The Shambolic State of the Ocean Observatories Initiative: Time to Speak Up

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In about 6 months the National Science Foundation (NSF) will complete the construction of the Ocean Observatories Initiative (OOI), an ambitious plan to build infrastructure for long-term studies of the oceans on coastal, regional and global scales. The physical portion of infrastructure will be built on budget and nearly on time and the whole system will, if things go to the current plan, be commissioned only a few months late. Not bad for such a complex project one might think.

However beneath this veneer of success lies a project that is in disarray. Support for the OOI amongst the ocean science research community has dwindled during construction as scientists have been shut out from scientific decisions, construction oversight, and planning for its operations. Data is now flowing to shore from many of the components of the system, but it mostly sits unavailable to the science community because in 5 years the project has been unable to create a functioning data management system. Rather than publically acknowledging this failure and coopting the extensive data management expertise and facilities that already reside within the NSF Geoscience community to solve this problem, the OOI is instead funding Raytheon engineers working at Rutgers University to cobble together a system at the last minute in the hopes that nobody will notice that anything has gone wrong. To help fund this effort, the OOI is laying off personnel at the University of Washington (UW) who I believe are critical to the operation of the OOI's flagship asset, the cabled observatory. Despite only being months away from commissioning, the OOI has no coherent published plan for the operations and maintenance (O&M) in part because it appears that NSF has made cloistered decisions that have led to a system it cannot afford to operate.

I have been at the UW for over 20 years. Soon after I arrived, my colleague John Delaney started promoting the idea of a cabled observatory off our coast. Initially he proposed a straight shot to a single science node on the Endeavour Segment of the Juan de Fuca Ridge, a hydrothermally active volcano where for over a decade he had been leading a series of field studies investigating the links between submarine volcanoes, hydrothermal venting and chemosynthetic biological communities. Soon his vision for the cabled observatory expanded to the concept of "wiring a tectonic plate" in a region that also fortuitously encompassed many interesting oceanographic processes. John is nothing if not persistent and he spent a decade tirelessly promoting the vision, which he termed NEPTUNE (North East Pacific Time-series Undersea Networked Experiments), and organizing a careful planning effort involving several US and Canadian institutions. In 2003 the Canadian Government announced funding for the NEPTUNE Canada cabled observatory and the US finally followed suit in 2009 when NSF launched the OOI as a $386M Major

Research Equipment and Facilities Construction (MREFC) project that directly incorporated the NEPTUNE designs.

The OOI was planned with 4 components, the NEPTUNE cabled observatory, a co-sited coastal experiment off the coast of the Pacific Northwest that includes some components attached to the cable observatory and others as standalone moorings, a moveable array of coastal moorings currently located on the East Coast, and a handful of rugged deep-water buoy systems designed to provide sustained observations in challenging high latitude locations. The strong scientific rationale for long-term observations in the oceans had been developed over many years but perhaps inevitably for a new and expensive approach to observational science, the OOI had both supporters and detractors. There were several big meetings to discuss the OOI at which strong arguments were articulated for each component but there were also skeptics present and other opponents stayed home. Some oceanographers argued that the most expensive part of the OOI to operate, the fixed high-latitude buoys, placed too much emphasis on making observations around a few fixed locations. Others felt that too many assets were being concentrated in the Northeast Pacific Ocean. There was a sense that the moveable coastal buoys were a belated addition to appease a vocal group that felt left out but could not settle on a permanent observatory site.

Many levelheaded opponents of the OOI and proponents of particular parts pointed out that the components had little that necessitated linking them scientifically or operationally into a single facility. Rather than listening to the community and letting each component of the OOI stand independently on its own scientific merits, NSF decided that in order to secure funding it had to insist that they were building a single system. This may have been the correct short-term strategic decision but it has had some unfortunate long-term consequences. NSF encouraged the development of a poorly defined, but all encompassing cyberinfrastructure component that would somehow link the disparate elements into a coherent observatory or "system of systems". In order to promote this view of a single facility, they eventually went so far as to require that the University of Washington cabled observatory team drop its high profile NEPTUNE "brand name" and instead the cabled observatory was to be known by the insipid moniker, the Regional Scale Nodes (or RSN) of the OOI.

