AGENDA (v1: 10-11-06)
ORION STAC Meeting – October 17-19, 2006

Tuesday, Oct 17

8:00–8:30 *Continental Breakfast*

8:30-8:40 Welcome and Introductions (*Luther*)
- Brief iteration of meeting's purpose.

8:40–9:00 ORION Project Office Report (*Daly*)
- New hires.
- Status of IO solicitations & source selection process.
- JOI conflict of interest policy; impact on ORION committees.

9:00–9:30 Summary of "Blue Ribbon" review panel report & response process (*Daly*)

9:30-10:15 Summary of Conceptual Design Review recommendations & ORION office response (*Daly*)

10:15-10:45 *Coffee Break*

10:45-11:15 New boundary conditions on the OOI budget – capital and O&M (*Luther*)
- Expand scope of budget control, e.g., incorporate management, contingency, etc.

11:15-12:00 De-scoping process; meeting purpose; anticipated outcome (*Luther*)
- Non-fiscal constraints from the OSC, BRP & CDR.
- Possible de-scoping scenarios.
- What are the transformative technologies/characteristics offered by the OOI for each of its components?
- Science that ***requires*** the OOI infrastructure versus science that simply ***benefits*** from it; avoid "overselling" syndrome.
- Identify inadequacies in CND implementation of science objectives.

12:00–1:30 *Lunch*

1:30-2:30 Review of Regional Cabled Observatory component (*Kelley*)
- Technology, science, and capital and O&M costs of each major element.

2:30-3:30 Review of Global Scale Observatory component (*Send*)
- Technology, science, and capital and O&M costs of each major element.

3:30-4:00 *Coffee Break*

4:00-5:00 Review of Coastal Scale Observatory component (*Trowbridge*)
- Technology, science, and capital and O&M costs of each major element.

5:00-5:15 Wrap-up and re-evaluation of meeting plans for Wed & Thurs (*Luther*)

6:30 Dinner: Newport Bay Restaurant, 2865 NW Town Center Loop, Beaverton

Wednesday, Oct 18

8:00–8:30	*Continental Breakfast*
8:30-8:45	Charge to breakout groups (*Luther*)
8:45–10:00	Session 1 – Coastal, RCO & Global groups meet separately.
10:00–10:30	*Coffee Break*
10:30–12:00	Session 2 – Coastal, RCO & Global groups meet separately.
12:00–1:30	*Lunch*
1:30-2:00	Plenary – Discuss problems/questions that have arisen (*Luther*)
1:30–3:00	Session 3 – Coastal, RCO & Global groups meet separately.
3:00–3:30	*Coffee Break*
3:30–5:00	Session 4 – Coastal, RCO & Global groups meet separately.

Thursday, Oct 19

8:00–8:30	*Continental Breakfast*
8:30-8:40	Call to order & reiteration of morning's purpose (*Luther*)
8:40-9:40	RCO Progress Report (*Kelley*)
9:40-10:10	GSO Progress Report (*Send*)
10:10-10:30	*Coffee Break*
10:30-11:00	GSO Progress Report - continued (*Send*)
11:00-12:00	CSO Progress Report (*Trowbridge*)
12:00-12:30	Plans for the Preliminary Design Review (*Daly*) • OOI timeline.
12:30–1:30	*Lunch*

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Dear STAC!ers,

The next STAC meeting (this month) will be a working meeting (mostly), as many before have been. I!ve prepared below a synopsis of the issues, which unfortunately has grown to be somewhat lengthy. So, in a nutshell, we will need to prepare a document that contains proposals for modifying the current Conceptual Network Designs, given such new draconian constraints from NSF as a restriction that ORION!s planned Operations & Maintenance (O&M) expenses in 2013 not exceed $50M in 2013 dollars (currently, we!re at $91M in 2013 dollars), and NSF!s requirement that the $309.5M spent during FY07-FY12 is in Òas spentÓ dollars, that is, there will not be any automatic inflation adjustments (resulting in a net loss of about $50M to the current OOI plan).

The material below is organized as follows:

I. Desired STAC Meeting Outcome
II. Problem #1 Ð Reduced & Capped O&M in 2013 (Our Biggest Constraint)
III. Problem #2 Ð OOI Budget Reductions
IV. Other Boundary Conditions from the Observatory Steering Committee
V. Conceptual Design Review Panel Remarks that are Relevant to the Tasks of this Meeting
VI. Issues Relevant to the Tasks of this Meeting Derived from the ÒBlue Ribbon Review of the "OOI Scientific Objectives and Network Design! Ó
VII. Some Guidance Toward Your Solutions

I. DESIRED STAC MEETING OUTCOME

The results of our deliberations are not intended to be official re-writes of the CND!s just yet, although our recommendations may end up looking like CND!s. Rather, given the new constraints, we need to compose a document(s) that proposes changes to the CND!s that

(i) take into account the fiscal and other constraints below;
(ii) reiterate the transformative technology (both physical

projections. NASA is using 3.2%. At the OSC meeting two weeks ago, it was anecdotally mentioned that salaries are increasing at a rate of 7%/yr and ship costs at a rate of 10%/yr. Therefore, I think 5%/yr is an appropriate (and conservative) inflation rate to assume. (Note that the Moore Inflation Predictor, a respected financial industry product, expects inflation to be well within 5% for 2007. Unfortunately, they don't predict more than a year in advance.)

Assuming 5% inflation from now to 2013, the $44.4M in 2013 dollars is equivalent to $31.6M in 2006 dollars. This is all we have for O&M & IO management of the OOI infrastructure!

The current O&M cost projections (in 2006 dollars) from the CND's, plus IO management cost projections taken from the PEP (Appendix 4B), are as follows:

- CSO - $18.4M
- RCO - $22M
- GSO - $14.6M (includes top 9 priority sites only)

TOTAL = $55M (in 2006 dollars)

In other words, we have to reduce the current planned CSO, RCO & GSO O&M by 43%! (N.b., the O&M proportions above are considerably different from the capital expenditure proportions. It could be argued that RCO only needs to reduce its O&M cost by 20%, while CSO & GSO need to reduce their O&M costs by 58%.)

III. PROBLEM #2 – OOI BUDGET REDUCTIONS

Given that the $309.5M is now in "as spent" dollars, and given a 5%/yr inflation rate, and given the projected spending schedule (i.e., $13.5M, $48.0M, $77.0M, $78.0M, $53.0M, $40.0M in FY07, 08, 09, 10, 11, and 12), the $309.5M is equivalent to $258.5M in 2006 dollars (or, $249.7M if 6% inflation is assumed).

On the positive side, NSF has said that there is a good chance that we could ask for and receive as much as $350M for the OOI during its lifetime (assuming we beef up the science justification). This equates to $292.3 in 2006 dollars (or, $282.4M if 6% inflation is assumed).

THEREFORE, WE'LL BE WORKING WITH A RANGE FOR THE OOI OF
$258.5M TO $292.3M (in 2006 dollars).

We are now required by NSF and the OSC to subtract the following:

- $10M for an NSF management reserve;
- $15M for ORION Project Office, including Systems Engineering;
- $30M for CI, including contingency;
  (the scope of the CI effort will be evaluated and prioritized at the CI committee meeting scheduled for late October);
- $5M for E&O; and,
- $6M for EIR/EIS, primarily for RCO & CSO.

We are left with $192.5M to $226.3M to pay for the following:

- project management (IO), including systems engineering (PM/SE; nominally 10%);
- contingency (nominally 20%);
- surveying;
- development;
- cables, nodes;
- shore landings and stations;
- installation;
- commissioning;
- moorings, fixed platforms;
- mobile platforms;
- instrumentation, etc.

Note that this list includes items, i.e., project management/systems engineering, contingency, surveying and shore station, that previously were subtracted in blocks and were thus outside our budget considerations. These items are now brought inside for our examination, especially since we now have an example of cost estimates for an IO (i.e., the RCO IO).

Breaking down the $192.5M - $226.3M by component, using Isern's Feb 2006 budget for component ratios, results in the following:

- Coastal receives $ 45.6 M - $ 53.6 M
- RCO receives $112.0 M - $131.7 M
- Global receives - $ 34.9 M - $ 41.0 M

Be careful with these numbers. They aren't directly comparable to the $30M, $90M, and $40M for CSO, RCO, and GSO, respectively, that you're used to seeing. For example, consider RCO:

RCO - $112.0 M - $131.7 M

Previously, we would have subtracted the following:

- PM/SE (10%) $11.2 M - $13.2M
- Contingency (20%) $22.4 M - $26.3M
- Surveying $ 2.3 M
- Shore Landing $10.4 M

This leaves $65.7 M - $79.5 M **for the RCO infrastructure, compared to the $90 M we had before.**

IV. OTHE BOUNDARY CONDITIONS FROM THE OSC

- High priority must be given to new and transformative technology (both physical & CI) including interactive, real-time or near-real time connectivity.
- High priority must be given to science questions that REQUIRE this infrastructure. Explain why this science can't be accomplished with existing technology, and thus requires the OOI infrastructure. E.g., phenomena are episodic, requiring continual presence of instruments. Or, instruments require high power, making normal battery-powered deployments inadequate vis-à-vis length of deployment. Or, instruments require high bandwidth in order to achieve needed spatial and temporal resolution of variables. Or, phenomenon may vary considerably over time requiring real-time monitoring and command-and-control re-tasking of instrument sampling protocols. And so forth.
- The revised CND's must pass the test of excellence of science and transformative nature of the infrastructure as evaluated by an independent, peer review panel. (The OOI plans will be reviewed in 2007. The NSB will probably choose NAS members to review the OOI plan. Would these senior peers (e.g., people like Wunsch) give it an Excellent?)
- All three physical components of the OOI (CSO, RCO, GSO) must be retained, but the scope of these elements will have to be reduced from the current CNDs.
- High priority must be placed on minimizing life cycle costs to minimize O&M; re- evaluate the O&M cost projections in light of changes to the CND's.
- Maintain an appropriate balance between high-risk elements and lower risk elements with high probability of success.
- Maintain an appropriate balance of fixed and mobile assets to avoid either spatial or temporal aliasing.
- The minimum funding possibility requires investigation of a NE Pacific multi-scale "regional" observatory (not "regional cabled" observatory) involving global, regional-cabled and coastal components as a viable and attractive option to meet the above constraints. Other options developed by STAC that involve multiscale, coherent experiments and meet the above constraints are also welcome.

V. CONCEPTUAL DESIGN REVIEW PANEL REMARKS THAT ARE RELEVANT TO THE TASKS OF THIS MEETING

(This material has been excerpted from Kendra's re-organization and ranking of the CDR Panel's recommendations; see attached document. Kendra sent the original report to all of you on September 25.)

V.A. COASTAL:

- High Priority - 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. (And it should be explicit about which science questions REQUIRE the OOI infrastructure to be investigated, and which simply would BENEFIT from the OOI infrastructure.)
- Priority - 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.
- Priority - 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.
- Important - The RCO/CSO interface agreement should include a clear division of the build and management and O&M responsibilities as well as funding sources for the shared cable.

V.B. REGIONAL:

- Essential - 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.
- Important - The RCO/CSO interface agreement should include a clear division of the build and management and O&M responsibilities as well as funding sources for the shared cable.

V.C. GLOBAL

- Priority - The preliminary design should evaluate costs and scientific benefits of adding meso-scale arrays at additional global sites rather than the single site presently envisioned.
- Essential - 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.

- Essential - 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 or fuel cells 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.
- Important - Sufficient funding should be maintained to account for changing ship day-rates in the construction and implementation phases.

VI. ISSUES RELEVANT TO THE TASKS OF THIS MEETING DERIVED FROM THE "Blue Ribbon Review of the 'OOI Scientific Objectives and Network Design' "

(While the comments were explicitly aimed at the "OOI Scientific Objectives and Network Design" document written by the OSC, the CND's were part of the review and several of the comments are quite relevant to our revision of the CND's. Both the OSC document and the Blue Ribbon Panel review were sent to you by Kendra on September 25.))

- Siginificant - Need to enhance mobile platform capabilities. OOI planning has been a decade-long endeavor. During this time, the reliability and usability of mobile platforms, such as gliders and AUVs, have been greatly enhanced. Because of programmatic boundaries placed on the OOI and the previous lack of highly reliable mobile platforms suitable for use in an observing context, mobile assets are not well integrated into OOI network plans. Where they do appear in the CND, mobile assets are not allocated sufficient resources to provide the capabilities needed to address horizontal heterogeneities that will be present in various ocean parameters. Therefore, the panel recommends 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. **[**Oddly, this remark was directed at the Coastal program, which was being criticized for only mentioning "yesterday"'s technology, even 'though the CSO CND has plenty of AUV's and gliders.]

- Significant - Better description of the exciting science and capabilities provided by the OOI. Although the document discussed the broad utility of the OOI network, the text should radiate a clear sense of excitement. If OOI infrastructure will lead to a transformation in the way the ocean research community will operate, the document should better capture this transformation and the exciting discoveries that will result. On balance, this enthusiastic portrayal still needs to carefully avoid mismatch between OOI infrastructure capabilities, and high priority science questions.

- Additional - Plans for the coastal array should be revisited in light of needed capabilities for power and bandwidth as well as interactive capabilities provided by seafloor cables versus the more limited capabilities provided by moorings. [Bandwidth and interactivity concerns also exist for the global array.]

- Additional - The rationale for the Southern California Bight coastal array in particular should be reviewed to see if this element is really needed for the scientific questions to be addressed by the rest of the west coast array and whether a moored array is the best approach.

- Additional - The report should be candid about limitations in the OOI network as one that will provide the capability to address some questions but will not be well suited to other types of questions.

VII. SOME GUIDANCE TOWARD YOUR SOLUTIONS

- O&M must include IO management and systems engineering costs.
- Survey costs are within your purview to estimate now.
- Contingency costs are within your purview to estimate now. Consider that, in a very real sense, the priority lists of sites in the OOI CND's are a contingency plan. In other words, should cost over-runs occur at the higher priority sites, the lower priority sites can be sacrificed. There are exceptions, such as the RCO backbone and nodes, etc.
- The efficacy of core instrument purchases can be re-examined. From the CDR Panel: "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."
- RCO: delete Stage I – Stage II connection cost.

Please let me know if you have any questions.

Aloha, Doug

DRAFT

ORION - OOI Conflict-of-Interest Policy

INTRODUCTION

The objective of the conflict-of-interest (COI) policy for the Science Advisory Structure (SAS) of the ORION Program and the Ocean Observatories Initiative (OOI) is to minimize both real and perceived conflicts of interest while maintaining the involvement of knowledgeable scientists and engineers in providing scientific and technical advice to the program. The ORION/OOI SAS needs a comprehensive, effective, and, to the extent possible, flexible COI policy that takes into account the need to maintain broad community involvement in ORION/OOI, derive needed expertise and guidance from across the oceans community, and also deals effectively and forthrightly with real and perceived conflicts of interest involving members of the science community, implementing organizations (IOs), and employees and Governors and their Alternates of Joint Oceanographic Institutions, Inc. (JOI).

A conflict of interest is a situation in which the interests (for example: personal, familial, professional or commercial) of an ORION/OOI SAS member or designated alternate involved in ORION/OOI-related scientific, technical, financial or commercial activities related to the execution of the ORION and OOI Programs, have a real or perceived impact on the objectivity of advice given to the ORION/OOI Program Office concerning the policies of ORION/OOI, the scientific and technical directions of the Program, and the cost, schedule, and performance of the OOI facility. Conflict of interest depends to a limited degree on the situation and not necessarily the individual - scientific field of expertise or technical capabilities – or the individual's institutional affiliation.

Principles:

The COI policy is based on the following principles:

An individual scientist or engineer can be a voting member of only one standing SAS committee or panel.

An individual who derives any salary through funding from the ORION/OOI Program, e.g. JOI employees, ORION/OOI-funded members of implementing organizations (IOs) and their subcontractors, cannot serve as a member on SAS committees and panels.

Members of the JOI Board of Governors or their Alternates can serve as members of the Observatories Steering Committee, provided the Governor or Alternate Governor is not affiliated with an Implementing Organization for ORION/OOI.

All potential conflicts of interest will be declared at the start of every meeting, or at an otherwise appropriate time during the meeting.

Committee and panel members or other meeting attendees determined as having a conflict of interest regarding an ORION/OOI related activity should not be present when the relevant issue is considered by the committee, evaluated, and a finding recommended to the ORION/OOI Program Office.

Committee members or other meeting attendees determined as having a conflict of interest regarding ORION/OOI-related financial or commercial enterprises should not be present during discussions relevant to such financial or commercial enterprises.

CONFLICT OF INTEREST POLICY

The issues of conflict of interest have three foci: an understanding of who may serve on panels; procedures and safeguards with regard to the objectivity of advice given to the Program Office; and procedures and safeguards with regard to ORION/OOI-related financial or commercial enterprises.

Who may serve:

Any individual scientist or engineer can be a voting member of only one standing SAS committee or panel.

An individual who derives any salary through funding from the ORION/OOI Program, e.g. JOI employees, ORION/OOI-funded members of implementing organizations (IOs) and their subcontractors, cannot serve as a member on SAS committees and panels.

Members of the JOI Board of Governors or their Alternates can serve as members of the Observatories Steering Committee, provided the Governor or Alternate Governor is not affiliated with an Implementing Organization for ORION/OOI.

Definitions:

Interested Person.

Any member of the ORION/OOI SAS who has a direct or indirect disclosable interest, as defined below, is an interested person and may have a conflict of interest.

Disclosable Interest.

A person has a Disclosable Interest if the person has, directly or indirectly, through personal, business, investment, family or domestic partner:

a. an ownership or investment interest in any entity with which JOI has a transaction or arrangement;
b. a compensation arrangement with JOI as a member of an Implementing Organization or with any entity or individual with which JOI has a transaction or arrangement that relates directly to ORION/OOI;
c. a potential ownership or investment interest in, or compensation arrangement with, any entity or individual with which JOI contemplates negotiating a transaction or arrangement;

d. involvement, other than in his or her capacity as an SAS member, in any project sponsored or supported by JOI, including but not limited to:
   (1) applying for, or preparing any proposal for, any award or contract from JOI, on behalf of the organization that is a corporate member of JOI; and
   (2) evaluating any application or proposal with respect to which any organization with which the SAS member is affiliated has submitted, or is considering submitting, to JOI; or
e. involvement on behalf of any entity, other than JOI, in the preparation of any proposal, bid or application for any contract or grant in competition with JOI.

Compensation includes direct and indirect remuneration as well as gifts or favors that are substantial in nature.

A Disclosable Interest is not necessarily a conflict of interest. A person who has a Disclosable Interest may have a conflict of interest only if the appropriate Committee decides that a conflict of interest exists (see below).

Procedures and Safeguards:

1. Duty to Disclose.

An Interested Person must disclose the existence of his or her Disclosable Interest and must disclose all material facts to the Committee for the purpose of evaluating the possible conflict of interest.

2. Determining Whether a Conflict of Interest Exists.

After disclosure of the Disclosable Interest and all material facts, and after any discussion with the Interested Person, the Interested Person shall leave the Committee meeting while the determination of a conflict of interest is discussed and voted upon. The remaining Committee members shall decide if a conflict of interest exists.

3. Procedures for Addressing the Conflict of Interest.

An Interested Person may make a presentation at the Committee meeting, but after such presentation, the Interested Person shall leave the meeting during the discussion of, and the vote on, the issue or concern that results in the conflict of interest.

4. Violations of the Conflicts of Interest Policy.

a. If a member of a ORION/OOI SAS Committee has cause to believe that another committee member has failed to disclose actual or possible conflicts of interest, that member will being the matter to the Committee Chair who shall inform the committee member of the basis for such belief and afford the member an opportunity to explain the apparent failure to disclose.
b. If, after hearing the response of the member and making such further investigation as may be warranted in the circumstances, the Committee determines that the member has in fact failed to disclose an actual or possible conflict of interest, it shall take appropriate corrective action, up to and

including, recommending to the Program Office that the member be replaced on the Committee.

Records:

Any minutes of the Committee meetings shall contain:

1. The names of the persons who disclosed or otherwise were found to have a Disclosable Interest in connection with an actual or possible conflict of interest, the nature of the Disclosable Interest, any action taken to determine whether a conflict of interest was present, and the Committee's decision as to whether a conflict of interest in fact existed; and

2. The names of the persons who were present for discussions and votes.

Other procedures:

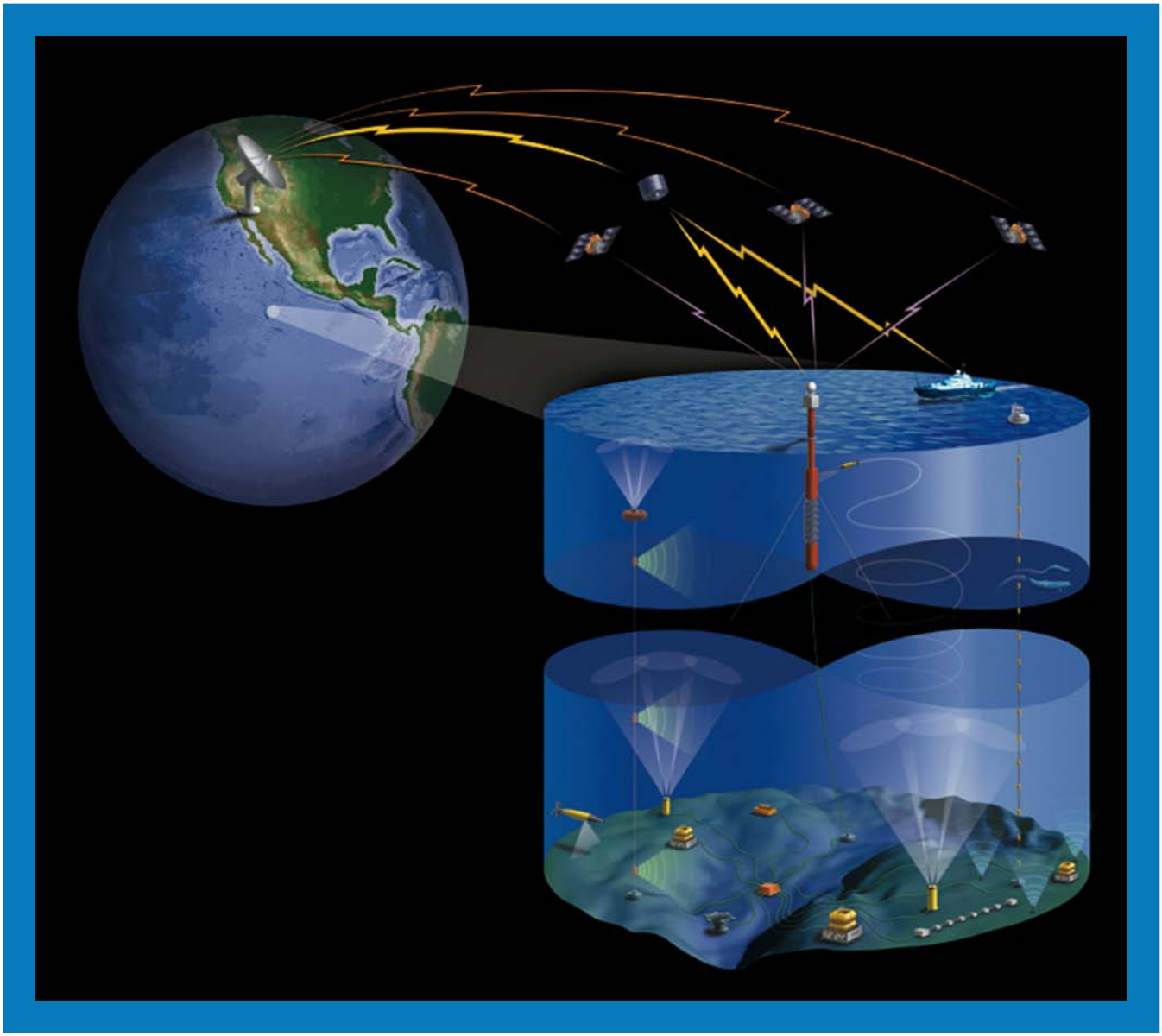
1. Members of ORION/OOI SAS committees shall not use their positions or information obtained there from to provide an unfair advantage to themselves or their employers or any other organization with which they are affiliated, with respect to matters involving ORION/OOI or JOI contracts, grants or other approvals and appointments.

