**8/7/06**

| | | |
|---|---|---|
| August 15th | **Monterey Bay Aquarium Research Institute** | |
| 8:00-8:30 | *Continental Breakfast* | |
| 8:10-8:30 | ***Executive Session IV*** | Pacific Forum |
| 8:30-12:00 | Breakout Groups: Session II | |
| | • Program Support (*Williams/Kokinda*) | Pacific Forum |
| | • Cyberinfrastructure (*Arrott/Graybeal*) | Scientists |
| | • Coastal Scale Observatory (CSO) (*Schofield/Chaffey/Luther*) | Ships View |
| | • Regional Cable Observatory (RCO) (*Kelley/Delaney/Raybould/Lunde*) | Tank View |
| | • Global Scale Observatory (GSO) (*Weller/Detrick/Frye*) | Hadal |
| | • Operations and Maintenance (*Daly/Detrick/Raybould/Frye/Chaffey/Luther/Lunde*) | Harbor View |
| 12:00-1:30 | Lunch | |
| 12:30-1:30 | ***Executive Session V (working lunch for panel)*** | Pacific Forum |
| 1:30-5:00 | Tour of MBARI and MARS | |

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|---|---|---|
| August 16th | **Monterey Bay Aquarium Research Institute** | |
| 8:00-9:00 | *Continental Breakfast* | |
| 8:15-9:00 | ***Executive Session VI*** | Pacific Forum |
| 9:00-10:00 | Plenary: Review Comments/Questions Discussion | Pacific Forum |
| 10:00-10:15 | Coffee Break | |
| 10:15-12:00 | Breakout Groups: Session III | |
| | • Program Support (*Williams/Kokinda*) | Pacific Forum |
| | • Cyberinfrastructure (*Arrott/Graybeal*) | Scientists |
| | • Coastal Scale Observatory (CSO) (*Schofield/Chaffey/Luther*) | Harbor View |
| | • Regional Cable Observatory (RCO) (*Kelley/Delaney/Raybould/Lunde*) | Tank View |
| | • Global Scale Observatory (GSO) (*Weller/Detrick/Frye*) | Hadal |
| | • Operations and Maintenance (*Daly/Detrick/Raybould/Frye/Chaffey/Luther/Lunde*) | Ocean View |
| 12:00-1:00 | Lunch | |
| 1:00-3:00 | ***Executive Session VII: Panel discusses concerns*** | Pacific Forum |
| 3:00-5:00 | Plenary: Presentation of Panel concerns and questions | Pacific Forum |

**ORION Ocean Observatories Initiative (OOI)**
**Conceptual Design Review (CDR)**
August 14th-17th, 2006
Moss Landing, California

**DRAFT AGENDA**
**8/7/06**

| | | |
|---|---|---|
| August 17th | **Moss Landing Marine Lab** | |
| 8:00-8:30 | *Continental Breakfast* | |
| 8:10-8:30 | ***Executive Session VIII*** | Seminar Room |
| 8:30-10:15 | Plenary: Clarification of issues by program team | Seminar Room |
| 10:15-10:30 | Coffee Break | |
| ***10:30-2:00*** | ***Executive Session IX: Panel deliberations, report writing, and working lunch*** | Seminar Room |
| 12:00-1:30 | Lunch | |
| 2:00-3:00 | Plenary: Review Panel presents findings | Seminar Room |
| 3:00 | Review ends | |