Just prior to securing MREFC funding and after the program passed a Final Design Review, NSF decided rather mysteriously to add an additional high-latitude buoy in the South Atlantic and to descope the cabled observatory, eliminating two of five experiment sites and removing instruments from a third. Instead of a regional observatory that would span the Juan de Fuca Plate with two sites on the Cascadia subduction zone and single sites on a spreading center, an oceanic transform and at a mid plate site, the cable now hosted two local observatories (each comprising two nodes), one at Axial Seamount on the Juan de Fuca Ridge and one on the Cascadia subduction zone spanning Hydrate Ridge. While both these are fascinating sites that are important geologically and span a range of water column environments, the

cabled observatory was left without the regional footprint required for many important geophysical and oceanographic objectives; the only saving grace is that the system architecture was designed from the outset to allow for future expansion.

The scientific folly of descoping the cabled observatory was highlighted when first the 2010 Chile earthquake and then the 2011 Tohoku earthquake off Japan illustrated the inevitability of similar catastrophic earthquake on the submarine portion of the Cascadia subduction zone. Cabled observatories are a powerful tool for long-term scientific investigations of the seismic and tsunamigenic potential of subduction zones and will be needed to optimize an earthquake early warning system in the Pacific Northwest. The operational folly of adding another global buoy became apparent when it was leaked that this change would add $10M/yr to the operational budget of a facility that many in the community already feared would break the bank. The NSF Division of Ocean Sciences has been struggling for some while to deal with the escalating costs of its facilities.

Despite numerous informal requests that it do so, NSF would not publicly explain this decision, one that was opposed by a Blue Ribbon Science Panel that NSF convened, but whose report has never been made available to the science community. Privately NSF intimated that this change in emphasis was in response to the new Obama administration's request that the MREFC project demonstrate more emphasis on research related to climate change and its impacts. If it is true that NSF allowed private political considerations to influence its scientific decisions behind closed doors, then it is very disconcerting. All government agencies require political oversight, but that is inherently a public process. Private pandering to political influence from the Left would undermine NSF's many supporters, including myself, who seek to defend it from criticisms, by pointing out its commitment to evaluating scientific proposals on their intellectual merits and broader impacts in an objective, rigorous and apolitical manner. If it is not true that NSF was influenced by outside pressure, then the last minute redesign must have been an internal decision made at a high level within NSF and against the wishes of the scientific community.

In October 2009, the Consortium for Ocean Leadership (COL) signed a collaborative agreement with NSF to manage the construction and then the initial operation of the OOI. Under COL's management three implementing organizations (IOs) would construct the facility. Woods Hole Oceanographic Institution (WHOI) would collaborate with Scripps Institution of Oceanography (SIO) and Oregon State University (OSU) to construct the coastal and global moorings, the UW would construct the cabled observatory, and the University of California San Diego (UCSD) would develop cyberinfrastructure.

NSF decided that the construction phase of the OOI would be handled by a single overworked program manager at NSF with experience in engineering and project management but with little background in ocean sciences and, as far as I can see, no desire to see the scientists get in the way of a construction project. Several years prior to the initiation of the MREFC, there was an opportunity to submit conceptual

proposals for observatory experiments and this resulted in nearly 50 detailed submissions involving over 500 scientists. For a while ongoing planning for the OOI involved a somewhat unwieldy collection of >80 enthusiastic scientists and engineers from throughout the community who were organized into numerous groups aligned with various subcomponents of the program. Rather than streamlining this expertise into three active advisory and oversight committees for the three IOs, NSF rather unceremoniously discarded these groups.

Throughout the construction phase only two small advisory groups of outside scientists have played any role at all. The Program Advisory Committee (PAC) is a COL-selected committee of eight scientists set up to provide advice to COL, but it does not presently seem very active and its deliberations are private. The Ocean Observing Science Committee (OOSC) is a University-National Oceanographic Laboratory System (UNOLS) committee that describes itself as having "a modest understanding of the OOI"[1]. The OOSC is essentially waiting for the operation and maintenance (O&M) phase before becoming active. At a broader scale, the 5- to 6-year construction phase of the OOI has seen only a handful of small focused science meetings. Many of my colleagues are thus, remarkably uninformed about the OOI's status and intentions.