2. Members shall not use information acquired by virtue of being a member of the ORION/OOI SAS to obtain private gain or gain from or for their employers or any other organizations with which they are affiliated, whether during or after their term as a member.

3. No member shall serve as principal investigator on any contract or grant issued by JOI.

4. No member shall receive any direct compensation from any award or contract granted by JOI.

Ocean Observatories Initiative (OOI)
Scientific Objectives and Network Design



July 2006

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Preface

The National Science Foundation's Ocean Observatories Initiative (OOI), part of the research-driven Ocean Research Interactive Observatory Networks (ORION) Program, is a major contribution by NSF to a broader national and international effort to establish a global Earth observing system, the Global Earth Observation System of Systems (GEOSS). The underlying goal of the OOI, and the ORION Program, is to develop the new knowledge and technologies that will advance our understanding of fundamental ocean and Earth processes. The OOI will deliver an advanced, interactive, distributed sensor network, with an operational lifetime of 25-30 years, for studies in locations ranging from the coastal waters of North America to the remote Southern Ocean. A system-wide cyberinfrastructure will deliver data in near-real time to a scientist's desktop from almost anywhere in the world's oceans, as well as allow users to remotely control their instruments, perform in situ experiments at observatory sites, and construct virtual observatories of suites of sensors specifically tailored to their scientific needs. The OOI promises to transform the ocean sciences in the coming decade by opening entirely new avenues of research, encouraging the development and application of new sensors and technologies, providing new opportunities to convey the importance of the oceans to students and the general public, and providing essential information for decision-makers responsible for developing ocean policy.

The purpose of this document is to describe examples of high priority science questions within the broad science themes posed in the OOI Science Plan published in 2005 that will be investigated using the OOI infrastructure at the sites described in the OOI Conceptual Network Design (CND). Opportunities span all disciplines of the ocean sciences. The examples given here illustrate how continuous observations and interactive experiments provided by ocean observatories are required in order to make significant progress in many areas of the ocean sciences. Where appropriate, research questions that can be addressed across all scales of the infrastructure (global, regional, coastal) are noted. In addition, we highlight some examples of observatory-based research that are anticipated to lead to early success and/or lead to major advances in our understanding of ocean and Earth processes.

This document was prepared under the guidance of the Steering Committee of the ORION Program and the ORION Program Office. An ad hoc writing committee, chaired by Jim Yoder (Woods Hole Oceanographic Institution) and including Ginger Armbrust (University of Washington), Kendra Daly (ORION Program Director), Robert Detrick (Woods Hole Oceanographic Institution), Steve D'Hondt (University of Rhode Island), Rick Jahnke (Skidaway Institute of Oceanography), Doug Luther (University of Hawaii), Oscar Schofield (Rutgers University) and Anne Trehu (Oregon State University) prepared this document for review by an NSF-appointed "Blue Ribbon Review Panel". It draws heavily from the OOI Science Plan and the CND prepared by ORION's Science and Technical Advisory Committee (STAC, Chair Doug Luther) with input from ORION's Engineering (Chair Keith Raybould, Monterey Bay Aquarium Research Institution), Cyberinfrastructure (Chair Larry Mayer, University of New Hampshire), Sensors (Chair Scott Gallager, Woods Hole Oceanographic Institution) and Education and Public Awareness (Chair George Matsumoto, Monterey Bay Aquarium Research Institution) committees. We especially want to thank the chairs of the STAC subcommittees that prepared the CND for text and figures used in this document. They include John Collins (Scripps Institution of Oceanography), Deb Kelley (University of Washington), Collin Roesler (Bigelow Laboratory), Uwe Send (Scripps Institution of Oceanography), John Trowbridge (Woods Hole Oceanographic Institution) and William Wilcock (University of Washington).

1. Vision and Motivation for the OOI

The quality of life on Earth is strongly affected by the ocean, which covers two-thirds of our planet. The ocean modulates both short and longer-term variations in climate, harbors major energy and raw material resources, contains and supports the largest biosphere on Earth, significantly influences rainfall and temperature patterns on land, and occasionally devastates heavily populated coastal regions due to storms or tsunamis. More than a century and a half of ship-based observations and research has described the basic features and processes operating in the ocean and their interactions with terrestrial and atmospheric systems. The delineation of major ocean circulation patterns, the development of plate tectonics, the discovery of the bacteria and archeae that dominate open ocean biogeochemical processes, and documentation of the coupled ocean-atmospheric interactions that lead to the El Niño-Southern Oscillation (ENSO) are all major achievements of the ocean sciences over the past five decades.

Yet, as our understanding of the oceans has advanced, it has become increasingly apparent that many critical processes occur at temporal and spatial scales that cannot be effectively studied using only traditional tools such as ships, moorings, drifters, and satellites. Ship-based studies, for example, are very limited in their ability to investigate episodic events or to study dynamic systems that change over very short time periods (seconds to hours) or over time periods longer than a few months. While satellite observations have provided a unique, synoptic global perspective of the ocean, they remain primarily limited to measuring properties at the air-sea interface and in the uppermost ocean.

The National Science Foundation's Ocean Observatories Initiative (OOI) is designed to enable powerful new scientific approaches for investigating complex ocean-atmosphere-Earth interactions. The OOI will transform ocean research by developing pioneering new technology and establishing a network of interactive, globally distributed sensors and instrumentation for the research-driven Ocean Research Interactive Observatory Network (ORION) Program. Recent technological advances in sensors, low-power and miniaturized electronics, in situ genomic analyses, satellite and fiber optic communications, high-definition imaging, robotics, and data assimilation-modeling-visualization are opening entirely new opportunities for in situ experiments and investigations of ocean processes changing over time periods of seconds to decades. The OOI will enable innovative new studies of ocean and Earth processes, and foster technological innovation that will contribute to maintaining American leadership in scientific advancement and the global economy, as well as provide unprecedented educational opportunities.

The purpose of this document is to describe examples of high priority science questions within the broad science themes posed in the OOI Science Plan that will be investigated using the OOI infrastructure at the sites described in the OOI Conceptual Network Design (CND). While we have emphasized some expected scientific returns from the OOI, we also recognize that the novel technology provided by the OOI will lead to scientific exploration and new discoveries not yet imagined.

2. OOI Science Themes

The OOI Science Plan, published in 2005, outlined five major science themes that were representative of the breadth of ocean research that will be enabled by the OOI infrastructure and supported through the ORION Program.

Climate Variability, Ocean Food Webs, and Biogeochemical Cycles

The impact of human activity on Earth's climate and its marine ecosystems is one of the overarching scientific questions of our time. Human activity has altered the Earth's biogeochemical cycles through massive releases of greenhouse gases (e.g., CO_2), the synthesis and mobilization of nutrients (N and P) and associated biogenic elements (S), and by the harvesting of many top predators within coastal and open-ocean ecosystems. The ocean plays a critical role in the Earth's response to climate change by providing a sink for CO_2, absorbing heat from the atmosphere and redistributing it through ocean currents, processing nutrients and contaminants,

and changing sea level. Examples of key scientific questions for which observatories are anticipated to supply critical information include:

- What is the ocean's role in storing anthropogenic carbon?
- How will ocean acidification due to rising atmospheric CO_2 levels affect marine ecosystems and food webs?
- What is the magnitude and cause of recent sea level rise and how rapidly will it rise in coming decades?
- Can we detect and predict the influence of longer-term climate change on ocean food webs in the presence of low frequency climate cycles?

Our understanding of global climate dynamics is limited by our knowledge of the interactions between the ocean, atmosphere, and land. These interactions are affected by the numerous modes of climate variability, such as the El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), and Pacific Decadal Oscillation (PDO) that alter the transport of heat, salt, carbon and nutrients. Furthermore, many critical processes such as cross-isopycnal mixing at ocean boundaries and at rough topography, as well as exchanges across frontal interfaces such as those found at many shelf-breaks, may occur aperiodically on interannual or even shorter time scales. Until our understanding of such processes is improved, interpretation of trends in ocean properties, potential ecosystem responses, and feedbacks on the climate system will be limited. Understanding the processes that underlie these phenomena requires high frequency, sustained measurements from coastal, regional, and global observatories coupled to physical-chemical-biological numerical models.

Coastal Ocean Dynamics and Ecosystems

Coastal systems have been highlighted as a research theme by OOI because most human-ocean interactions occur in the coastal zone and many important processes are concentrated and intensified at ocean-continent boundaries. Greater than 90% of the world's fish catch is harvested from coastal waters that also support major recreation and maritime industries. Chemical transport across the coastal ocean exerts a dominant control on major global geochemical cycles determining, for example, material exchange between the terrestrial and oceanic realms. Because >50% of the human population resides near coasts, understanding marine-related hazards is of particular importance.

While continental shelves represent approximately 8% of the ocean's surface area, they support approximately 30% of marine primary production. Additional factors, such as enhanced water stratification due to fresh water input, high rates of respiration and diverse sedimentary environments, create a patchwork of unique habitats that dominate critical biogeochemical processes such as removal of biologically-available nitrogen via denitrification and provide important nursery grounds for living marine resources. As a result, coastal systems play disproportionately important roles in the ecology and biogeochemistry of the oceans. To further understand and manage these important systems, we are faced with numerous specific research challenges. Examples include elucidating the external forcings and internal marine processes that control water quality

Figure 1. A harmful algal bloom of the dinoflagellate Noctiluca scintillans, known as a red tide. There is a growing sense that blooms of toxic algae are occurring more frequently, are lasting longer, and are spreading to more places possibly due to human influence. However, the conditions that trigger the occurrence and severity of harmful algal blooms remain poorly understood. Ship-based sampling strategies alone cannot capture the time and spatial variability of the processes responsible for these outbreaks. Sustained observations in the coastal ocean are required to detect these episodic, short-term events and resolve longer-term trends.

(e.g., formation of hypoxia); recruitment of marine organisms; benthic and water column habitats; invasion of harmful algal species (Fig. 1); and the occurrence of hazards to life and property (e.g., coastal inundation). Most of these phenomena reflect the combination and interaction of multiple processes.

Making this task more difficult is the realization that the relevant processes operate on a wide spectrum of space and time scales. A significant advancement in understanding coastal processes will require a continuous, distributed observational presence to detect episodic, short-term events and to resolve longer-term trends. Establishing this observational presence in representative eastern and western boundary current systems of North America and other representative shelf environments will maximize advances in our understanding. Examples of key scientific questions include:

- What processes determine the transport of carbon, nutrients, planktonic organisms and other materials within the coastal ocean ecosystem?
- What conditions trigger the occurrence of harmful algal blooms and regime changes in the species composition of coastal ecosystems?
- What mix of physical and biological processes lead to hypoxic conditions in the coastal ocean?

Turbulent Mixing and Biophysical Interactions

Turbulent mixing occurs over a broad spectrum of time and space scales and plays a critical role in the transfer of materials within the ocean and in the exchange of energy and gases between the ocean and atmosphere. Horizontal and vertical mixing within the ocean have a profound effect on a wide variety of biological processes, including phytoplankton community structure, cycles of primary productivity in the upper ocean, predator-prey interactions, larval dispersal, and the transfer of organic material to the deep sea. Turbulence in the bottom boundary layer plays an important role in determining benthic community structure, cross-shelf sediment transport, and the sequestration of organic material in sediments. A better understanding of turbulent flow, from the ocean surface to its bottom, is essential for developing improved models of processes ranging from large-scale ocean circulation to local ecosystem dynamics.

While important advances have recently been made in measuring small- and mesoscale-turbulence, these processes remain extremely difficult to study. First, turbulent flow in the oceans encompasses a wide range of scales from essentially the molecular level to mesoscale eddies having dimensions of tens to hundreds of kilometers. Second, the dynamics of turbulent flow are inherently unstable and non-linear, resulting in a strong intermittency and complexity in the flow. Third, the response of ecosystems to changes in their physical environment (nutrient levels, turbidity and light, biomechanical stresses) are themselves non-linear and complex. As a result, high-resolution, long time-series observations are needed to characterize statistical measures of these processes. However, obtaining continuous, simultaneous information on mixing and responses at the required spatial resolution (mm to 10s or 100s of km) and temporal range (seconds to decades, to resolve the turbulence itself, and to deal with changing seasonal and interannual contexts) is simply not feasible using conventional ship-based expeditionary studies.

Measurements from mobile platforms and ships will be integrated with those from fixed observatories to examine such questions as:

- What is the role of vertical mixing in the ocean interior for determining the global distribution of heat and nutrients in the ocean?
- What factors control the development of the mixed surface layer, the entrainment of stratified waters into the mixed layer and the exchange of gases between the mixed layer and the atmosphere?
- What is the role of vertical and horizontal mixing in determining plankton community structure in the upper ocean?
- How is benthic community structure affected by near-bottom turbulent events?

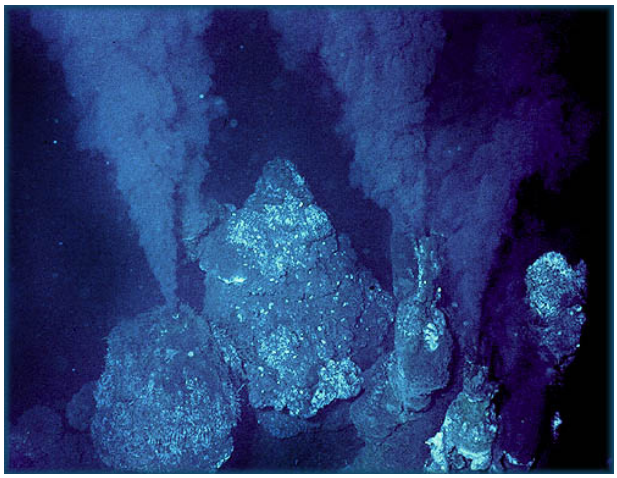

Figure 2. Mid-ocean ridge hydrothermal systems, and their associated biological communities, are thermally driven by episodic volcanic events, including dike intrusions and submarine eruptions. The flow rates and chemistry of these vents can remain stable over many years or can change rapidly over days or weeks. The only means of studying these systems is to install infrastructure and sensors necessary to detect transient events, and to provide the capability to adaptively measure and remotely sample the changes induced by volcanic or tectonic events.

Fluid-Rock Interactions and the Sub-Seafloor Biosphere

The upper oceanic crust comprises the largest aquifer on Earth. Fluid circulation within this aquifer influences the thermal state and composition of oceanic plates and interacts with hot, newly emplaced volcanic crust at mid-ocean ridges and at back-arc spreading centers to form spectacular “black smoker” hydrothermal vents with their unique biological communities (Fig. 2). On ridge flanks, and along continental margins, these fluids react with ocean crust and sediments at lower temperatures, slowly altering their composition and concentrating massive reservoirs of methane and methane hydrates along continental margins. The chemical changes associated with these fluid-rock interactions play important roles in controlling ocean chemistry while nutrients in these fluids sustain a vast, microbial biosphere below the seafloor that is just beginning to be explored.

Fluid flow through the thick sedimentary sequences that accumulate at both active and passive continental margins is driven by a wide range of factors, including sediment compaction and compression, tides, and density contrasts related to fluid composition. This flow results in widespread deposits of gas hydrates and low-temperature fluid seeps and gas vents along the margin that support biological communities that are distinct from those at hydrothermal vents. The extent and temporal evolution of vents and linkages between the ocean and the terrestrial hydrosphere are poorly documented and understood but are likely of critical importance to coastal ecosystems. These low temperature systems are now recognized to be widespread and of potential critical importance to coastal ecosystems. Subsequent mechanical dewatering and metamorphic dehydration of the oceanic crust and upper mantle due to temperature and pressure increases as the lithosphere is subducted has a major impact on generation of volcanoes and on earthquake processes and hazards along convergent margins and in the adjacent tectonic plates.

The overall geological, chemical and biological significance of both high and low temperature hydrothermal systems is still largely unknown. Fundamental questions exist regarding how ridge-crest hydrothermal systems, and the biological communities they support, are affected by episodic volcanic and tectonic events, the processes controlling the formation and dynamics of gas hydrates and their climatological significance, the depth and extent to which life may occur within the seafloor and overlying sediments, and the linkages between submarine plate-tectonic and sedimentary processes and this sub-seafloor biosphere. Similarly, the dynamics of flow and biological communities within shallower permeable sediments is mostly unexplored. However, there is increasing evidence that transient events – earthquakes, volcanic eruptions, massive slope failures, and storms – play a critical role in many different environments including mid-ocean ridges, passive and active continental shelves and slopes, and in the fore-arc and back-arc regions of subduction zones. Advancing understanding of the linkages and feedback mechanisms among geological, chemical, and biological processes within these highly dynamic environments will only be achieved through the use of long-term, in situ observatories on and beneath the seafloor with the capability to detect, respond, sample, and measure the major processes involved.

Examples of questions that can be addressed include:

- What is the extent, abundance, distribution and diversity of the sub seafloor biosphere?
- How do submarine hydrothermal systems, and their associated biological communities, vary over time?
- What are the limits of life in these extreme environments?
- What processes control the formation and destabilization of gas hydrates?
- What role do gas hydrates play in catastrophic slope failure?
- How do seawater-groundwater interactions control biogeochemical cycling on continental shelves?

Global Earth Structure and Plate-Scale Geodynamics

Plate tectonics has revolutionized our understanding of the dynamics of the Earth's surface, including such aspects as the formation of ocean basins, mountain building, rifting of continents, and the global distribution of earthquakes and volcanoes. This scientific revolution had a profound impact on society, explaining why and where earthquakes occur, providing a conceptual framework for determining where new oil and gas reservoirs are likely to be found, and helping us understand the pattern of volcanic activity observed at Earth's surface. While plate tectonics has been enormously successful at providing a quantitative description of the past motions of continents and a kinematic model of present-day tectonics, there are many fundamental questions regarding global and plate-scale geodynamics that remain unanswered, including the composition and dynamics of the Earth's deep interior, the origin of Earth's magnetic field, how plate boundaries interact and deform, stress redistribution following large earthquakes, and the links and feedbacks that exist among tectonic, magmatic, hydrothermal and biological processes along active plate boundaries.

Progress in addressing these important questions has been limited by two major factors: (1) the difficulty of making sustained geophysical observations over the 70% of Earth's surface beneath the ocean; and (2) the inability to instrumentally "capture" episodic, short-lived events such as earthquakes or volcanic eruptions along plate boundaries, most of which lie beneath the ocean. Although many of the instruments needed to make these measurements exist (e.g. hydrophones, seismometers, pressure sensors, and geodetic instrumentation), the deployment of these sensors in the ocean has typically lasted only a few weeks or months, instead of years, because of the limited power of autonomous, battery-operated instruments. Without a means of telemetering data from these instruments to shore in real time or near-real time, episodic events could only be detected long after they occurred, precluding any effort to study their immediate aftermath by deploying additional sensors or to take appropriate action if these events posed a threat to coastal populations.

OOI infrastructure will support long-term observations that will be able to address questions such as:

- What is the physics of earthquake nucleation and rupture propagation for different types of plate boundaries (subduction zones, transforms, spreading centers)?
- How does the oceanic crust form?
- What is the interaction between volcanic, tectonic and hydrothermal processes in geologically active regions?
- What is the pattern of convection in the Earth's mantle and the origin and scales of mantle heterogeneity?
- What are the properties of Earth's core, core-mantle boundary and lowermost mantle?

3. Summary of the OOI Conceptual Network Design

The OOI has three major components:

(1) an open-ocean distribution of deep-water moored buoys to address planetary-scale processes, especially in the more remote and inaccessible parts of the global ocean;

(2) a regional cabled observatory (RCO) that will provide unprecedented levels of power and bandwidth to sensors in the water column, and

on and below the seafloor spanning an entire tectonic plate; and

(3) a suite of permanent and relocatable assets to study the dynamics of the coastal ocean of North America.

These three elements will be integrated into a single "system-of-systems" by a network-wide cyberinfrastructure that will deliver data in near-real time to a scientist's desktop from almost anywhere in the world's oceans, as well as allow users to remotely control their instruments, perform in situ experiments at observatory sites, and construct virtual observatories of suites of sensors specifically tailored to their scientific needs.

The ORION Science and Technical Advisory Committee (STAC), working with the ORION Engineering and Sensor Committees and the ORION Program Office, has developed a Conceptual Network Design (CND) for the OOI. The CND is based on dozens of workshops and planning documents dating back to the late 1980s. A major input to the CND was proposals submitted to a Request for Assistance (RFA) issued by the ORION Program Office in January 2005 in cooperation with NSF's Division of Ocean Sciences. The submission of 48 RFA proposals, representing the thoughts and ideas of more than 550 investigators, and the involvement of over 130 separate research and educational institutions, attests to the exceptional level of interest and enthusiasm on the part of the U.S. oceanographic community for observatory-based ocean science. A review panel comprised of scientists with no connection to any RFA proposal was convened by NSF in September 2005 to evaluate the RFA proposals and provide a binning based on the importance and uniqueness of the proposed research, the adequacy of the experimental plans, the readiness of the experimental designs and proposed technologies, and the innovative use of the OOI infrastructure.

A preliminary version of the CND was posted on the ORION web site in March 2006 and presented at the ORION Design and Implementation (D&I) Workshop on 27-30 March 2006 for discussion and evaluation by the more than 280 ocean scientists who attended the meeting. Utilizing the recommendations developed at the D&I Workshop (http://www.orionprogram.org/di_workshop.html), and revised cost estimates developed by the ORION Engineering Committee, the STAC revised and finalized the CND in May and June 2006. This was an extraordinarily difficult task given the excellence of the proposed science across all disciplines and their associated infrastructure requirements which would have claimed several times the resources currently available through the OOI. This section presents a brief summary of the revised plans. The complete CND is available on the ORION website at http://www.orionprogram.org/capabilities/cnd.html

OOI Coastal Observatory

The OOI Coastal Observatory experimental design has three major elements:

(1) a permanent West Coast Endurance Array concentrated in the Pacific Northwest (PNW) with complementary assets off California,

(2) a permanent East Coast Endurance Array located in the South Atlantic Bight (SAB) off the southeast U.S., and

(3) a moveable Pioneer Array that will be initially located in the Mid-Atlantic Bight (MAB) region off southern New England to study processes at the shelf-break front.

The West Coast and East Coast Endurance Arrays capitalize on the contrast between: (i) a narrow shelf (off the West Coast) forced by seasonal, upwelling-favorable winds, a large buoyancy source and an eastern boundary current and (ii) a broad shelf (off the East Coast) forced by a western boundary current, distributed buoyancy sources and extreme wind events.

The two endurance arrays, therefore, provide the opportunity to address complementary interdisciplinary scientific questions in contrasting systems representing two canonical classes of coastal margins with numerous analogs worldwide. Furthermore, both systems are affected by the ocean climate system with El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) more important on the West Coast, and the North Atlantic Oscillation (NAO) on the East Coast. The interan-

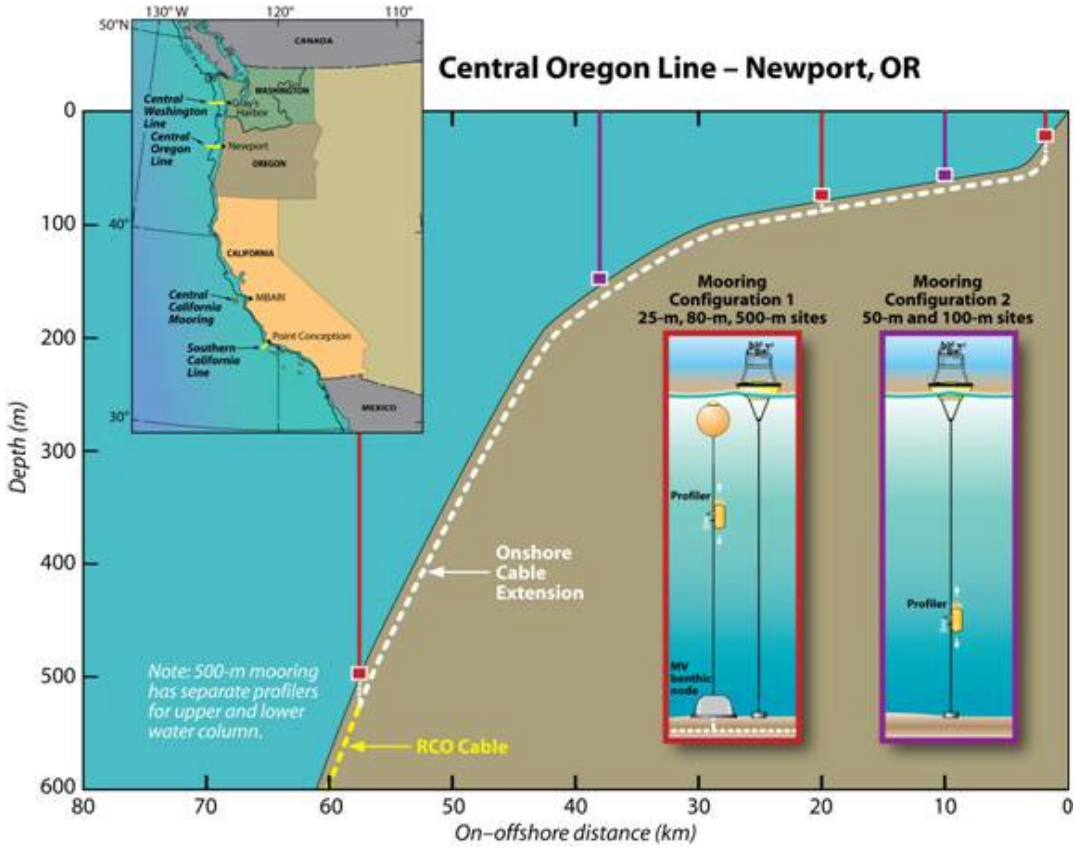

Figure 3. Map of the West Coast Endurance Array (inset) with schematic diagram of the Central Oregon line. The West Coast coastal observatory consists of a Central Washington Line, a Central Oregon line, a Central California mooring, a Southern California line, and a glider array (not shown). The Central Washington and Central Oregon lines will each consist of five moorings, positioned to determine cross-margin variability, the variability of cross-margin transports, and the characteristics of the buoyant discharge from the Columbia River. At the Central Oregon Line, the RCO cable will be extended onshore from Node N1 (Fig. 6) to the 25-m isobath. Benthic nodes will be connected to the cable at the 25-m, 80-m and 500-m isobaths, and these sites will be equipped with cabled surface profilers and independent surface moorings to support meteorological sensors. Surface moorings with profilers will occupy the 50-m and 150-m sites. The Central California line will include a mooring on the Monterey Accelerated Research System (MARS) cable, an NSF-sponsored test-bed for ORION's cabled observatories and instrumentation. The Southern California line will consist of shelf and slope moorings. Instrumentation and glider transects are not shown.

nual and longer-period variability associated with the ocean climate system link the coastal margins with processes that originate in, and also affect, the open ocean. The Pioneer Array proposed as part of the coastal OOI coastal design will employ adaptive sampling strategies to resolve multiple temporal and spatial scales in a variety of coastal settings.

The OOI coastal observatories will provide an unprecedented opportunity to address broad classes of critically important coastal oceanographic problems. These include, in particular, shelf-ocean exchange, air-sea transport, benthic processes and benthic-pelagic coupling, transport and transformations of terrestrial discharges, response to extreme events, biogeochemical cycling, harmful algal blooms, hypoxia, and ecosystem dynamics.

West Coast Endurance Array - The proposed West Coast Endurance Array (Fig. 3) consists of the following:

(1) an uncabled line of four shelf moorings and one slope mooring off Grays Harbor in Central Washington;

(2) four shelf moorings and one slope mooring on an existing long-term sampling line off Newport, Oregon, three of which will be cabled by means of an onshore extension of the OOI Regional Cabled Observatory (RCO; see node N1 in Fig. 6);

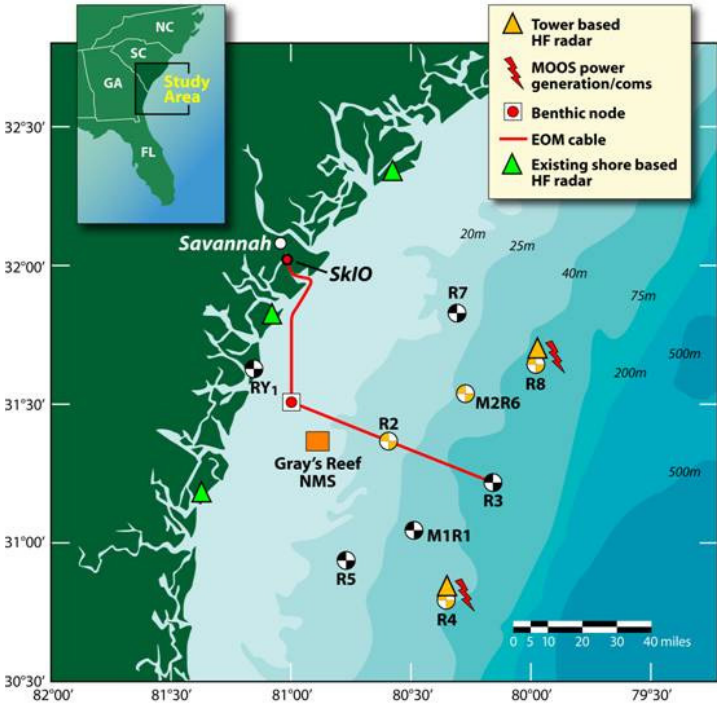

Figure 4. Map showing the elements of the South Atlantic Bight (SAB) Endurance Array. R2, R3, R4, R5, R7, R8, M1R1 and M2R6 are existing Navy towers, some of which are components of the ongoing SEACOOS and SABSOON programs. The seafloor cable will extend from a shore landing near Skidaway Institute of Oceanography to a seafloor node near 31.5°N, 81°W and then to towers R2 and R3, which will be equipped with air-side (dry) nodes, benthic nodes, and water-column profilers (not shown). High-frequency (HF) radars will be placed on towers R4 and R8, which will complement existing shore-based HF radars, and Monterey Ocean Observing System (MOOS) units will be placed on towers R4 and R8 for power and two-way communications. Glider transects (not shown) will complement the fixed assets.

(3) a mooring at the cabled Monterey Accelerated Research System (MARS) node in Central California;

(4) an uncabled line with one slope and one shelf mooring in the Southern California Bight; and

(5) an array of gliders.

The basic components of the infrastructure in this West Coast Endurance Array (as well as in the other two coastal elements of the CND) are surface buoys with capabilities for power generation and satellite communications, electro-optical-mechanical (EOM) moorings to provide power and communications to the seafloor, mechanical moorings with acoustic communication delivery, profiling moorings with real-time communications and battery re-generation capabilities, low-voltage (LV) and medium-voltage (MV) benthic nodes, seafloor cables, gliders, autonomous underwater vehicles (AUVs), and core instrumentation.

The assets in the West Coast Endurance Array are concentrated along the Central Oregon and Central Washington lines. The purposes of these lines are to contrast shelf and slope processes in regions influenced differently by the outflow from the Columbia River (e.g., the coastally attached northward plume off Washington during downwelling events and the detached south-southwest plume off Oregon during upwelling events) 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 moorings on the Washington and Oregon lines will include highly capable installations with full-depth water column profiling, surface expressions for atmospheric measurements, and benthic nodes for intensive near-bottom measurements at the 25, 80 and 500-m isobaths, 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 offshore infrastructure associated with the RCO.

The objectives of the moorings off Central California and in the Southern California Bight are to sample different biogeographical regimes and to provide spatial measurements of northward-propagating disturbances (ENSO-forced) originating in the tropical Pacific, which will aid in the interpretation and analysis of the more densely sampled measurements in the Pacific Northwest. The OOI assets off Central California will capitalize on the cabled MARS node and will add a full-depth profiling capability to this facility. An array of gliders will be initially deployed to characterize shelf-wide features. Over time, a

subset of the gliders will be allocated to characterize smaller-scale features, in a process informed by measurements and modeling.

East Coast Endurance Array - The main element of the South Atlantic Bight (SAB) East Coast Endurance Array (Fig. 4) is a cable extending from shore to a medium-voltage inner shelf benthic node and then to dry and wet nodes on a mid-shelf tower (R2) and finally to dry and wet nodes at a shelf-break tower (R3). The inner shelf node will be equipped with a full-water-depth profiling capability. Each of the cabled towers will have a cabled profiling capability remote from the tower (by approximately 1 km) to minimize flow disturbances and reef effects associated with the towers. Two additional uncabled towers (R4 and R8) will be instrumented with high-frequency (HF) radars, provided with power and two-way communications by Monterey Ocean Observing System (MOOS) packages to measure surface currents over the outer shelf and slope. Observations from an array of gliders will be used to quantify spatial variability.

Pioneer Array - The coastal Pioneer Array employs fixed moorings, profiling moorings, and adaptive sampling by means of gliders and autonomous underwater vehicles (AUVs) to produce synoptic samples of multi-scale coastal oceanographic phenomena. The array consists of four electro-optical-mechanical (EOM) moorings with surface expressions and capabilities for local power generation and satellite data transmission, five subsurface profiling moorings with internal power and acoustic telemetry capabilities, four acoustic repeater moorings with internal power, three long-range (~400 km) AUVs, two AUV docking stations, twelve gliders (~ one month duration), and core instrumentation. In the configuration contemplated at present (Fig. 5), two EOM moorings are dedicated to bottom-mounted AUV docking stations, and two are dedicated to fixed sensors. The subsurface profiling moorings transmit data by means of the acoustic repeaters (where necessary) to the EOM moorings for satellite transmission. The AUVs sample spatially in response to two-way communications and obtain power and transmit data by means of the docking stations. Glider operations are handled by ship.

The initial location of the Pioneer Array is planned for the shelf-break front of the Mid-Atlantic Bight (MAB), off southern New England. This site was chosen because of the compelling, high priority science that can be done here and because of the complexity of the array, which dictates that its first application should be in the environment for which it was originally designed. Because of the developmental nature of AUV docking operations, espe-

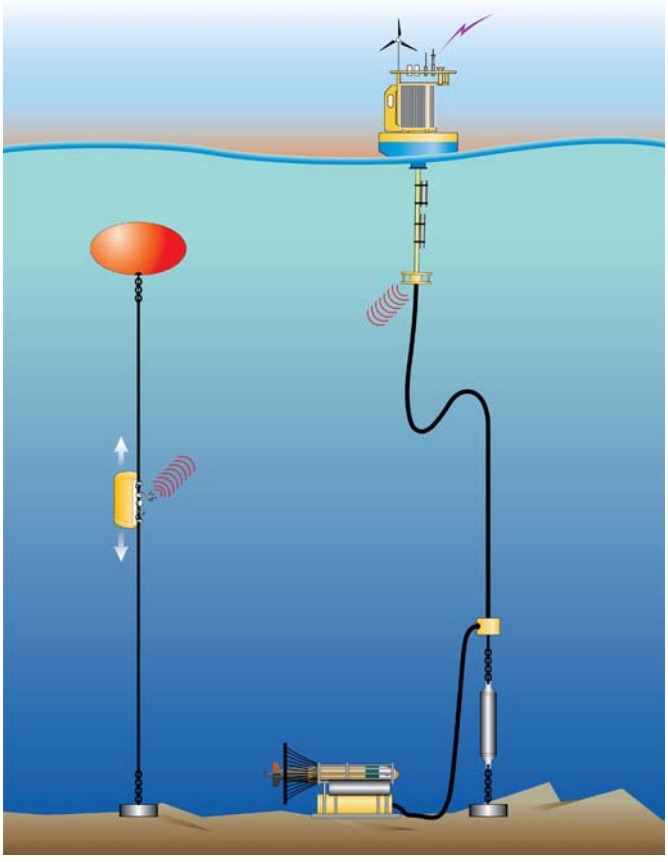

Figure 5. Schematic diagram of elements of the Pioneer Array. EOM moorings (with surface expressions equipped with capabilities for power generation and satellite transmissions) provide power and two-way communications to an AUV fleet by means of a bottom mounted docking station, while also providing two-way communications to a sensor suite on a nearby internally powered profiling mooring, by means of acoustic telemetry. Elements of the array not shown here include EOM moorings (with surface expressions equipped with capabilities for power generation and satellite generation) that are devoted to instrumentation on the mooring itself, repeater moorings for longer-range acoustic transmissions, and gliders for spatial sampling that complement the AUV measurements.

cially at moorings, plans call for the AUV dock to be deployed initially at the nearby Martha's Vineyard Coastal Observatory. The array will span approximately 50 km and 40 km in the along- and cross-front directions, respectively. AUVs will sample within the front and over the shelf, and gliders will sample the slope water.

OOI Regional Cabled Observatory (RCO)

The OOI Regional Cabled Observatory (RCO) is a plate scale experiment of unparalleled scope that is focused on integrated investigations extending from the sub-seafloor biosphere across the benthic boundary layer through the entire ocean water column to the sea surface-atmosphere interface. Spatially associated with the Juan de Fuca tectonic plate (Fig. 6), the RCO will enable in-depth study and decadal time–series observations of globally significant oceanographic and Earth processes expressed regionally – including biogeochemical cycles, climate forcing of ocean dynamics, the carbon cycle, fisheries, earthquake and tsunami hazards, life in extreme environments, and plate tectonic processes. Dense spatial and temporal sampling, coupled with interactive capabilities will allow the ocean science community, for the first time, to make fundamental measurements and exciting discoveries about processes that occur over centimeter to 100's of kilometer distances, and at seconds to decade time scales.

The RCO experimental design is shown in Figure 6. The northern loop (Stage I) of the RCO is being constructed by the University of Victoria with CAN $62.4M

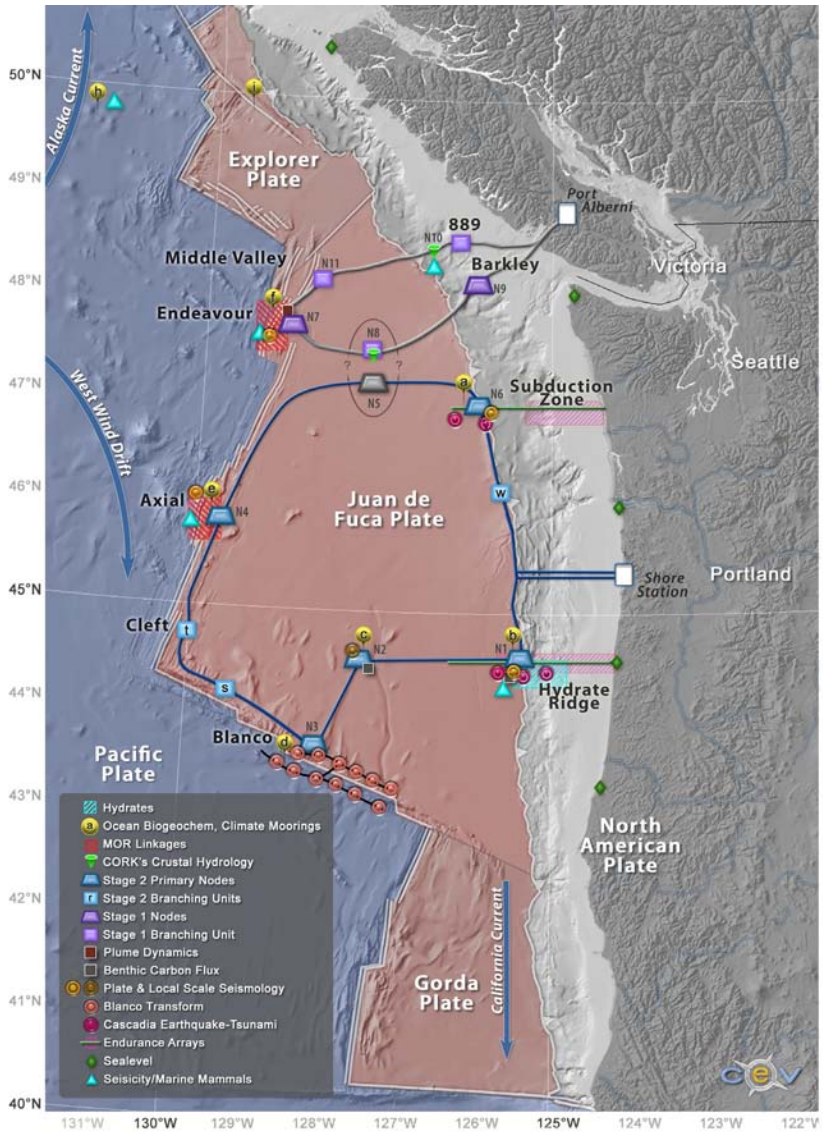

Figure 6. Regional cabled observatory (RCO) integrated experimental design. This plate scale experiment will be installed in two stages. The northern loop (Stage I) of the RCO is being constructed by the University of Victoria with funding from the Canadian Foundation for Innovation and the British Columbia Development Fund and is slated for installation in 2007. Stage II of the RCO (southern loop), which will be funded through NSF's OOI, will include 5 primary nodes, 6 branching units for future expansion and 9 full water column moorings connected by 1490 km of fiber optic cable.

funding from the Canadian Foundation for Innovation and the British Columbia Development Fund. The Stage I northern loop will have up to six instrumented nodes (the current baseline design is for two instrumented nodes and two expansion nodes). Stage I is slated to begin installation in 2007. The current design of Stage II of the RCO (southern loop), which will be funded through the OOI, includes 1490 km of electro-optical backbone cable on the seafloor with five primary nodes and three branching units for future expansion. The design includes six vertical profilers and two buoyed vertical profilers for water column studies. This infrastructure will provide unprecedented levels of power (kW/node) and real-time, high bandwidth (Gigabit/sec) two-way communication to sensors on the network to enable in-depth study and decadal time-series observations of globally significant ocean and Earth processes that are expressed regionally.

The following is a brief description of the five primary nodes being proposed through the OOI as part of Stage II of the RCO:

Node 1 (N1) Hydrate Ridge – Node 1 is located on the abyssal plain seaward of the central Cascadia deformation front along the Newport transect (Figs. 6 and 7). This transect serves a variety of interdisciplinary objectives, including studies of dynamic processes that control methane transport and hydrate formation, biogeochemical processes, geophysical studies of megathrust earthquake events and tsunamis, and regional and coastal water column studies. An extension cable with three sub-nodes is planned for the summit of Hydrate Ridge and the adjacent subduction zone forearc. The primary node will support a seismic/geodetic station and a water column mooring, as well as a 90-km-long extension cable that extends across the accretionary complex and up on to the shelf. This cable provides power and communications to several moorings of the West Coast Endurance Array at this site (see Fig. 3).

Figure 7 shows the location of the primary and secondary nodes along the eastern portion of the Newport Line. Gas hydrate related studies are primarily focused at secondary node NP1 on the southern summit of Hydrate Ridge (light purple shading). Subduction zone related objectives are addressed by instrumentation placed at each of the three proposed secondary nodes (NP1-NP3). Benthic studies, physical oceanographic, biogeochemical, and carbon flux studies will be addressed at a series of six moorings (five of which are part of the coastal PNW coastal observatory (blue stars)). The sixth mooring is a full water column vertical profiling

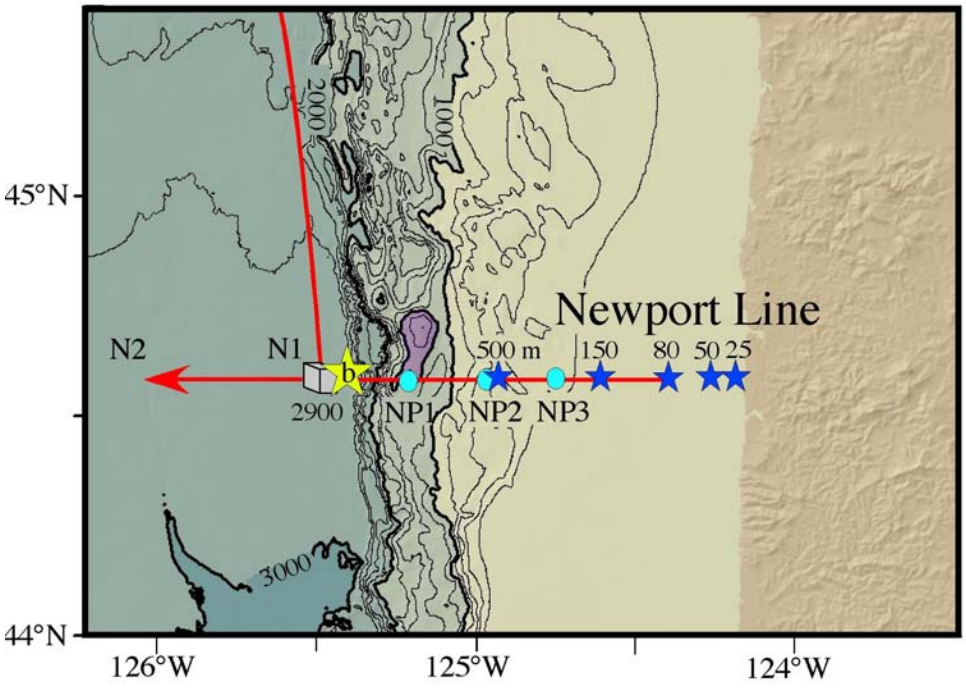

Figure 7. Map showing location of the primary and secondary nodes along the Newport Line. Gas hydrate related studies are primarily focused at secondary NP1 on the southern summit of Hydrate Ridge (light purple shading). Subduction zone related objectives are addressed by instrumentation placed at each of the three proposed secondary (NP1-NP3). Benthic studies, physical oceanographic, biogeochemical, and carbon flux studies will be addressed at a series of 6 moorings. Five of these are outlined in the coastal component of the CND (blue stars). The sixth mooring is a full water column vertical profiling mooring that will be placed on the backbone of the RCO (yellow star).

mooring that will be placed on the backbone of the RCO (yellow star). This node is also a key site for examining the coupling of pelagic particulate matter fluxes and benthic community processes across the shelf.

Node 2 (N2) Newport Line West – Node 2 is located in the interior of the Juan de Fuca plate at the western end of the Newport Line (Fig. 6). This node is critical for three types of regional scale studies: 1) it provides one of the few mid-plate sites for plate-scale seismology and geodynamics; 2) coupled with cabled profiling moorings at Node N1 and on the shelf along the Newport Line (through the coastal component of the OOI), the water column mooring proposed for Node N2 will enable studies of biophysical processes from the exceptionally productive upwelling zone over the shelf to the nutrient-poor, subtropical waters west of the shelf break; and 3) this node is key to studying the relationships between temporally-varying particulate fluxes and benthic community processes from slope to abyssal depths in real time. This transect of stations is important because it crosses the continental margin from the base of the slope (out of range of commercial fishing activity) and reaches the mid-plate.

Node 3 (N3) Blanco Fracture Zone – Node 3 is located along the active Blanco transform fault (Fig. 6). The Blanco node will be used for a seismic-geodetic experiment to understanding the basic physics of earthquake rupture by utilizing the short recurrence interval of magnitude 6-6.5 earthquakes on the Blanco transform fault to distinguish between the effects of geological heterogeneity and stress-state. This is also one of the sites identified for interdisciplinary water column studies that will link ocean dynamics, climate and ecosystem response. A network of secondary benthic nodes will cover a ~60 by 20 km wide area straddling the fault with a network of relatively low power instruments such as seismometers, strong motion sensors, fluid temperature probes, and geodetic transponders.

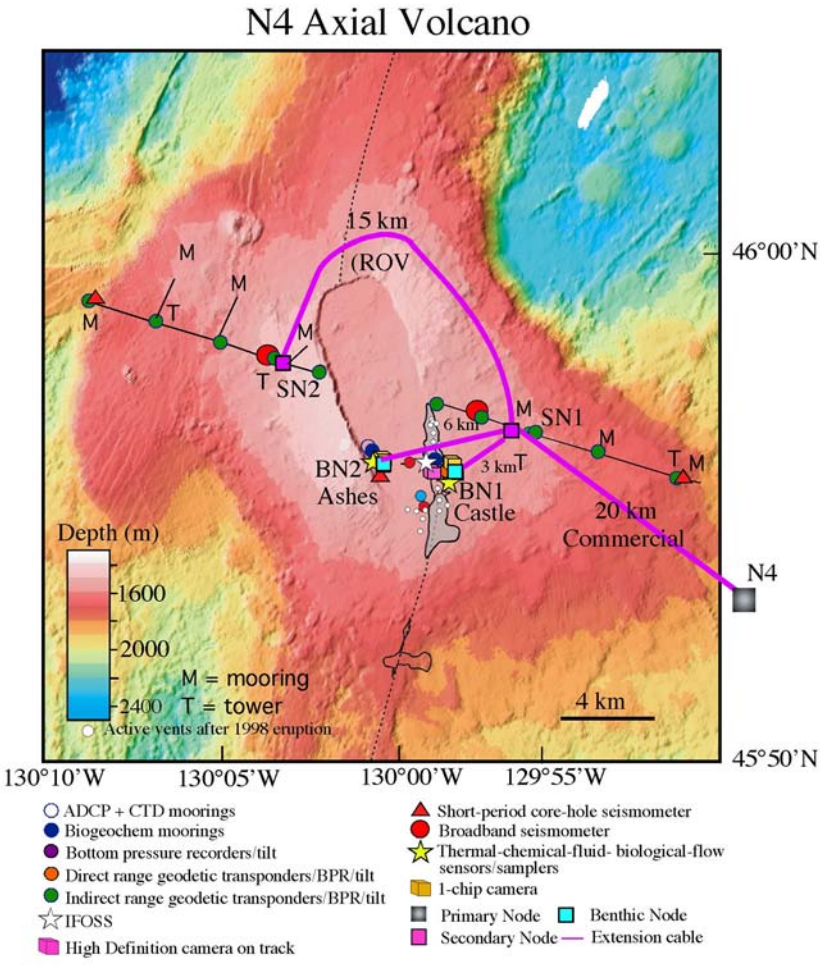

Figure 8. Axial Volcano is the largest volcano on the Juan de Fuca Ridge and hosts three robustly venting hydrothermal sites (Ashes, Castle, and Chasm (not shown)) within its summit caldera. NOAA has maintained a moored buoy observatory at this site for several years (NeMO). It has the longest co-registered time-series analyses of fluid and microbial community evolution following a volcanic eruption in the oceans. This area was the focus of five RFA's, and because of its importance in addressing the linkages among volcanism, crustal accretion, hydrothermal flow, and biological processes, extensive secondary infrastructure is planned for this site. Because this could be a hazardous environment, a 20 km extension cable is planned from the primary backbone cable. Multiple shorter cables will be laid with an ROV to provide power for an extensive array of sensors.

Node 4 (N4) Axial Seamount – Node 4 is located at the summit of Axial Seamount along the intermediate spreading Juan de Fuca Ridge (Figs. 6 and 8). Axial Seamount, which last erupted in 1998, has the most robust magma supply on the Juan de Fuca Ridge and is the site of the NOAA's New Millenium Observatory (NeMO; see http://www.pmel.noaa.gov/vents/nemo/). Given the work that has already been accomplished at this site, it presents an unparalleled opportunity for integrated long-term studies of active seafloor volcanism. It is also one of the sites identified for the deployment of a mooring that will be used for interdisciplinary water column studies that link ocean dynamics, climate and ecosystem response in the Northeast Pacific. The deployment of a vertical hydrophone mooring and a broadband seismometer at Cleft will maximize the area that will be covered by the hydroacoustic monitoring and plate scale seismology experiments. Two secondary nodes will be deployed on the western and eastern sides of the caldera at the summit of Axial Seamount (Fig. 8). A cable will extend from the eastern secondary node to a benthic node at the Castle vent site.

Node 6 (N6) Cascadia Subduction Zone – Node 6 is located seaward of the Cascadia deformation front and includes a cable with two sub-nodes to address subduction zone and water column objectives (Fig. 6). This transect is also co-located with a transect being planned as part of the PNW coastal observatory (see Fig. 3). The Cascadia Subduction zone is known to have generated historically enormous (Mw 9+) earthquakes and tsunamis. Recently reported correlations between forearc basin structure and the slip history of large earthquakes in other subduction zones provide a framework for designing a seismic and geodetic network that will lead to a better understanding of the subduction zone dynamics and earthquake/tsunami hazards in the Pacific Northwest.

OOI Global Observatory

Long-term continuous open-ocean observations are required for quantifying and understanding interannual-to-decadal changes in ocean circulation, water properties, water mass formation, and ecosystems, for observing episodic events and their impact, for providing reference sites for atmospheric time series

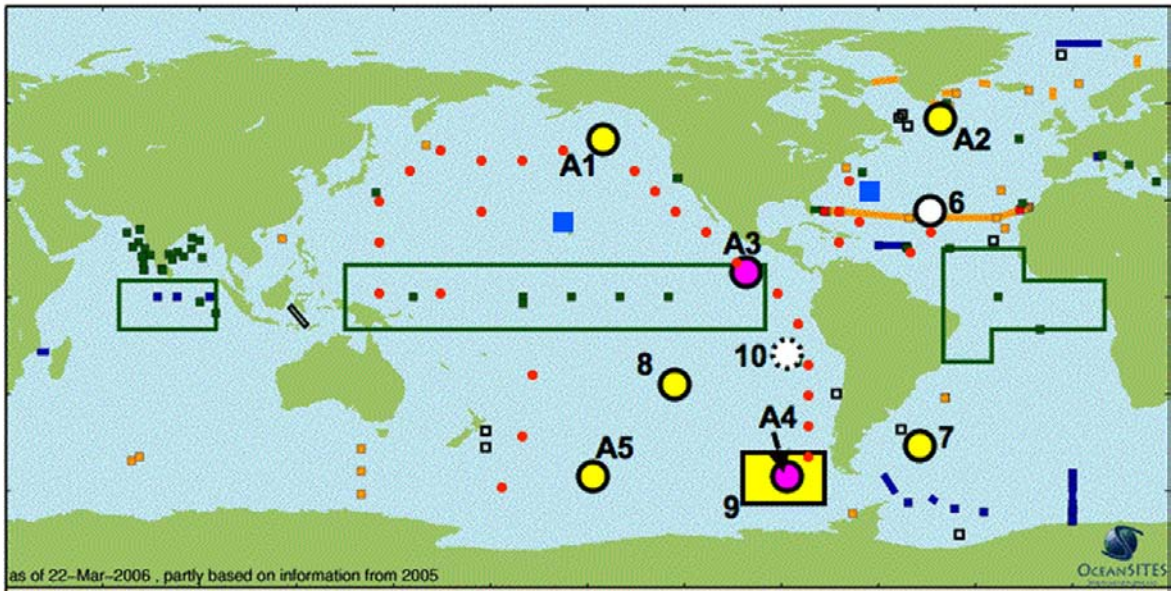

Figure 9. Distribution of OOI global observatory sites (large labeled filled circles and rectangle) relative to the OceanSITES near-term network and future DART buoy locations (red dots). The OOI sites labeled "A" have the highest but equal priority; the priorities of the remaining OOI sites indicated by numbers 6-10. Mooring types are indicated by color: yellow disks for acoustically-linked discus buoy, purple disks for SPAR buoy; and white disks for discus buoys with electrical-optical-mechanical (EOM) cables. The yellow rectangle shows one possible location for the relocatable Global Pioneer Array, which will consist of a backbone of four sub-surface moorings and four gliders. The existing long-term oceanographic time series sites at Hawaii and Bermuda, which are recommended for continued support through the ORION program (but no new OOI infrastructure), are shown by the blue rectangles. An acoustic source/receiver mooring tied to a separately-NSF-funded cabled junction box at HOT site ALOHA is also part of the CND.

and quantifying air-sea fluxes, for determining the role of the oceans in the global carbon cycle, for improving our understanding of the Earth's interior and geodynamics, and for measuring global plate motions and studying plate boundary processes. Moored buoy, open-ocean observatories are well suited to address these requirements, especially in remote ocean areas where cabled observatories are unavailable or prohibitively expensive to install. Moored buoy observatories are an important complement to other components of a global ocean observing system, like satellite remote sensing, profiling floats, surface drifters, gliders and research vessels.

Figure 9 shows the eight open-ocean, moored buoy observatories (labelled A1 through A5, and 6, 7, & 8) proposed for the global component of the OOI. The approach taken by ORION is to build a system that can address global science questions in truly novel ways and to contribute to a global network that by necessity will be international in scope. In Fig. 9 the OOI global sites are superimposed on a map from the international OceanSITES project which coordinates the international global ocean time series network, and is part of the Global Ocean Observing System (GOOS). This map also shows the locations of NOAA's Deep-ocean Assessment and Reporting of Tsunami (DART) buoys (red dots) in the Pacific and Atlantic. The OOI Global Observatory will be embedded in a larger network operated by NOAA and international partners, to which it will contribute new technology and occupy sites, especially in the Southern Ocean, from which observations are not currently available.

Three types of surface moorings will be used in the global observatory program: (1) an acoustically-linked discus buoy; (2) a discus buoy with a electro-optical-mechanical (EOM) cable linked to a seafloor junction box, and (3) a tri-moored spar buoy with an electro-optical (EO) cable to a seafloor junction box. The acoustically-linked system will be used in those cases where power does not need to be provided to sensors in the water column or on the seafloor. A key feature of this system is the ability to add or remove sensors from the observatory without recovery of the buoy or mooring, providing considerable flexibility in the operation and maintenance of sensor network. The EOM cable-linked buoys provide modest amounts of power (a few 10s of W) and two-way communication to a seafloor junction box and will be used, for example, with instrumented boreholes or where power needs to be provided to profiling moorings. The most advanced and technically challenging buoyed observatory envisioned for the OOI is the large tri-moored spar buoy. This system has been designed to deliver ~500W of power to a seafloor junction box and utilizes a C-Band satellite telemetry system to send ~500 Mbytes of data (or more) to shore each day. In comparison to the wave-following discus buoy, the spar design reduces the platform's motion in waves, especially heave and pitch motions, which are important for utilization of a high-bandwidth satellite telemetry system. The tri-moored design may also increase the survivability of the buoy, and the electro-optical cable connecting it to the seafloor, in very rough seas, as expected in the Southern Ocean.

In addition to fixed moorings at the eight sites shown in Fig. 9, the OOI CND includes plans for a relocatable array of moorings and gliders (a so-called global "Pioneer Array") that would temporarily enhance the single point, time series observations at one global site by providing greater spatial coverage and adaptive sampling capabilities. The relocatable array would consist of 4 subsurface moorings and several dockable AUV's. The initial deployment would be off southern Chile at global site A4 for a 2-3 year period (see yellow box in Fig. 9), but the location of subsequent deployments would be determined through peer-reviewed proposals. The CND also includes installation of a subsurface mooring with an acoustic source/receiver at the Hawaii Ocean Time-series (HOT) ALOHA site 100 km north of Oahu, Hawaii, to enable basin-scale acoustic thermometry using the other OOI global moorings in the North and South Pacific and to provide an acoustic network to track autonomous vehicles in the region. The CND does not recommend additional OOI infrastructure investments at the HOT/ALOHA or BATS sites. However, the importance of sustaining the long time series at these

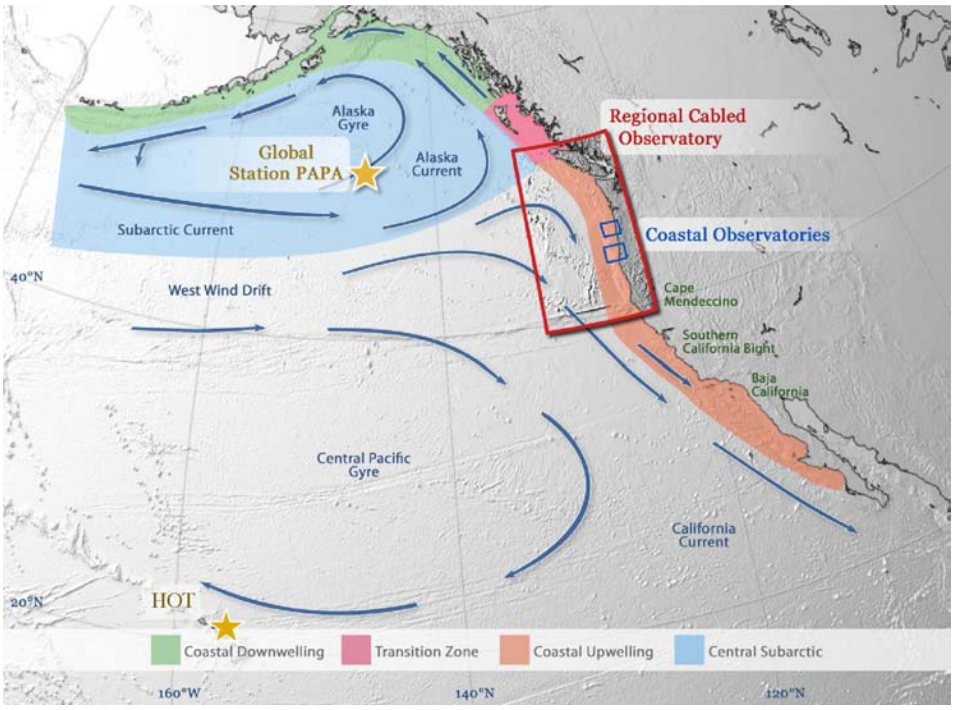

Figure 10. The Northeast Pacific is an example where opportunities exist to integrate results from of all three components of the OOI - global, regional, and coastal observatories. Station Papa (global site A1) is designed to study global circulation, biogeochemistry, and air-sea fluxes in the Northeast Pacific. It will thus provide a far-field reference point for the OOI-supported RCO (red box) and coastal Endurance arrays (two small blues) being installed off the coasts of Washington, Oregon and California.

sites for biogeochemical and oceanographic studies is widely recognized and the CND endorses continued support of time series studies at these sites.

The following is a brief summary of each global observatory site:

Site A1 - Gulf of Alaska, Station Papa
Nominal Site Location 50°N, 145°W.
Water Depth: 4,250 m
This northern site is characterized as a region of net CO_2 uptake with a productive ecosystem. It will provide an upstream physical and biological reference for the RCO and the West Coast coastal observatories (see Fig. 10), will extend long-term historical time-series obtained by ship occupation of the site and by occasional process mooring deployments, closes a gap in the global seismic network, will provide air-sea flux forcing information, and will exploit future synergy with a DART buoy in the vicinity.

Site A2 - Southeast Greenland
Nominal Site Location: 60°N, 39°W.
Water Depth: 2,800 m
This site is a high-latitude location in the North Atlantic, in a strong total and anthropogenic CO_2 uptake region coupled with water mass formation, which is a productive ecosystem and fisheries regime responding strongly to climate variations, and it provides a site to study air-sea flux forcing in an extreme and until now unobservable environment. Real-time access and control of the simultaneous multidisciplinary observations will permit investigations of the forcing of processes leading to climate-related changes in the ecosystem, CO_2 dynamics, and water mass formation.

Site A3 - RIDGE, East Pacific Rise
Nominal Site Location: 9° 50' N, 104°17' W;
Water Depth: 2,500 m
Transient geological processes such as hydrothermal cracking, tectonic earthquakes, and seafloor eruptions will be detected by a local array of seafloor seismographs and geodetic sensors at this RIDGE 2000 Integrated Studies Site. Optical, chemical, and biological sensors and analyzers will be used to examine the temporal and spatial responses of the hydrothermal system to these transient perturbations. The hydrothermal system will be monitored using a diverse suite of instrumentation receiving power from a source on a buoy and having a wired telemetry link to the buoy. Cabled instrumentation will be distributed over an area 11 km x 9 km. Real-time monitoring and instrument command will allow the sampling strategy of in-situ and AUV-mounted instrumentation to be adapted appropriately.

Site A4 - Southern Ocean, Southwest of Chile
Nominal Site Location: 55°S, 90°W.
Water Depth: ~4,800 m
This Southern Ocean site received the highest overall interest as a truly transformative observatory location. It is an important water mass formation site (AAIW), a strong localized southern CO_2 uptake region (Fig. 11), is a productive ecosystem regime, has virtually unobserved processes, closes a gap in the global seismic network, and will provide critical Southern Ocean air-sea flux forcing information. Real-time access and control of the simultaneous multidisciplinary observations will permit the investigation of the forcing of processes leading to climate-related changes in the Southern Ocean.

Site A5 - Southern Ocean, Pacific-Antarctic Ridge
Nominal Site Location: 55°S 150°W.
Water Depth: ~3,500 m (nominal)
This site is a Southern Ocean equivalent in some aspects to station PAPA in the north Pacific. It is a high-latitude location, in a southern CO_2 uptake region (Fig. 11), a productive ecosystem regime, has virtually unobserved processes, closes a gap in the global seismic network, provides critical southern ocean air-sea flux forcing information.

Site 6 - DSDP Hole 396B, Mid-Atlantic Ridge
Nominal Site Location: 22°59.142'N, 43°30.900' W.
Water Depth: 4,459 m
This site is located at Deep Sea Drilling Project (DSDP) Hole 396 B on 13 Ma crust immediately west of the Mid-Atlantic Ridge. Hole 396 B is equipped with a re-entry cone, and has a total penetration of 406 m, of which 255 m is in basement. The equatorial Atlantic, located 145°-170° from the Western Pacific subduction zones, is the optimum region to observe seismic waves that sample the outer core and core-mantle boundary. A broadband borehole seismic station at this site will record these phases; allow measurement of the anisotropy structure and spectrum of lateral heterogeneity of the oceanic upper mantle; and provide long-term observations of earthquake rupture along a large oceanic transform fault. Seismic measurements will be augmented by seafloor electromagnetic and

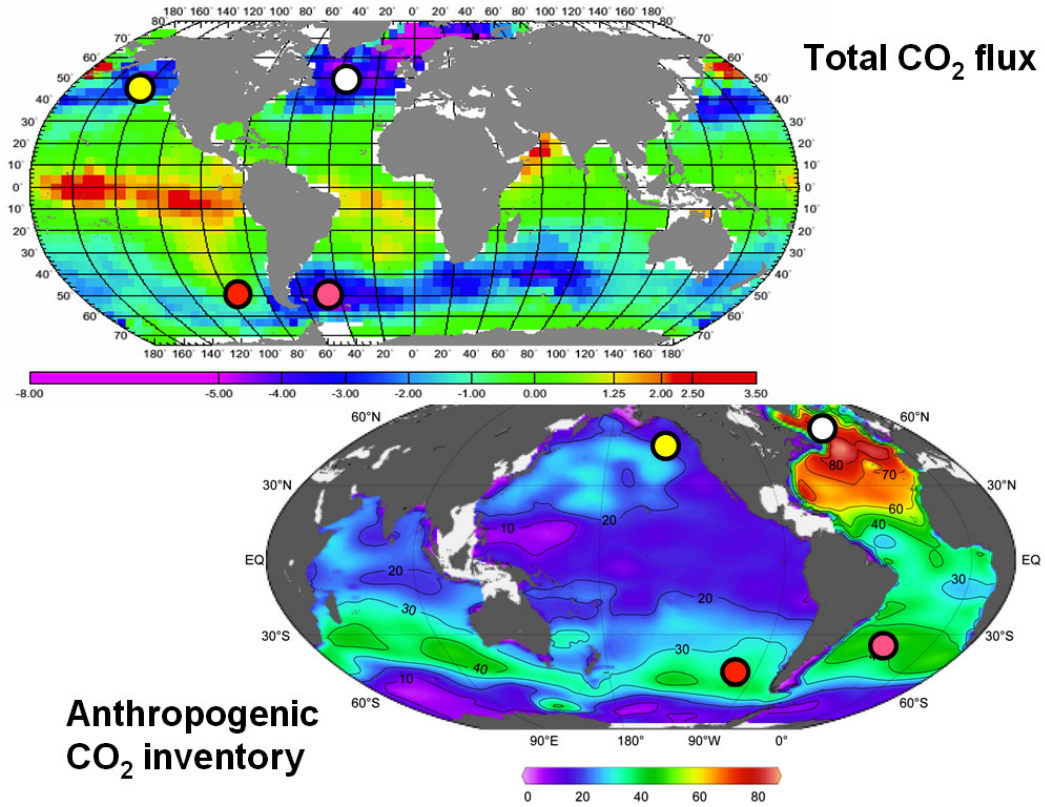

Figure 11. Recommended high-latitude global sites (circles) in regions with large CO2 uptake or inventory without present long-term observing capability.

magnetic field measurements. This site will also allow study of the effects of Saharan dust input to this region of low primary productivity.

Site 7 - Argentine Basin, South Atlantic
Nominal Site Location: 42°S, 42°W.
Water Depth: 5,200 m
This high-latitude site in the South Atlantic is in a region of large CO_2 uptake (Fig. 11), high primary productivity, and strong vertical variation of ocean dynamics. The site closes a gap in the global seismic network, and will provide critical Southern Ocean air-sea flux forcing information.

Site 8 - South Pacific Subtropical Gyre
Nominal Site Location: 28°S, 120°W.
Water Depth: 3,400 m
This site, like Site 6, is located in a region of low primary productivity, and hence contrasts with sites A1, A2, and 7. The site is an important node for the acoustic tomography network.

4. Representative Science Questions and their Links to the OOI CND

This section describes how the infrastructure described in the OOI CND, and summarized in Section 3, will be used to address four specific science questions. These questions, which fall within the broad scientific themes outlined in the OOI Science Plan, are presented only as examples to illustrate the diversity of important scientific investigations the OOI infrastructure will facilitate. We do not mean to imply that these are the only scientific questions the ORION Program will address or that that these are even the highest priority questions. The observations and experiments conducted by the ORION Program at these sites will be chosen based on an NSF-run, peer-review process and will encompass the broad range of ocean and Earth science.

What is the ocean's role in storing anthropogenic carbon and controlling future atmospheric CO_2 levels?

A fundamental and urgent scientific question that requires sustained ocean observations is determining the ocean's role in storing anthropogenic carbon and thus its effect in mitigating future increases in atmospheric CO_2 levels. Ocean waters contain greater than 50-fold more CO_2 than the atmosphere, and hydrate deposits in continental margin sediments contain more than twice the hydrocarbon carbon of all known fossil fuel reserves. Thus, small perturbations in ocean and sediment carbon cycling potentially can result in substantial changes to atmospheric concentrations. Since the Industrial Revolution, atmospheric CO_2 levels have risen from pre-industrial, interglacial values of 280 ppm to approximately 385 ppm today. This increase represents approximately half of the total estimated anthropogenically released CO_2, with the oceans adsorbing most of the other half.

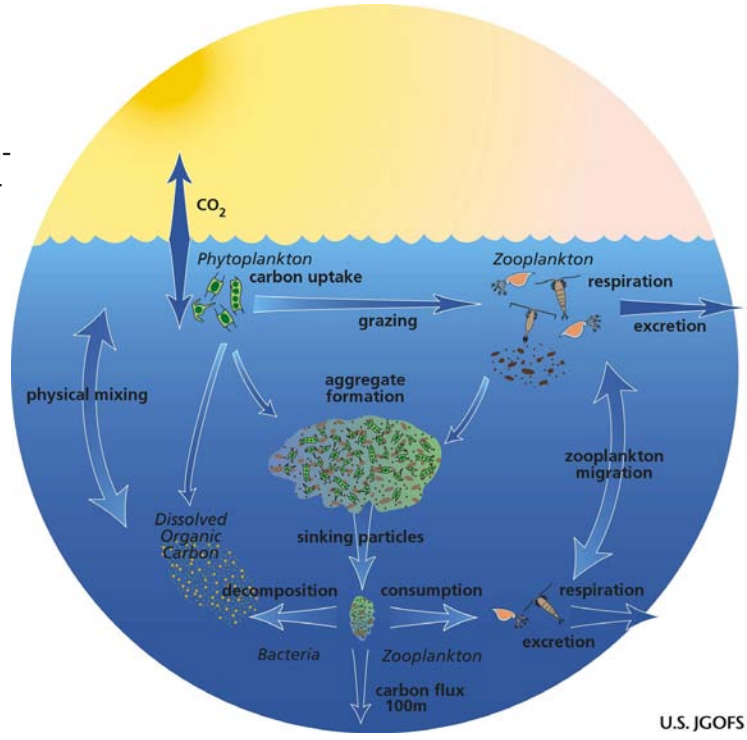

Figure 12. Schematic drawing of the "biological pump" – a set of biological processes that convert dissolved CO_2 in surface waters into particulate and dissolved organic C; some of which sinks or is otherwise moved to deep ocean waters. Some of the C removed from surface waters can be replaced by CO_2 that exchanges between the atmosphere and the ocean. Thus, the net effect of these processes is to "pump" CO_2 from the atmosphere to the deep ocean.

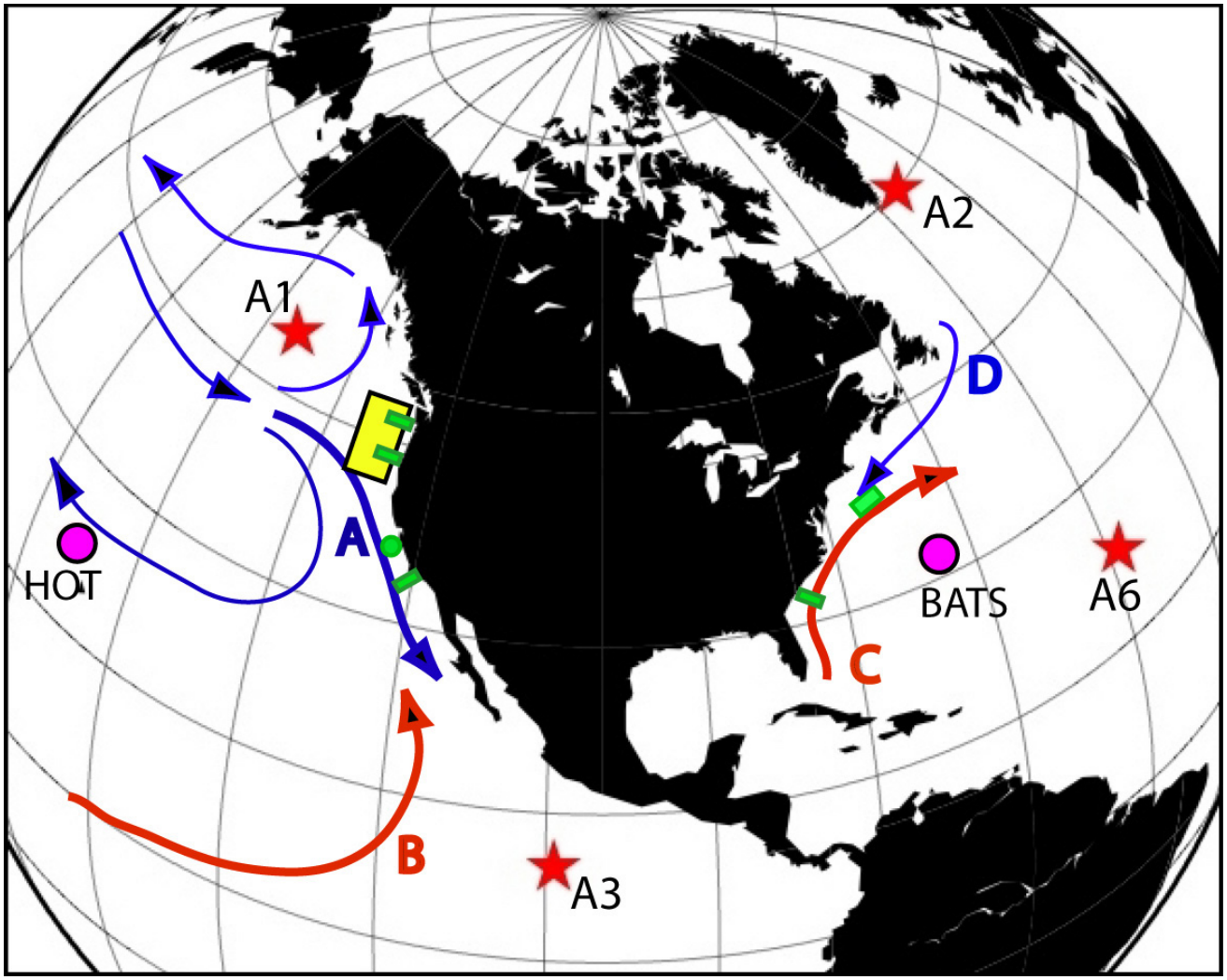

Figure 13. All components of the OOI (global, regional, coastal) will be required to understand the complex interactions of changes in ocean circulation, ecosystems and climate on the North American coastal ocean. The RCO (yellow box) and West Coast coastal observatory (green boxes) will be installed on a narrow continental shelf, bounded by an southward flowing eastern boundary current (California Current, labeled “A”). Wind-driven coastal upwelling in this region supports high rates of primary production. In contrast, the East Coast, where the SAB Endurance Array and Pioneer Array off southern New England will be located (green boxes), is associated with a broad, shallow continental shelf and a western boundary current (Gulf Stream, labeled “C”). Winter storm and wind patterns in the North Pacific change on a 30-50 year cycle (Pacific Decadal Oscillation). These effects are measurable at Station Papa (global site A1; red star) and also in the nutrient content and other properties of the water masses that will move south through the RCO and along the West Coast. The ENSO cycle has effects that propagate from south to north (“B”) along the west coast. During large El Nino events (e.g.1997-98) adverse effects of warm, nutrient-poor waters that move north along the coast adversely impact ecosystems and fisheries as far north as the RCO. The ENSO cycle also affects rainfall patterns and river runoff on the U.S. East Coast affecting coastal waters, for example, in the SAB. Off the East Coast, the Gulf Stream is the primary source of nutrients for the SAB and for the slope waters north of Cape Hatteras. The strength of the Labrador Current (“D”) differs from year-to-year, apparently associated with the state of the NAO. It is a source of cold, low salinity waters that move south along the northeast coast, into the Gulf of Maine and the slope waters. During years of strong flow, it pushes the north wall of the Gulf Stream more than 100-km south. Ecosystem productivity is lower during years of strong flow apparently owing to the lower nutrient content of waters that originate from the north.

The exchange of CO_2 between the atmosphere and the oceans and its fate are mediated by two phenomena. The "solubility pump" is controlled by CO_2 solubility in seawater and gas exchange rate between the atmosphere and the ocean, which principally depend upon water temperature and wind speed, respectively. Net storage of anthropogenic CO_2 is, in turn, controlled by ocean transport away from the sea surface. The second mechanism important to the fate of CO_2 in the ocean is the "biological pump" (Fig. 12). Biological productivity produces particulate and dissolved organic carbon in the surface photic zone. Those materials not recycled within the food web are ultimately transported to deep waters and ocean sediments where they are not exchanged with the atmosphere for centuries to millennia due to the long residence time (thousands of years) of deep ocean waters. Higher CO_2 concentrations in deep ocean waters, compared to surface waters concentrations, is the long-term result of the biological pump.

The OOI CND targets a variety of the critical research needs to understand the ocean carbon cycle. The planned distribution of the global observatory buoys emphasizes high latitude regions that are critical areas for anthropogenic CO_2 uptake and deep water transfer (Fig. 9). Owing to the harsh conditions, especially during winter seasons, there are few existing and no sustained ship-based gas exchange observations at these locations. Thus, gas exchange measurements are planned for site A4 and A5 in the Southern Ocean and at sites A1 and A2 in the North Pacific and Atlantic, respectively, to provide year-round observations at high latitudes not currently available by any other means.

The OOI coastal observatory will enable several critical aspects of carbon cycle dynamics and terrestrial-coastal-open ocean C exchange to be studied. The relocatable coastal Pioneer observatory array, for example, is designed specifically to integrate fixed and mobile platforms to ensure that the measurement resolution needed to define specific mixing and exchange processes is obtained. Although this array is intended to be relocatable with deployment locations and scientific focus competed within the research community, the initial, 5-year deployment is envisioned to be on the Mid-Atlantic Bight shelfbreak off southern New England. The goal of this experiment is to examine cross-margin exchange processes at the shelfbreak, which is at the interface between the broad continental shelf and adjacent slope that is influenced by the Gulf Stream further offshore. Quantifying mass and chemical exchanges at the shelf break is fundamental to advancing understanding coastal-open ocean C exchanges.

The long-term coastal Endurance arrays OOI will establish in the South Atlantic Bight (SAB) off Georgia and off the coasts of Washington, Oregon and California (Figs. 3 and 4) are well situated for studies related to the role of the ocean margins in the ocean carbon cycle. These locations represent major, and contrasting, types of coastal systems, both in the U.S. and globally (Fig. 13). The West Coast Endurance Array will be installed on a narrow continental shelf, bounded by an equatorward flowing eastern boundary current system. Wind-driven coastal upwelling in this region support high rates of primary production, and the coupled biological and physical dynamics are representative of the eastern coastal systems of the Pacific from Vancouver Island to central Chile, and the eastern coast of the Atlantic from the Iberian Coast to Cape Town (Chen et al., 2003). Compilations suggest that these types of systems provide ~40% of the particulate organic carbon transported to below the main thermocline. The other general category of continental margin environment is the "recycling" system (Chen et al. 2003) of which the SAB is representative. These systems are those with wide, generally shallow, sandy continental shelves and a relatively long water residence time. On the U.S. East Coast this system is bounded by the Gulf Stream, a major poleward flowing western boundary current. This type of shelf environment is thought to recycle rather than export most organic matter produced.

Recent studies of the upwelling system off the West Coast of North America indicate an important set of processes of potential significance to the net flux of CO_2 from the atmosphere to the ocean, but which are not yet well understood (Hales et al., 2005). In particular, under circumstances in which plankton production in upwelling waters consumes all of the nutrients in the upwelling water, including the pre-

formed nutrients (thus depleting CO_2 content to the concentrations at or below levels at the time the water mass was formed), there is a potential for a net flux of CO_2 from the atmosphere to the ocean. For this to be a significant process, however, the net flux of CO_2 has to occur before the upwelled waters sink beneath the thermocline or are warmed to the extent that CO_2 begins to flux back to the atmosphere. Measurements along the West Coast Endurance Array of PCO_2, heat flux, phytoplankton biomass, phytoplankton productivity, and nutrient concentrations at fixed depths or measured continuously from vertically profiling platforms could resolve the question of whether plankton production in upwelling waters occurs at sufficiently fast rates to consume preformed nutrients. Ocean current and water density measurements at the fixed sites on the West Coast, supported by measurements from satellites and from mobile assets such as gliders, can be used to determine the residence time and fate of upwelled water masses. Integration of these measurements will resolve questions related to the net flux of CO_2 between the atmosphere and upwelling waters and how the rates of these processes change under different ocean climate conditions (e.g. different stages of ENSO) or with latitude along the west coast of North America. All the sensors needed to make these measurements are available and results can be expected early in the ORION program.

While the U.S. East Coast, represented by a broad shelf and western boundary current, is thought to recycle rather than export most organic matter produced, these types of shelf systems may impact the ocean carbon cycle in other ways. Extensive salt marshes and other terrestrial vegetation that line the coast contribute significant organic and inorganic carbon to nearshore waters that are efficiently transported to the shelf via tidal exchange (Ducklow and McCallister. 2004). With this added C source, the shelf can export C to both the atmosphere and adjacent ocean waters. In the SAB and in other similar regions, the traditional strategy of estimating net ocean CO_2 uptake solely by air-sea exchange is invalid. Detailed studies of the relative dynamics of the rates and controls on lateral transport versus air-sea exchange are needed. Additionally, during the winter, the shallow shelf waters are cooled to temperatures well below the adjacent Gulf Stream. At present, it is unknown to what extent shelf waters containing comparatively high concentrations of C cascade over the shelf break and sink below the less dense Gulf Stream, although recent estimates indicate that this is potentially an important process (Ivanov et al. 2004).

The combination of seafloor measurements of current and pressure under the Gulf Stream using inverted echosounders, HF radar measurements of surface currents across the shelf and Gulf Stream, and detailed measurements planned at the cross-shelf observatory nodes will greatly advance understanding of the interplay between the Gulf Stream dynamics and shelf exchange which is critical to assessing these potential C transfers (Fig. 4). The SAB tower station couplets R7/R8, R2/R3 and R4/R5 could be instrumented with sensors to measure gradients of important C system constituents across the mid to outer shelf. Sensors to measure PCO_2, organic particles and dissolved organic matter (or at least that portion of dissolved organic matter that strongly absorbs at near-UV wavelengths) are currently available. Any or all of the towers could be instrumented for air-sea exchange experiments including direct measurements of the CO_2 flux, as well as the flux of sensible and latent heat. Towers near the shelfbreak at locations R8, R3 and R4 could provide direct measurements of the C system parameters mentioned above, as well as measurements of T and S to calculate water density. These direct measurements, coupled with heat flux calculations, could then be used to calculate the potential for shelf waters to sink during the colder months of the year and to what depth. Thus, an accurate calculation of the seasonal C flux from shelf to sub-thermocline ocean waters based on direct measurements will be possible.

What is the impact of storms and other extreme events on exchanges of heat, gases and nutrients within the ocean-atmosphere-Earth system?

The large surface area and volume of the world's oceans, the high heat capacity of sea water, its chemistry and marine life, and the ocean's ability to

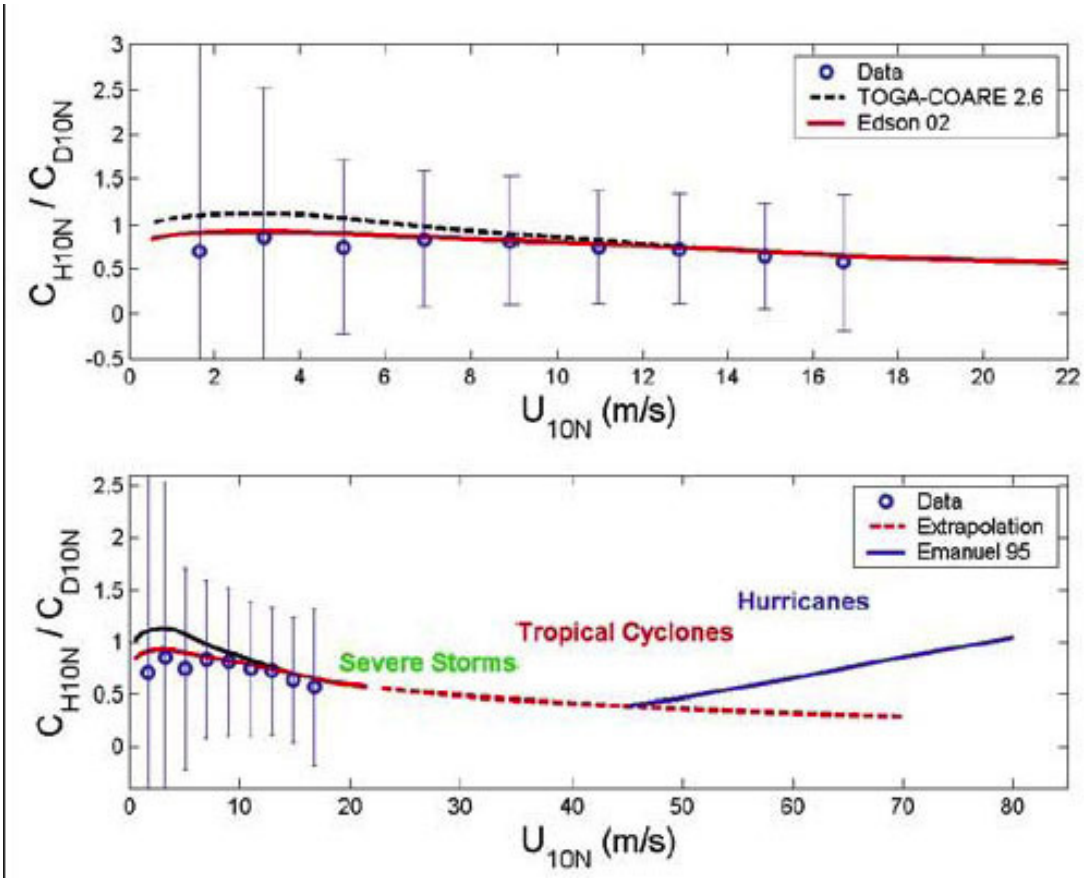

Figure 14. Relationship between the ratio of heat to momentum exchange coefficients (y-axis) versus wind speed (x-axis). Points show where measurements have been made; lines represent extrapolations made for models by Emanuel (1995) and Edson (2002). Note how few data exist for extreme storm events (>20 m/s or ~45 mph).

transport properties across a wide range of latitudes make the oceans a key component of the coupled ocean-atmosphere-land system. For example, the interaction between the sea and the atmosphere strongly influences the development and intensification of storms, including tropical storms and hurricanes, and controls our changing weather on time scales of days to centuries. Wind-induced turbulent mixing in the uppermost ocean affects planktonic community structure, the exchange of nutrients between the mixed layer and deeper ocean, and cycles of primary productivity in the upper ocean. The exchange of heat and gases between the ocean and atmosphere also play a critical role in longer-term changes in the global climate. An accurate quantification of the exchanges of mass, heat, momentum, and chemical constituents between the ocean and atmosphere is essential for a better understanding of these processes.

In the last few decades, substantial progress has been made in making direct measurements of air-sea momentum, mass and heat exchange from buoy, research vessels and other moving platforms (Anctil et al, 1994; Edson et al., 1998; Fredericksson and Davidson, 2003). These measurements have been used to develop the latest generation of flux parameterizations, which agree well with established drag and transfer coefficients for wind speeds between 5 and 18 m s^{-1} (Fig. 14; top panel). However, decades of measurements from research vessels have done little to advance our understanding of air-sea exchanges in severe storms at wind speeds above 20 m s^{-1} (~45 mph) or in tropical storms or hurricanes (Fig. 14; bottom panel). This lack of data at higher wind speeds is a major impediment to forecasting storm intensity accurately. For example, numerical modelers have shown that extrapolation of current parameterizations (broken red line in Fig. 14) does not explain hurricane formation due to too much drag and/or too little heat exchange between the ocean and atmosphere (Emanuel, 1995; Edson, 2002). Hurricane modelers have proposed a different parameterization (blue line in Fig. 14), but it is untested by direct observations.

Our inability to make measurements at high wind speeds is due to the harsh conditions encountered

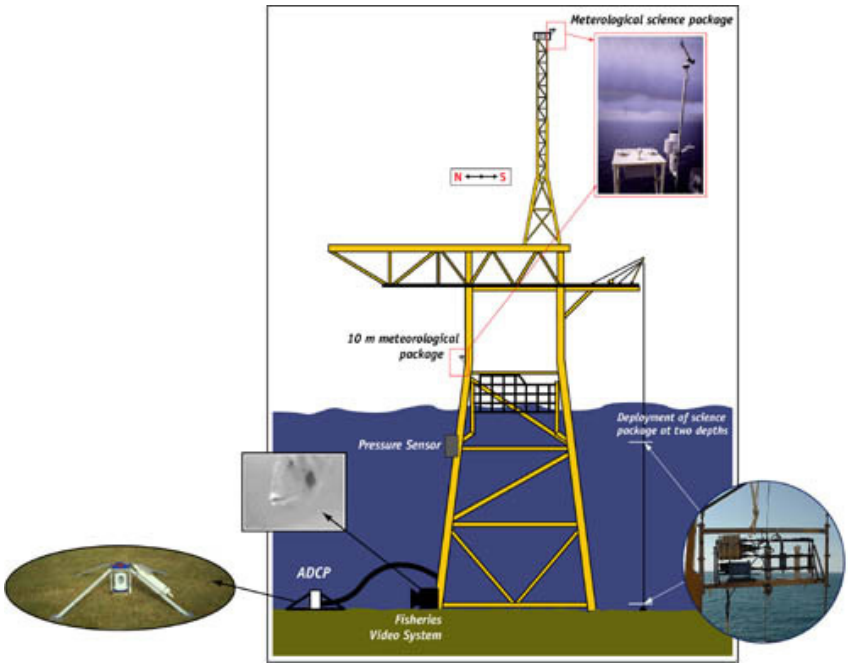

Figure 15. One of eight towers that are part of the South Atlantic Bight Offshore Observation Network (SABSOON) that are being instrumented to provide measurements of shelf meteorology, circulation, hydrography and bio-optical variability with continuous real-time data telemetry to shore. OOI plans to link its South Atlantic Bight Endurance Array to the SABSOON observational network (Fig. 4) providing unprecedented, simultaneous measurements of the importance of episodic events, such as severe storms and hurricanes, on vertical fluxes across the air-sea boundary, through the water column, and at and across the benthic boundary.

at sea during storms and concerns for the safety of the vessels and those aboard. High sea states and surface winds, low visibility and corrosive sea spray often make aircraft operations near the sea surface too dangerous to conduct during intense storms. For example, a recently completed component of the Office of Naval Research's Couple Boundary Layers and Air-Sea Transfer (CBLAST) used aircraft and air-deployed sensors to investigate air-sea exchange in hurricane conditions. The aircraft component of this program successfully measured fluxes near the ocean surface in wind conditions that exceeded 30 m s^{-1} (Black et al., 2006). However, damage to one of the engines due to ingestion of sea-spray forced operations to higher altitudes during the latter phases of the experiment.

Aircraft and ship-based operation will continue to play an important role in air-sea interaction investigations. This is particularly true for the latest generation of oceanic profiler that can be air-dropped into the ocean in advance of severe storms. However, a number of the meteorological and upper ocean components of the OOI will take a significantly different observational approach to overcome current operational limitations in studying severe storms. Specifically, some OOI infrastructure will be placed in regions of the world's oceans that routinely experience severe weather such as "hurricane alley" southeast of Cape Hatteras in the SAB, in the Southern Ocean, and high latitudes in the North Pacific and Atlantic. The high bandwidth, two-way communication and power afforded by these platforms (compared to traditional moorings) will allow the deployment of sophisticated instrumentation that can be run continuously or be activated whenever necessary by command from shore. In particular, the OOI will make a unique contribution to investigations of severe storms by establishing sites in both the coastal and open ocean where long-term, continuous, direct measurements of momentum, heat and mass (e.g., water vapor and CO_2) fluxes can be made and by promoting the development of new generations of sonic anemometers, hygrometers and thermometers that can operate in high wind speed and spray conditions. These measurements will be combined with the oceanographic measurements at all sites to improve our understanding of air-sea exchange and oceanographic forcing/response at all wind conditions.

All surface expression moorings deployed by OOI will be equipped with a standard suite of sensors for air-sea interaction measurements, providing data from both the coastal and open ocean. Of particular interest, however, will be the surface moorings and instrumented SABSOON towers along the South Atlantic Bight (SAB) coastal Endurance Line (Figs. 4 and 15). A variety of atmospheric processes affect the SAB shelf. Winter cyclones that impact the U.S.

East Coast can develop in or cross this region, and tropical storms and hurricanes can pass through the SAB in summer and early fall. Interestingly, maximum wind speeds observed at the SABSOON towers to date have been associated with the passages of squall lines and thunderstorms. These extreme wind events were associated with rapid decreases in air temperature, downpours, and 6-minute-averaged wind speeds of >40 m s^{-1} (89 mph). The fully instrumented SABSOON tower network combined with information from the SAB Endurance Line will provide a unique observational opportunity for spatial coverage below and above the water surface over the duration of extreme storm events. For example, the towers are capable of supporting upward looking remote sensing devices and automated raw insonde systems to provide continuous measurements of boundary layer winds, temperature, humidity, and cloud base height for extensive periods. As such, the ability to conduct in-depth investigations of coupled ocean-atmosphere processes in the SAB region provides an ideal location to develop and improve coupled air-sea models for marine forecasts of wind, waves and currents.

Our poor understanding of air-sea fluxes during winter at high latitudes, especially in the remote Southern Ocean, also limits our ability to quantify these fluxes on a global scale. The OOI will make a unique contribution to improving global estimates of air-sea fluxes by establishing the first permanent instrumented mooring in the remote Southern Ocean (e.g., sites A4 and A5, Fig. 9). Additionally, the West Coast Endurance Array (Fig. 3) will provide ample opportunities to investigate the impact of mid-latitude cyclones upon the Northeast Pacific. These are areas of persistent high winds and storms, which will be ideal for studies of air-sea fluxes under these conditions. This is particularly true of the exchange of CO_2 between the ocean and atmosphere at mid to high latitudes where CO_2 exchange may be significantly enhanced by whitecapping (e.g., Wanninkhof and McGillis, 1999; McGillis et al., 2001). The mid to high latitudes represents the primary oceanic sink of atmospheric CO_2 over the global ocean. Therefore, an accurate parameterization of the CO_2 flux in these regions is of critical importance for accurate estimates of the global carbon budget, climate model forecasts, and ultimately predictions of climate change.

What is the planetary significance and evolutionary importance of microbial activity in the ocean and in the newly discovered subseafloor biosphere?

The oceans cover ~70% of the planet and the most abundant forms of life in the oceans are the marine microbes - the bacteria, archeae and protozoa. These microscopic organisms are the principal engines that drive biogeochemical cycling of major elements such as carbon, nitrogen, phosphate, and sulfur. For example, about 50% of organic carbon production on Earth occurs within the ocean and the vast majority of this organic carbon is generated and remineralized by marine microbes. Microbial processes also control all sulfur reduction/oxidation, nitrogen fixation, ammonia oxidation and denitrification that occurs within the oceans. Microbes additionally serve as important “reporters” for physical-chemical changes in the marine environment as their growth is closely coupled to environmental conditions. Identifying the community of microorganisms present in an ecosystem and how the composition of this community changes over time is a critical first step for understanding ecosystem function and for predicting how ecosystems will respond to changes in environmental conditions from either shorter-term (e.g., eutrophication of coastal waters, over-fishing) or longer-term perturbations (e.g., global climate change).

Current notions of the oceanic food web and the carbon and energy cycles of marine ecosystems are rapidly evolving due to ongoing discoveries of new and diverse groups of marine microbes and microbial capabilities. These new discoveries are occurring despite the fact that relatively few marine microbes can be isolated and cultivated in the laboratory. The marine cyanobacterium Prochlorococcus is now known to be the most abundant photosynthetic organism in the open ocean (Fig. 16). Archaea with unknown community functions were recently discovered to numerically dominate deep-sea planktonic communities. Newly discovered marine microbial

capabilities include novel light-dependent pathways in pelagic marine bacteria (Béjà et al, 2000; Kolber et al., 2001) and nitrate-reducing methanotrophy in marine sediments. Many of the most recent discoveries about microbes have been derived from new DNA-based approaches, the most spectacular example of which is the environmental DNA sequencing of the Sargasso Sea where millions of genes were identified in a single experiment (Venter et al., 2004). These discoveries are exciting, but incomplete; the diversity, functional complexity, vertical distributions and temporal variability of marine microbial communities remain largely unknown.

Even less is known about microbial processes in sub-seafloor environments. Microbial cells in sub-seafloor sediments constitute a large fraction of Earth's total biomass. Tantalizing features, in the form of mineral-weathering textures, provide evidence of microbes in the basaltic crust below the sediment. The greatest depth of life beneath the seafloor, the impact of sub-seafloor microbes on global biogeochemical cycles, the linkages between geological, biological and chemical processes, and the extent to which sub-seafloor life is fueled by geologic processes (mineral weathering, mineral-catalyzed hydrocarbon formation, radiolysis), are unknown. Community connections between oceanic microbes and sub-seafloor microbes are also unknown. The roles of oceanographic processes (e.g., tides, ocean circulation), geologic processes (e.g., crustal deformation, sediment compaction), and combined processes (e.g., heat transport) in driving sub-seafloor fluid movement are little explored. All of these processes must be monitored at relatively fine timescales (hours to weeks) for long intervals of time (years to decades); this need is particularly acute for the geologic processes, which are often expressed episodically and unpredictably (e.g., as earthquakes and volcanic eruptions). The roles played by those processes in formation of sub-seafloor communities and in microbial exchange between oceanic and sub-seafloor communities are completely unexplored.

Water column: The marine realm has been and continues to be dramatically impacted by human activities. It remains exceedingly complicated, however, to assess the current impacts (let alone predict future impacts) of these physical and chemical changes on marine food webs. For example, there is a growing sense that outbreaks of harmful blooms of toxic algae are occurring more frequently, are lasting longer, and are spreading to more places (Fig. 1). In addition, the average pH of the surface ocean has decreased significantly due to the burning of fossil fuels. All organisms that precipitate calcium carbonate to form their shells will ultimately be affected by lower pH ocean waters (Orr et al., 2005). These organisms include corals (with their incredibly diverse microbial communities), coccolithophorids (phytoplankton), and many planktonic snail-like organisms that serve as important food sources for fish. Are the increase in harmful blooms a reflection of disrupted ecosystems as many suggest? How will removal of a major group of microbes such as the coccolithophorids ripple through the food web?

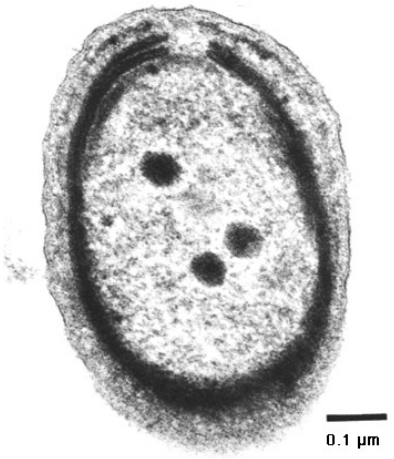

Figure 16. The marine cyanobacterium Prochlorococcus, discovered only in the last 2 decades, is now known to be the most abundant photosynthetic cell in the oceans, often reaching 105 cells ml-1 and accounting for a significant fraction of the chlorophyll in the oceans. The cells are less than 1 micron in diameter, and are quite unusual for prokaryotes in that they contain divinyl chlorophyll a and b as their primary light-harvesting pigments.

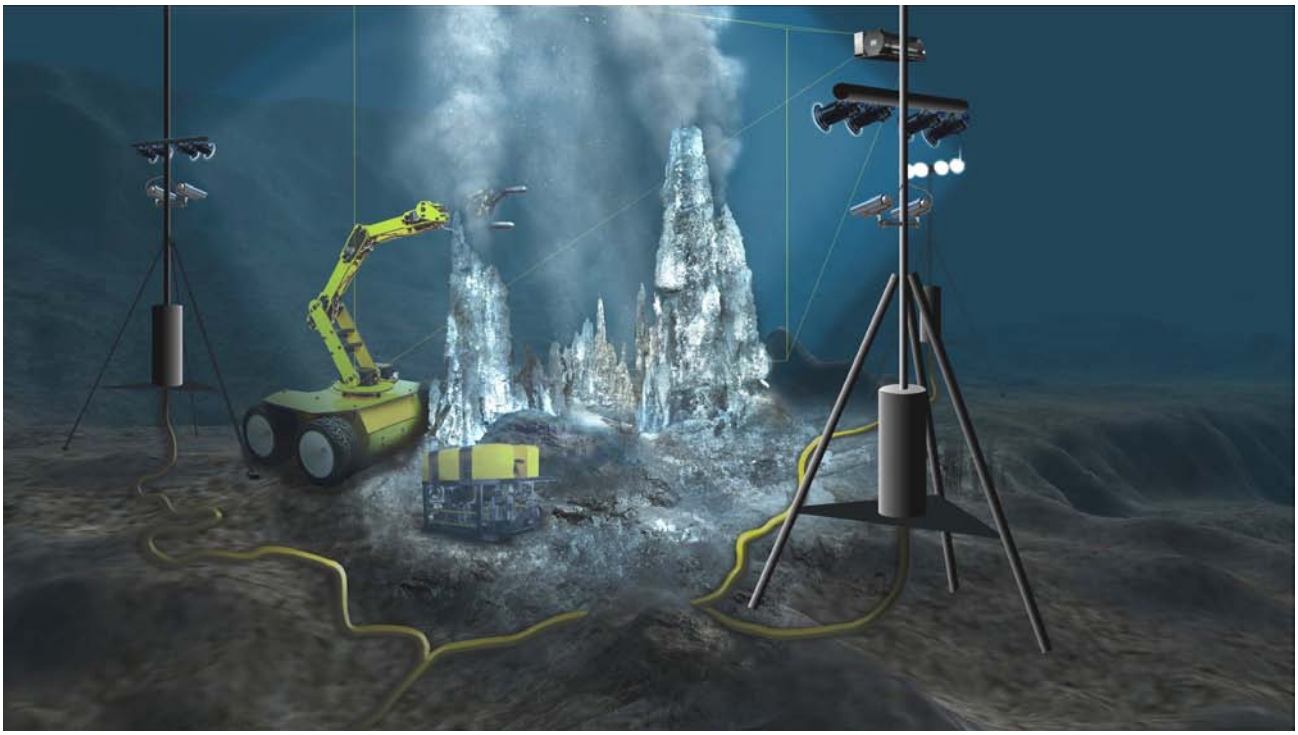

Figure 17. RCO Nodes N4 (Axial Seamount) and N7 (Endeavour Segment) and global site A3 (East Pacific Rise) will provide the power and bandwidth to study microbial activity in the presence of active submarine volcanic systems. One of the most exciting prospects in this field of research is that sophisticated seafloor observatories incorporating in situ seafloor laboratories, like that shown here, or instrumented drill holes, will provide microscopic and molecular analyses of microbial communities, quantitative analyses of fluid chemistry and continuous measurements of temperature, pressure, and fluid flow that will place new constraints on the nature and extent of life in extreme environments on Earth.

Microbes impact ocean processes on timescales ranging from seconds/hours/days to decades/millennia and on spatial scales that range from microns to kilometers. Ship-based sampling strategies simply cannot capture these different time and spatial scales nor the complexity of the microbial communities. Long-term, continuous observations associated with ocean observatories will provide information within the hourly to yearly window of time and on spatial scales that will average over hundreds of kilometers, depending on the complexity of the array. The ability to collect biological/chemical/physical data over long time series will ultimately provide insights into the resiliency/stability of marine ecosystems.

Sub-seafloor: Study of sub-seafloor life requires ocean observatories for at least three reasons. First, microbial activities and rates must be studied in situ. Second, many of the processes likely to affect sub-seafloor communities and activities are episodic [e.g., changes in fluxes of nutrients and electron donors (food)] due to volcanic events, earthquakes, or episodic release of hydrocarbons from deep reservoirs. Third, the process of entry into the sub-seafloor (e.g., by drilling) alters the environment and days to years are required for the environmental properties of fractured subsurface systems to return to stable background values.

Several different fracture-permeable environments are of interest for study of sub-seafloor life. These include:

(1) carbonate vent systems where H_2 and CH_4 are generated by interaction between seawater and mantle peridotite,

(2) sediment-rich continental margins where methane is produced and intermittently vented, and

(3) mid-ocean-ridge hydrothermal systems, where a variety of magmatic gases (CO_2, H_2, H_2S, SO_2, CH_4) are present.

Each of these types of venting systems operates in an episodic manner driven by unpredictable

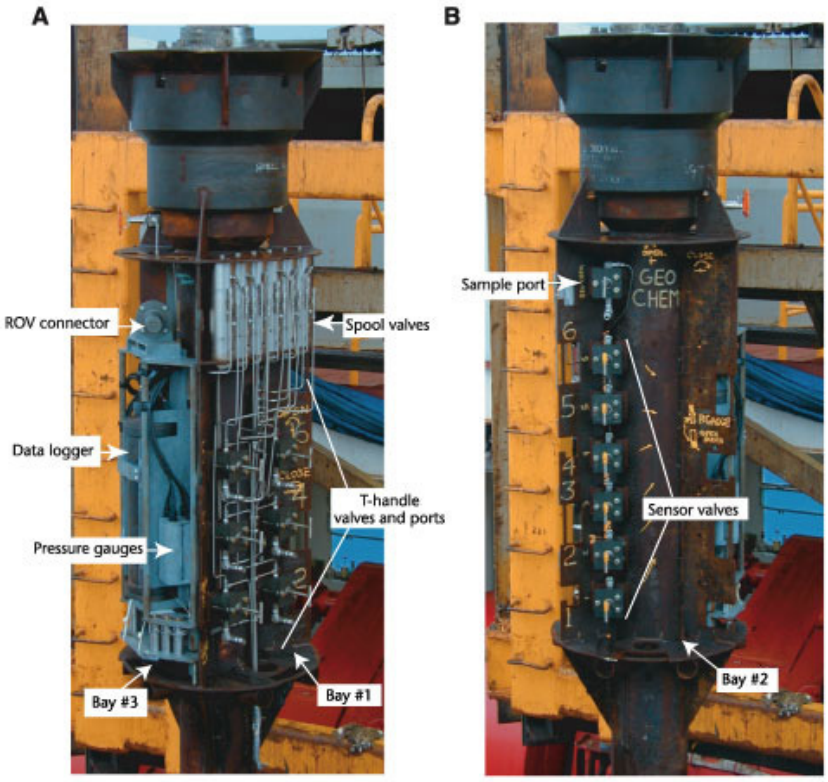

Figure 18. Cooperation between OOI and the Integrated Ocean Drilling Program (IODP) will provide exciting new opportunities to understand sub-seafloor microbial communities and processes in a variety of geologic settings. The OOI network can provide power and two-way, real-time data telemetry to these borehole observatories. Shown on the right are two views of the head of the IODP ACORK (Advanced Circulation Obviation Retrofit Kit) that has been designed to isolate multiple zones in a borehole for independent investigation. ACORKs allow sub-seafloor biosphere studies in the context of their hydrological, chemical, microbiological, and thermal regimes, as well as hydrologic responses to seismic ground motion, tides, and barometric loading. The RCO will link several existing borehole observatories on Juan de Fuca plate to the OOI network (Fig. 4).

geophysical or thermal events. The only means of studying these systems is to install the infrastructure and sensors necessary to detect these events, and to provide the capability to adaptively measure and sample remotely the microbial and biogeochemical changes induced by these events.

All components of the OOI (global, regional, and coastal) will contribute to better understanding of microbial communities, activities and significance in the ocean. The RCO, for example, will be particularly useful for studying sub-seafloor microbial processes. Node N1 is located on Hydrate Ridge and thus ideally located for studies of sub-seafloor microbes on a continental margin where methane is produced and intermittently vented. N4 on Axial seamount and N7 on Endeavour, as well as global site A3 on the East Pacific Rise will study microbial activity in the presence of active submarine volcanic systems (Fig. 17). RCO node N2 is located in a unique mid-plate setting far from any active plate boundary, and will help elucidate microbial processes on the vast abyssal seafloor. RCO nodes are excellent candidate sites for instrumented drill holes for studies of microbial communities, quantitative analyses of fluid chemistry and continuous measurements of temperature, pressure, and fluid flow (Fig. 18). The RCO is also a logical site to test new in situ instrumentation that will likely require, at least initially, more power than can be easily provided by moorings. The proposed global CND sites (Fig. 9) will also sample a wide range of ecosystems including regions of both high and low surface productivity at both mid and high latitudes. The high latitude sites, especially those in the Southern Ocean, are of particular interest since almost nothing is known about the microbial communities in these remote areas.

The use of ocean observatories for effective study of oceanic and sub-seafloor microbial systems will require integrated analyses of biological, chemical and physical properties. To maximize progress over the next ten years, complete characterization of these properties will require a long-term program of in situ analyses, paired with sampling for significant properties that are not currently measurable in situ. Sensors that detect biological properties are currently the least well developed instrumentation, but are critically important from both scientific as well as societal perspectives.

Existing in situ biological sensors consist largely of bio-optical devices that measure light scattering as a proxy for biological particles, or chlorophyll a (and other pigments) fluorescence as a proxy for phytoplankton. Biological sensors under development include in situ flow cytometers that measure light scatter and fluorescent properties of individual particles (Sosik et al., 2003) and genome-based sensors that detect DNA or RNA of different organisms. Genomic-based technologies continue to expand rapidly and many of the newest genomic and proteomic techniques have been successfully applied to laboratory studies of marine microbes. However, none of these technologies are currently used to study microorganisms in situ. The sensitivity, specificity and reliability of ocean-going biological sensors will require intense and accelerated development so ocean observatories can provide a maximum amount of information.

Molecular detection methods (gene chips and protein chips) can be used in situ to characterize aspects of genetic potential, community composition, and genetic expression. A variety of physical and chemical probes can be used in situ to measure key environmental properties, including temperature, chlorinity, chlorophyll content, and concentrations of key microbial products and reactants. For the foreseeable future, some key properties, such as microbial diversity and occurrences of unanticipated microbes, may require biological samples to be taken at appropriate intervals, fixed, and eventually retrieved. Osmotic samplers sample continuously and, after retrieval, allow a very broad range of chemical concentrations to be determined, including many chemicals not measurable by in situ analyzers. At sub-seafloor observatories, incubation arrays (e.g., polished rock chips, mineral-packed columns) will provide a direct measure of mineral weathering rates, biofilm development rates, and biofilm composition. Both biological samplers and chemical samplers can be retrieved and replaced during a standard maintenance trip to an observatory (e.g., once per year). These systems of combined in situ analyzers and samplers will document community composition and environmental context at individual points in time.

An exciting aspect of ocean observatories is that real time detection of particular events will allow sampling protocols to be modified “on the fly.” For example, a sampling protocol could be modified in response to detection of a species of toxic algae (a relatively ephemeral event) to focus the sensor system on monitoring whether a full scale bloom is in progress or is simply a low level event. Likewise, episodic oceanographic or geological events could trigger a new set of observations related to the change in microbial populations and their physiological activity. The power of such event-driven strategies is extraordinary and opens broad new areas of investigation and knowledge generation about marine ecosystems, their functions and the factors that influence their ability to provide the ecosystem services that influence the global climate.

What controls the initiation and propagation of rupture along a fault, and thus the frequency and size of earthquakes?

The great Andaman-Sumatra earthquake in December 2004 illustrated how vulnerable coastal communities are to major earthquakes and associated tsunamis. While considerable progress has been made in forecasting and providing early warning for many types of natural disasters (e.g., volcanic eruptions, hurricanes, tornados), earthquake prediction remains beyond our reach. At present, plate tectonics provides a framework for understanding where earthquakes are most likely, but the processes that control the initiation and propagation of a rupture along a fault remain elusive. In spite of a number of false alarms, no consistent and reliable indicators of imminent rupture have been identified. The OOI will lead to better understanding of the fundamental physics of earthquake rupture, which should in turn lead to better estimates of seismic and tsunami hazards.

Although many earthquakes occur in the oceans, including the largest historical events, which have occurred on offshore subduction zones (e.g., Chile, 1960; Alaska 1964; Sumatra, 2004), studies of earthquake physics to date have focused on continental faults. This has been in large part due to the difficulty of making long-term observations in

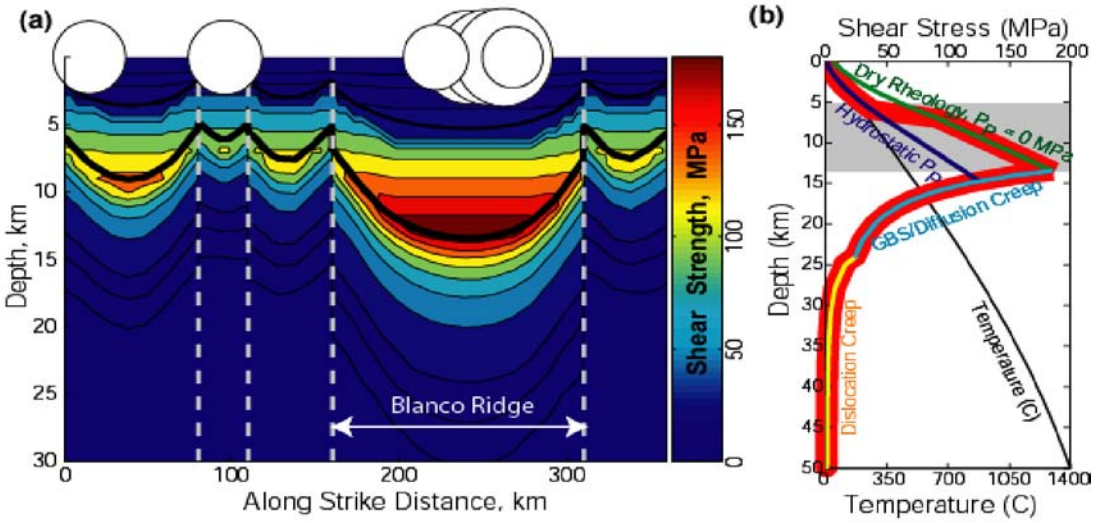

Figure 19. (a) Predicted maximum shear strength on the Blanco Transform Fault. Magnitude 6 and greater earthquakes (white circles) are plotted at their epicentroids and are sized assuming a stress drop of 1 MPa and that slip scales with rupture area. Black curves show the 250 °C and 600 °C isotherms and delimit the seismogenic zone. (b) Strength envelope (red) for the calculated geotherm at the center of the Blanco Ridge fault segment assuming a model with 3 km of ocean, hydrostatic pore pressure in serpentinized oceanic lithosphere from the seafloor to the 350 °C isotherm, and a dry peridotite mantle below this depth.

the ocean. The RCO will enable such observations. Examples of three complementary observations made by the RCO that will lead to a better understanding of earthquake physics and related processes are:

1) observations of earthquakes and related geodetic strain and fluid flow through an entire seismic cycle on a typical oceanic transform fault;

2) monitoring of seismicity associated with the "locked zone" of a major oceanic subduction zone; and

3) identification of fluid flow and/or seismicity triggered by distant tectonic activity.

The global component of OOI will contribute to this effort by expanding seismic and geodetic coverage to remote parts of the ocean basins, contributing to higher resolution models of mantle dynamics and lithospheric tectonics.

The seismic cycle on a transform fault: Node N3 of the RCO, which will support an array of seismometers and strainmeters on the eastern Blanco transform (Fig. 6), will provide a unique data set for understanding seismic activity and strain throughout the seismic cycle in an oceanic transform fault, and the knowledge thus gained should lead to new constraints for interpreting the behavior of continental transforms like the San Andreas fault. Since 1967, the eastern Blanco transform fault, which forms the southern edge of the Juan de Fuca plate, has experienced five magnitude 6-6.5 earthquakes, implying a recurrence interval of ~10 years. We can therefore expect to record at least one full seismic cycle during the lifetime of the RCO. The predicted temperature structure and rheology of the Blanco transform fault are shown in Figure 19. At present the initiation depth and fault propagation history of earthquakes is poorly constrained. Accurate earthquake hypocentral locations, seismicity patterns, waveform records and geodetic strain measurements will be used to constrain models of detailed faulting histories for the larger events. This will lead to improved understanding of the effects of temperature, rock rheology, and pre-existing fault geometry on earthquake initiation and propagation. Particularly interesting for potential earthquake prediction is the suggestion that ocean transforms show distinct precursory seismic activity (McGuire et al., 2005).

The Cascadia megathrust: Paleoseismic data acquired over the past decade indicate that the Cascadia subduction zone has repeatedly experienced "great" earthquakes and tsunamis in the past (i.e.

Charge to the Ocean Observatories Initiative "Blue Ribbon" Review of the OOI Network Design

Rationale for Review

OOI planning has proceeded through the Concept Phase and a Conceptual Network Design (CND) has been developed from Request for Assistance (RFA) proposals, community comment, and advice from the ORION advisory structure. RFA Proponents were asked to submit proposals with well-described scientific objectives that relate to, or advance beyond the scientific themes identified in the OOI Science Plan.

This "Blue Ribbon" review will assess whether the ocean observing network proposed in the OOI CND will provide the capabilities for the ocean researchers to significantly advance knowledge of high priority questions challenging the ocean science community. Specifically, this review will determine whether the proposed OOI CND will provide capabilities to enable major advances in the scientific themes outlined in the OOI Science Plan now and over the lifetime of the network. In addition, this review will assess whether the network will enable researchers to answer high priority science questions that require *in situ*, real-time measurements across the three scales of the OOI.

Format of Review

The input to this review will be the "OOI Scientific Objectives and Network Design" document to be produced by the ORION Observatory Steering Committee. This document will clearly articulate priority science questions that will be examined using OOI infrastructure described in the CND. This document will be mail reviewed and then discussed by the panel during a half-day videoconference. The drafting of the review document will proceed in parallel to the CDR. This report will be submitted to NSF by July 14th for distribution to panelists. A videoconference to discuss reviewer concerns and comments will be scheduled in mid August to coincide with or precede the CDR. In this way, comments from the "Blue Ribbon" panel can be considered along with any changes to the CND that arise out of the CDR.

Charge to Panelists

Panelists are asked to review the "OOI Scientific Objectives and Network Design" document and assess:

- whether the questions posed in the document are of high priority for advancing ocean science research and understanding;
- whether the network infrastructure envisioned for the OOI will lead to major advances in the oceanographic questions posed in the OOI Science Plan,
- whether all scales of OOI infrastructure are being fully utilized, where appropriate, to answer the questions outlined
- what experiments, observations or activities are likely to yield early success for the ORION program and how can ORION facilitate that success.

Blue Ribbon Review of the "OOI Scientific Objectives and Network Design"

Summary of Panel Discussion

Introduction

A "Blue Ribbon" panel was assembled by NSF to provide a non-advocate review of whether the Ocean Observatories Initiative (OOI) Conceptual Network Design (CND) will provide the ocean research community with infrastructure capable of addressing high-priority science questions that have driven the need for this initiative. Panelists reviewed the "OOI Scientific Objectives and Network Design" document prepared by a writing team selected by the Observatory Steering Committee of the ORION Advisory Structure. To demonstrate the scientific capabilities of the OOI CND, the authors of this document had chosen five high-priority science questions that correlated to the five broad science themes in the OOI Science Plan.

The panel was informed that the purpose of this report and "Blue Ribbon" review was to provide the NSF with an assessment of whether OOI infrastructure being implemented using MREFC funds will be able to address high-level science questions facing the ocean science community. The audience for this report is not only the NSF but also the ocean science research community.

This panel was comprised of nine, non-advocate members of the ocean science research community:

Robert Beardsley	(WHOI)
Peter Brewer	(MBARI)
Annette deCharon	(Bigelow)
Edward DeLong	(MIT)
Paul J. Fox	(TAMU)
David Karl	(Hawaii)
Tom Rossby	(URI/GSO)
Sean Solomon	(Carnegie) - Chair
Cindy Lee Van Dover	(Duke University)

Panelists were asked to assess whether the network design summarized in the "OOI Scientific Objectives and Network Design" document would provide capabilities needed to address the science questions posed and, more broadly, whether OOI infrastructure would provide the ocean science community with infrastructure that is able to answer high-priority science questions. Panelists were asked to review the "OOI Scientific Objectives and Network Design" document and provide written comments that included answers to the following:

- Are the questions posed in the document of high priority for advancing ocean science research and understanding?

- Will the network infrastructure envisioned for the OOI lead to major advances in answering the oceanographic questions posed in the document?

- Will the OOI network provide capabilities to the ocean science community that will be transformational in nature?

- Are all scales of OOI infrastructure being fully utilized, where appropriate, to answer the functions outlined?

- Will the scientific objectives and network design discussed in the document have significant broader impacts?

Written comments were distributed to all panelists and then discussed on a conference call held on August 2, 2006. This report summarizes the outcomes of the group discussion and also provides specific comments from the written reviews that the panelists felt were of high priority. The outcome of the "Blue Ribbon Review" as summarized here will be provided to the Ocean Sciences Division Director and the Directorate for Geosciences Assistant Director. This report will also be provided to the writing team to guide revision of the "OOI Scientific Objectives and Network Design" document. The Blue Ribbon

Panel will review this revision and, if it is acceptable, will provide their signoff and approval of the final document.

Overall Assessment

The panel endorses the OOI as a worthy investment that when implemented will advance our understanding of the Earth and the oceans. The planned infrastructure attempts to strike a balance among the diverse scientific objectives of the ocean science community and the inevitable limitations on cost and scope. The "OOI Scientific Objectives and Network Design" document, after a number of issues identified by the panel and elaborated below have been addressed, will demonstrate by multiple examples that the current CND with at most modest modifications can achieve a broad range of important scientific objectives that cannot be met by other existing programs or facilities. While the proposed OOI infrastructure and approach cannot serve all needs of the ocean science community, it is an important first step in implementing new enabling technologies. It will be important to foster development of sensors and technologies that enable all sub-disciplines including physical, geological, chemical and biological oceanography. Critical to its success will be the appropriate matching of relevant science questions with appropriate enabling infrastructure and technology.

Panel Recommendations

Significant Concerns

Re-formulation of science questions posed in the document

The panel felt strongly that, although the science questions outlined in the "OOI Scientific Objectives and Network Design" document are of high priority, in many cases they are not those best addressed by the infrastructure as currently proposed in the OOI CND. **Therefore, the panel recommends that the authors re-visit the list of questions and develop a list that is more tightly coupled with the capabilities provided by OOI infrastructure.**

As only one example, on page 4 an example of a key scientific question relates to conditions that trigger harmful algal blooms (HABs), yet it is not clear from the document that the locations chosen for the coastal arrays are areas heavily impacted by HABs. Further, coastal arrays are located in areas influenced by major regime shifts, yet this topic received less emphasis in the text.

Matrix of science questions leading to required network capabilities

The panelists felt that, once the science questions provided in the document are revised, the authors should develop a "traceability" matrix in which each of these questions leads to high-level infrastructure and measurement requirements needed to address the question. In this framework, instances where the OOI provides the full capabilities needed could then be identified, and those areas where the network does not provide all of the needed capabilities would be apparent. As a primary purpose of the document was to link proposed network capabilities to the science they will enable, more detailed information on specific capabilities must be provided to more clearly articulate how they will address the science. The process of constructing such a matrix is an iterative one, in that the capabilities envisioned will help to narrow the focus of the questions to those best addressed by those capabilities.

Timeline of network installation and capabilities

The panel felt that a table providing an estimate of when essential sensor technologies will be ready for deployment on the OOI network and when major components of the network will be in place should be added. Such a timeline table will provide a basis for assessing when the earliest answers to the various science questions might be obtained. ***In particular, it would be prudent to include in this document discussion of an important science question that is likely to be well addressed early in the 25-30-year timeline for the network.***

Description of evolution of OOI network after initial installation

In some sections of the document there appeared to be a mismatch between the scientific questions and the likelihood that technologies would be available to address these questions within the 6-year implementation of the OOI. Presumably, sensor development will be ongoing, and once operational the network will evolve through the addition of capabilities and the replacement of components that are more efficient or more capable than those first installed. **The panel recommends that the sense of a network that continues to evolve and improve after the initial installation period be more explicitly described in the document. This should include some details on envisioned network development and new capabilities it will provide.**

Need to enhance mobile platform capabilities

OOI planning has been a decade-long endeavor. During this time, the reliability and usability of mobile platforms, such as gliders and AUVs, have been greatly enhanced. Because of programmatic boundaries placed on the OOI and the previous lack of highly reliable mobile platforms suitable for use in an observing context, mobile assets are not well integrated into OOI network plans. Where they do appear in the CND, mobile assets are not allocated sufficient resources to provide the capabilities needed to address horizontal heterogeneities that will be present in various ocean parameters. **Therefore, the panel recommends 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.**

Greater emphasis regarding the OOI as a driving force for new technologies

The International Decade of Ocean Exploration (IDOE) left the ocean science community with a legacy of essential tools that today form the core of many field experiments. In a similar fashion it could easily be argued that the OOI will provide the same technology push to develop and enhance platforms and sensors that will benefit the ocean science community more broadly than those investigators using the OOI network. **The document should better articulate the importance of the OOI in transforming the tools that will become readily available to the ocean research community in the future.**

Greater emphasis on cyberinfrastructure capabilities provided by the OOI

Cyberinfrastructure (CI) will provide essential capabilities for the OOI network yet these were not clearly articulated in the text, and it was not clear what benefits this system would provide to the end user. **The panel recommends that the document more clearly articulate the role of CI within the OOI network and its importance for the overall transformative ability of the OOI within the ocean science community.**

Better convey the exciting science and capabilities provided by the OOI

Although the document discussed the broad utility of the OOI network, the text should radiate a clear sense of excitement. If OOI infrastructure will lead to a transformation in the way the ocean research community will operate, the document should better capture this transformation and the exciting discoveries that will result. On balance, this enthusiastic portrayal still needs to carefully avoid mismatch between OOI infrastructure capabilities, and high priority science questions.

Additional Concerns

The reviewers also identified other areas of concern that the authors should address when revising the “OOI Scientific Objectives and Network Design” document.

- Education and outreach capabilities provided by the OOI need to be better integrated into the body of the report and not included at the end as if they were an afterthought.
- The need for modeling and data assimilation to be an integral part of the OOI cyberinfrastructure should be emphasized in the report.

- The report should be candid about limitations in the OOI network as one that will provide the capability to address some questions but will not be well suited to other types of questions.
- The report should better articulate how the OOI network will stimulate other activities that will build constructively on the observations by the OOI network.
- The report should provide a more comprehensive statement on partnerships, including those with other NSF programs, other agencies, international partners, and industry. These partnerships should be highlighted with specific examples in the report where appropriate.
- Plans for the coastal array should be revisited in light of needed capabilities for power and bandwidth as well as interactive capabilities provided by seafloor cables versus the more limited capabilities provided by moorings.
- The rationale for the Southern California Bight coastal array in particular should be reviewed to see if this element is really needed for the scientific questions to be addressed by the rest of the west coast array and whether a moored array is the best approach.
- It may be useful to take one or two representative questions in the report and use them to show how partnerships will be leveraged, education will be incorporated, mobile assets will provide essential capabilities, and other strengths of the program.
- Ships will remain a critical tool in ocean research, and this report should so acknowledge.
- The report should emphasize the importance of the OOI as a potential catalyst for using existing technologies in new ways, and further enabling sea-going science.
- It should be stated how those making critical design decisions on the OOI network will ensure that the most up-to-date technologies are integrated into the OOI network in later years of installation.
- The Preface to the report should include a statement on the intended audience for the report and should more clearly state that the report was assembled for the purpose of a programmatic review.
- 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. The coastal component has no presence in the Gulf of Mexico. Statements such as this should be replaced with "from many points in the world oceans".
- Scientific ocean drilling has drilled holes into the seabed to specifically study, measure and monitor the hydrogeology of oceanic crust. Some of these holes/observatories have been drilled into the Juan de Fuca plate. On page 27 of the OOI document in Fig. 18 there is acknowledgement that IODP endeavors regarding the geohydrology of the subseafloor provide a great capacity building opportunity, but there is no clear reference to linking the RCO network to these existing sites. In the Fig. 18 caption, there is reference made to a Fig. 4 that integrates these drill sites, but Fig. 4 is a map of the South Atlantic Bight Endurance Array.
- Overall, the text needs editing to help make it clearer and more compelling. It is desirable that the text read as if it were written in a single voice. Another run through on careful fact checking on some of the scientific detail also appears necessary.

Specific Report Comments

Some specific comments on the report were highlighted in written comments by the panel. These should be incorporated in revisions where appropriate.

- Throughout the text there is uneven referencing to statements that are made. For example, on p. 28 on the left in line 8, (Sosik et al. 2003) is called out but elsewhere key references are not given. The Chen et al. (2003) reference is missing in the reference list.
- "Archaea" should be properly spelled (pp. 2 and 24).
- p. 1, right, 6 lines from bottom: the institution for John Collins should probably be WHOI.
- p. 2, para 1: the "two-thirds" figure doesn't really dramatize the enormity of the ocean… what about 98% of Earth's water instead? (The ~70% ocean coverage statistic is used at least twice more later in the document.)
- p. 2, para 1: "modulates" is probably not the best term to use here because it infers that the ocean is "proactive" rather than reactive. (Definitions include "To adjust or adapt to a certain proportion; regulate or temper"; "To change or vary the pitch, intensity, or tone of (one's voice or a musical instrument, for example)."
- p. 2, para 1: add the word "theory" after "plate tectonics."
- p. 2, paragraph 6 => "The impact of human activity on Earth's climate and its marine ecosystems" is not a question.
- p. 2, right, last para, lines 5-7: The wording is awkward. It mentions the synthesis of nutrients...but matter cannot be created nor destroyed. The authors may have meant fixation (reduction) of N_2 gas to NH_4 as a possible way to synthesize available nutrients. There is no analogous pathway for P. Also N/P are listed as nutrients whereas S is an associated biogenic element. All (N/P/S) are elements, and all are nutrients.
- p. 5, para 2: need clearer segue from high-temperature to low-temperature fluid systems (diagram would help that shows how sediments thicken away from mid-ocean ridges towards continents but that fluid flow occurs throughout… also would help illustrate dewatering of subducted materials).
- p. 6, para 2: plate tectonics is more of a unifying theory than a "scientific revolution."
- p. 6, para 2: it is not clear how OOI will make a major impact on elucidating "the origin of Earth's magnetic field."
- p. 6, para 5: transition from "Science Themes / Questions" to "Summary of the OOI Conceptual Network Design" and associated description of the overall selection process is fairly abrupt. Did science questions from the proposals frame the CND, Did the "Top 5 science questions that could be answered with OOI technology" pre-date the proposals, or something else? The issue of "science / societal needs driving technology" versus "technology furthering science / meeting societal needs" could be nicely addressed here. (This issue is part of the National Science Education Standards for pre-college students – "Science in Personal and Social Perspectives.")
- p. 7, para 5: it would be easier on the reader if descriptions of the coastal - regional - global systems came in the same order as the list on pages 6-7 (i.e., presented as global - regional - coastal).
- p. 18, right at bottom: What about the terrestrial sink for CO_2?
- p. 24, right, last para, line 2: Should say pathways rather than cycles since energy flow is unidirectional.- p. 25, left, line 3. Delete "nitrate" and replace with "sulfate" – nitrate-reducing methanotrophy indeed occurs and its microbiology has been recently described – but it occurs in freshwater, not marine sediments. "Sulfate-reducing methanotrophy" works OK here.
- p. 25, left, line 9: Should exchange the word collection for experiment. This was not really an experiment in the scientific sense of the word.
- p. 26, right, para 2, line 10-12: pH of near surface seawater has decreased because of increased CO_2 content, which derives from the burning of fossil fuels. The statement may not be correct as it stands.
- p. 26, same section: what about forams; they are probably more important, or at least as important, than "snail-like" organisms (pteropods?).
- Fig 16 caption: There are 10e5 or 100,000 cells per ml, not 105 cells.

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?

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

Review Report of the
NSF Conceptual Design Review Panel

for the

Ocean Observatories Initiative

August 14 – 17, 2006
Monterey Bay Aquarium Research Institute
Moss Landing, CA

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

Program Team

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

August 14th A.M. **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*) • Meeting agenda; goals of review	Pacific Forum
9:15–9:30	OOI History & Organization (*Daly*) • Priority science questions • Observatory elements • Conceptual Network Designs	Pacific Forum
9:30–9:45	NSF Report (*Isern*) • Funding • MREFC process • "Blue Ribbon" review panel	Pacific Forum
9:45-10:30	OOI Network Overview (*Williams*) • Implementation Management • JOI Organization • Risk Management	Pacific Forum
10:30–10:45	*Coffee Break*	
10:45–11:00	Coastal Scale Observatory (CSO) (*Schofield*) • Science User Requirements • Conceptual Design	Pacific Forum
11:00-11:15	Regional Cabled Observatory (RCO) (*Kelley*) • Science User Requirements • Conceptual Design	Pacific Forum
11:15-11:30	Global Scale Observatory (GSO) (*Weller*) • Science User Requirements • Conceptual Design	Pacific Forum
11:30–11:45	Cyberinfrastruture (*Arrott*) • Requirements • Conceptual Design	Pacific Forum
11:45-12:30	Program Management (*Lunde*) • Project Baseline • Schedule • 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

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)

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

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	

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	

NSF Conceptual Design Review Panel

Response categories:

HP = Highest Priority, description of plans to address them must be submitted in written form to NSF by September 22nd
P = Priority, description of plans to address them must be submitted in written form to NSF by November 1st
E = Essential, plans to address must be included in the Project Development Plan and must be addressed by the PDR
I = Important, recommendation must be followed with plans outlined or completion by PDR
D = Level of compliance up to the discretion of the office but approach must be defended at the PDR

Response Log

Project

Rating	Recommendation	Response Group	Timeframe for task completion
HP	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.	JOI	
I	The process for allocation of contingency along with the division between centrally held contingency and contingency assigned to the IOs needs to be agreed to before the preliminary design review.	JOI	
D	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.	JOI	
HP	NSF/JOI should evaluate the schedule for the PDR to allow the maximum preparation time for the newly selected IOs. NSF and ORION should develop a clear description of project completion as soon as possible. **(In conjunction with NSF)**	NSF/JOI	
E	JOI should consider providing funds for the PDR preparation volunteers.	JOI	
I	Expansion of the public relations campaign should be pursued by the proponents 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.	JOI	
E	An OOI level CONOPS should be generated and could be used to help define the O&M staffing for each of the IOs.	JOI	

Management

Rating	Recommendation	Response Group	Timeframe for task completion
HP	JOI should reorganize its management of OOI to place the Project within ORION, reporting to the ORION Director.	JOI	
P	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.	JOI	
E	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.	JOI	
E	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.	JOI	
I	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.	JOI	
P	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.	JOI	
E	The qualifications and tasking of the JPL team to provide specific systems engineering support should be aligned with the project needs.	JOI	
P	Select and implement performance measurement system applications as soon as possible. In addition an automated document management systems should be evaluated, selected, and implemented quickly.	JOI	
I	A bottoms-up evaluation of contingency needs should be done for the PDR as part of the bottoms up cost estimate. JOI should be aware of "contingency" included in the base estimate.	JOI	
I	JOI should consider how its Systems Engineer can remain current with the systems engineering issues as they evolve within and among the IOs.	JOI	
I	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.	JOI	
E	The detailed project schedule should include sufficient time to review and process/award subcontracts.	JOI	
HP	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.	JOI	

Rating	Recommendation	Response Group	Timeframe for task completion
P	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.	JOI/NSF	
I	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.	JOI	
I	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.	JOI	
I	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. 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.	JOI/NSF	
I	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.	JOI	
P	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.	JOI	
E	The commercial/legal and technical significance of Acceptance must be defined as well as a mechanism for resolving disputes. 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.	JOI	
E	The OOI management structure should be proactive in finding and adopting successful new technologies.	JOI	
E	Implement a change log that tracks the status of each change and documents the effect of approved changes on the baselines and contingency.	JOI	

Cost Estimate

Rating	Recommendation	Response Group	Timeframe for task completion
E	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.	JOI	
P	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.	JOI	
E	The basis for 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.	JOI	
I	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.	JOI	

Coastal Scale Observatory

Rating	Recommendation	Response Group	Timeframe for task completion
I	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 be a different location with a different scientific mission.	JOI	
I	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.	JOI	
P	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.	JOI	
E	The panel recommends that an agreement be developed with the U.S. Navy and perhaps other agencies to provide use of these towers over an extended time period to support the resources required for this observatory.	JOI/NSF	
HP	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.	JOI	
I	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.	JOI	
I	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.	JOI	
HP	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.	JOI	
I	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.	JOI	

Rating	Recommendation	Response Group	Timeframe for task completion
P	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.	JOI	
I	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.	JOI	
I	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.	JOI	
E	The Panel recommends further consideration of the following key management topics in order to refine the observatory design process: definition of the key cost-drivers and risks, bottom-up derivation of costs, definition of the planned schedule of development and deployment, and 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.	JOI	
I	The Panel recommends that multiphase development of the three components of the observatory. The first phase would include: 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 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.	JOI	
I	The panel recommends additional investment in emerging technologies for sensor and mobile platforms (including profiling platforms, gliders, and AUV's) that will significantly augment the capabilities of all three components.	NSF	

Regional Cabled Observatory

Rating	Recommendation	Response Group	Timeframe for task completion
E	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 descoping or upscoping due to costs and budget.	JOI	
I	A solution needs to be obtained for provision of a ship(s) that can perform the RCO work required.	NSF/JOI	
E	The NSF/JOI/IO project structure and OOI CONOPS should be structured to maintain the existing USN/NSF process or clearly define a new structure for dealing with national security related issues.	NSF	
I	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 RCO infrastructure scope.	JOI	
I	The RCO Risk Register should be amended to include the risks associated with the power system.	JOI	
E	The relationship, communications, and responsibilities between Stage I and Stage II of the RCO need to be clearly defined.	JOI	
I	The RCO/CSO interface agreement should include a clear division of the build and management and O&M responsibilities as well as funding sources for the shared cable.	JOI	
D	The RCO project execution plan should identify resources to entrain and grow the RCO user community.	JOI	

Global Scale Observatory

Rating	Recommendation	Response Group	Timeframe for task completion
I	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. The cyberinfrastructure 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.	JOI	
E	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.	JOI	
E	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.	JOI/NSF	
P	The preliminary design should evaluate costs and scientific benefits of adding meso scale arrays at additional global sites rather than the single site presently envisioned.	JOI	
I	Sufficient funding should be maintained to account for changing ship day-rates in the construction and implementation phases.	JOI/NSF	
I	Optimal phasing of the global 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.	JOI	

Cyberinfrastructure

Rating	Recommendation	Response Group	Timeframe for task completion
I	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.	JOI	
HP	This subcommittee 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.	JOI	
E	A description of tests planned to ensure that the cyberinfrastructure system meets its desired performance capabilities is needed. Testing and performance are 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.	JOI	
E	Data management issues related to the collection, quality control, and storage of data from the OOI network must be addressed. 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.	JOI	
P	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 review at the PDR, and to make appropriate adjustments to their cost estimates.	JOI	
I	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.	JOI	
E	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, at what stage will instrument control and actuation be needed? 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?	JOI	

Rating	Recommendation	Response Group	Timeframe for task completion
I	The measures of success for supporting cross-observatory investigations should be articulated to an extent that the CI IO would be able to lie out their success criteria as asked for by the CDR design. For the PDR, the plan and/or associated reports should make clear how the CI IO would 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.	JOI	
I	A user and role analysis should be conducted to ensure effective implementation of the essential cyber infrastructure.	JOI	
I	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.	JOI	
I	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.	JOI	
P	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 PDR should be engaged in specifying the qualifications of such a person.	JOI	
I	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.	JOI	
I	The CI IO must interact closely with all other IOs. Funds should be allocated specifically for FTEs that provide this close coordination.	JOI	
I	CI has a big 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.	JOI	

Operation and Maintenance

Rating	Recommendation	Response Group	Timeframe for task completion
E	ORION should develop early in the project (with a dedicated person) 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.	JOI	
I	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 Concept to Preliminary Design.	JOI/NSF	
I	Project Managers from all IOs should work closely to coordinate Operations and Maintenance where possible to ensure cost savings.	JOI	
I	Include positions for an observatory scientist and education manager in the annual operations budget.	JOI	
E	The Operations and Maintenance budget needs to include more FTEs if the plan is to include 24/7/365 operations.	JOI	

Education and Public Awareness

Rating	Recommendation	Response Group	Timeframe for task completion
P	EPA Committee should revise the strategic plan based on the most recent understanding of allowable MREFC costs to support EPA planning and capital investment.	JOI	
E	The EPA Committee should look beyond the current list of potential collaborators to exemplars in other scientific disciplines for model programs and best practices.	JOI	
I	JOI should figure out how to set up and fund an 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.	JOI	
I	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.	JOI	

NSF Specific Recommendations

Rating	Recommendation	Response Group	Timeframe for task completion
HP	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.	NSF	
I	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.	NSF	
HP	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.	NSF	**Done**
NA	OOI-specific review panels to review science and technology development proposals may be an effective way of getting improved instrumentation in a timely way.	NSF	
P	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.	NSF/JOI	
E	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.	NSF	
E	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 associated with the OOI.	NSF	

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ocean research interactive ORION observatory networks

28 September 2006

Lamont-Doherty Earth Observatory of Columbia University

Florida State University

Monterey Bay Aquarium Research Institute

Oregon State University

Pennsylvania State University

Rutgers University

Stanford University

Texas A&M University

University of California, Santa Cruz

University of California, San Diego, Scripps Institution of Oceanography

University of Florida

University of Hawaii

University of Miami

University of Michigan

University of Nebraska, Lincoln

University of Rhode Island

University of South Florida

University of Texas, Austin

University of Washington

Woods Hole Oceanographic Institution

Dear Colleagues:

Since the ORION Design and Implementation Workshop in March 2006, the ORION Program Office and members of the ORION advisory committees have worked on refining the Ocean Observatory Initiative (OOI) Conceptual Network Design (CND) through an iterative process, as revised cost estimates of the proposed infrastructure have been developed. This information formed the basis of a Conceptual Design Review (CDR) of the OOI, which was successfully completed in August 2006. The NSF's Large Facilities Office requires several reviews of its large programs as one of the steps in moving towards the construction and implementation phase. For the OOI CDR a panel of 20 experts from the science, engineering, and education communities was convened to review the scientific merit and goals of the OOI, the technical feasibility and readiness of the CND, the proposed budget, schedule and milestones, the management plan, education and outreach plans, and a preliminary estimate of an operations budget. The panel noted that the OOI will transform the way oceanographic research will be carried out in the coming decades and concluded that the conceptual network design is credible and provides a good starting point for the next step in the development of the OOI.

One outcome of preparing for the CDR was obtaining more accurate estimates of operations and maintenance (O&M) costs. The current projected annual O&M costs for the ORION Program used by NSF in their budget planning was obtained from the National Academy of Sciences report, *Enabling Ocean Research in the 21st Century: Implementation of a Network of Ocean Observatories*, which represented the best estimate of O&M costs in 2003 when the report was published. ORION's recently revised O&M estimates are higher than the 2003 value, as a result of improved information on the type and location of infrastructure, along with inflation in the intervening years. As many of you are aware fuel costs for ships, in particular, have dramatically increased in the past two years, as well as the enhanced role of ships resulting from demand for offshore exploration, drilling, and production. Based on anticipated inflation in the coming years, these O&M costs will likely be substantially higher by 2013 when the OOI is completed. The ORION community is very sensitive to the need to limit O&M and life cycle costs in order to protect the core science funds within the current NSF budget constraints. As a result, the ORION Office and advisory committee members will be re-evaluating and descoping the existing network design in the coming months to ensure that the OOI funds are spent wisely, that we meet the budget targets given to us by NSF, and that the goals of the MREFC account are met, namely that the facilities provide new and transformative technologies that will enable major advances in understanding ocean processes.

The Observatory Steering Committee (OSC) met September 13-15, 2006 and endorsed the following high priority boundary conditions to guide the process of re-evaluating the observatory network design with respect to O&M costs: (1) the design must include new

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and transformative technology for both the physical elements of the OOI and its associated cyberinfrastructure (interactive, near real-time connectivity), (2) the multidisciplinary science questions used to design the network must be those that require this new technology in order to make major advances in understanding, while recognizing that the network also must support investigations of science questions that we are unable to anticipate at this time, (3) the design must retain all three physical observatory components (coastal, regional, global), (4) the design must maintain an appropriate balance between high-risk elements and lower-risk elements which have a high probability of success, (5) the design must maintain an appropriate balance of fixed and mobile assets to avoid spatial or temporal aliasing, and (6) capital costs must be re-evaluated with respect to minimizing life-cycle costs. The Science and Technology Advisory Committee (STAC), augmented by members of the Engineering Committee, will meet in October 2006 to discuss and recommend re-baselining options for the observatory network design given the above conditions. The OSC has provided the STAC with several options to guide their discussions. With input from the STAC and the OSC, the ORION Office will develop a revised observatory network plan. This plan will be posted on the ORION website in early December for public comment. A new network plan will be completed in January 2007 in consultation with the NSF. This plan will be used as the basis for further, detailed cost estimates required for the Preliminary Design Review in fall 2007.

The OOI is a tremendous opportunity for the ocean sciences community to demonstrate the transformative nature of having a continual presence in the oceans through a network of interactive, distributed sensors. This facility will enable powerful new approaches for investigating complex processes and foster technological developments for several decades to come. In the next year, we will strive to ensure that the OOI provides unique capabilities at the frontiers of ocean and Earth system science research to promote discovery, innovation, and learning.

Sincerely,

Kendra Daly
Director, ORION Program

Bob Detrick
Chair, ORION Observatory Steering Committee

Lamont-Doherty Earth Observatory of Columbia University

Florida State University

Monterey Bay Aquarium Research Institute

Oregon State University

Pennsylvania State University

Rutgers University

Stanford University

Texas A&M University

University of California, Santa Cruz

University of California, San Diego, Scripps Institution of Oceanography

University of Florida

University of Hawaii

University of Miami

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University of Nebraska, Lincoln

University of Rhode Island

University of South Florida

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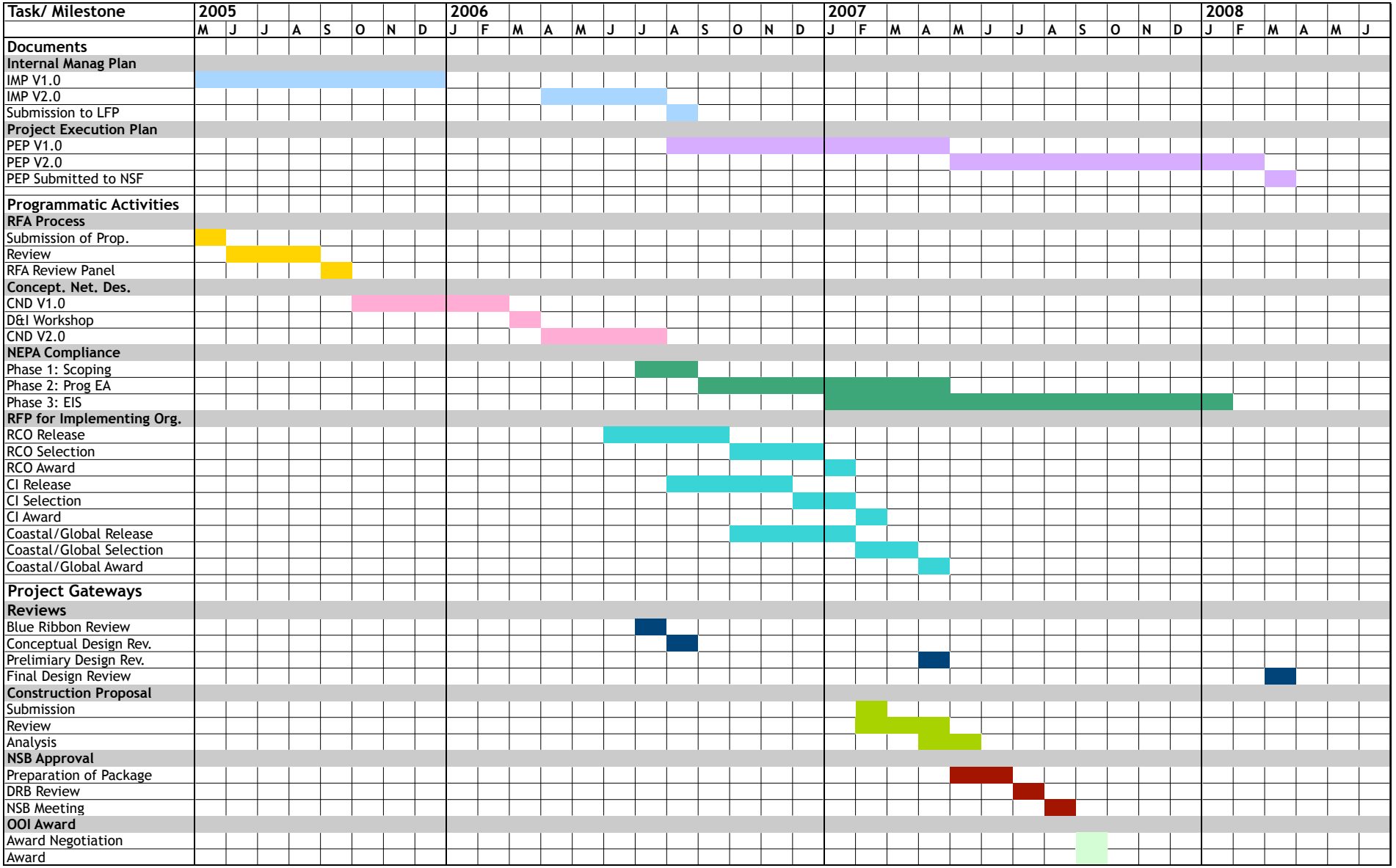
Woods Hole Oceanographic Institution


Task/ Milestone
2005
2006
2007
2008
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
Documents
Internal Manag Plan
IMP V1.0
IMP V2.0
Submission to LFP
Project Execution Plan
PEP V1.0
PEP V2.0
PEP Submitted to NSF
Programmatic Activities
RFA Process
Submission of Prop.
Review
RFA Review Panel
Concept. Net. Des.
CND V1.0
D&I Workshop
CND V2.0
NEPA Compliance
Phase 1: Scoping
Phase 2: Prog EA
Phase 3: EIS
RFP for Implementing Org.
RCO Release
RCO Selection
RCO Award
CI Release
CI Selection
CI Award
Coastal/Global Release
Coastal/Global Selection
Coastal/Global Award
Project Gateways
Reviews
Blue Ribbon Review
Conceptual Design Rev.
Prelimiary Design Rev.
Final Design Review
Construction Proposal
Submission
Review
Analysis
NSB Approval
Preparation of Package
DRB Review
NSB Meeting
OOI Award
Award Negotiation
Award