In my view, the construction of the OOI should have been accompanied by the establishment of a modest ocean observatory program at NSF run by a program manager with a scientific background. This program would have provided a venue for proposals from scientists anxious to develop instruments for the observatory or work with data from related observatories such as NEPTUNE Canada. It could also have entertained proposals from the community to host planning meetings for the OOI's use. Perhaps more importantly, the program manager would have provided a focal point at NSF to ensure that the COL involved the science community in realistic and detailed planning for the evolving needs of the OOI's O&M.

As construction got underway various rumors circulated of problems. It is clear that from early in the program, NSF has viewed COL as an ineffective manager, probably with good cause. It is my inference that from the IOs perspective, that COL often appears just a conduit for micromanagement originating from within NSF. The global buoy program run by WHOI fell behind schedule and Raytheon who had always been a commercial partner to contribute project management expertise started to play an increasingly prominent role in its construction. The Cyberinfrastructure IO at UCSD and SIO was clearly in trouble right from the very start. What was required was a nuts and bolts effort to implement simple and reliable pathways to accept data coming to shore from the sensors and place it in a database (or databases) where it could be accessed by scientists. Instead the Cyberinfrastructure IO was given an unrealistic mandate that extended from

[1] OOSC Report to UNOLS Council, March 2014, http://www.unols.org/sites/default/files/201403cncap27.pdf.

developing the software controlling sensors to the assimilation of data into sophisticated scientific models and encouraged to pursue what seems like a rather vague research plan to develop new approaches to the bind the physical infrastructure together.

In one conference paper written two years before the MREFC funding some of the principals in the Cyberinfrastructure IO wrote "*The Cyberlnfrastructure (CI) constitutes the integrating element that links and binds all three marine observatories and their associated sensors into a coherent system-of-systems - a global multi-scale observatory. The Cl facilitates the analysis of realtime and retrospective data and their assimilation into models. The CI will break down the traditional barriers posed by data and technology access, and empower traditional as well as new classes of users with increased understanding of the oceans*"[2].

It is probably not surprising that the engineers working within the OOI's culture of isolation from scientific users, managed to burn through $30M trying unsuccessfully to turn this grandiose vision into some useful software and hardware. It is very surprising, indeed quite shocking, that both COL and NSF allowed the problem to persist over many years even though they were presumably well informed by the required monthly reports. This summer the responsibility for cyberinfrastructure was stealthily moved from UCSD/SIO to Rutgers University with Raytheon engineers tasked with saving face for COL and NSF presumably at a significant price to both the MREFC and to the future O&M budget. This transition appears to have taken place without much discussion of the actual needs of the program and of the options for a rational descoping of the cyberinfrastructure.

The installation of the cabled observatory has not proceeded without significant hiccups. The various organizations forming the OOI clearly do not communicate well and I would hope that all of them, including my own, are willing to share the blame. There were many operational challenges including a long delay in the UW accepting the backbone cable and primary nodes from the commercial vendor on NSF's behalf and the need to develop a means to obtain data from the sensors in the absence of the drivers from the Cyberinfrastructure IO. Over a marathon 3-month cruise this summer with the research vessel *Thomas Thompson* and remotely operated vehicle *ROPOS*, the UW team installed numerous extension cables and secondary junction boxes, 3 innovative multi-component profiling moorings, and 140 seafloor and water column sensors. It was a remarkable operation, something the UW should justifiably be proud of. Nearly all of the installed sensors are now sending data back to the UW.

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[2] Arrott, M., A. Chave, I Krueger, J. Orcutt, A. Talalayevsky and F. Vernon, The approach to cyberinfrastructure for the Ocean Observatory Initiative, OCEANS 2007, Vancouver, BC, Sept. 29-Oct. 4, 2007.

A particularly intriguing side story to the operations this summer was the growing realization that Axial Seamount might be primed for a volcanic eruption. The volcano erupted in 1998 and 2011 and it had been assumed that the next eruption was likely a decade away. However, three independent studies have recently documented that the volcano is resurging at an unprecedented rate. If this continues, by early 2015 it will be as inflated as it was at the onset of the 2011 eruption. An eruption of Axial Seamount, captured in real time by in situ cameras and numerous geophysical, hydrothermal and water column sensors, would represent an enormous coup for OOI: a chance to prove to scientific skeptics the worth of real time observations in the oceans and a tremendous opportunity to engage the public in ocean observatory science.

Unfortunately, within weeks of celebrating their return to shore in early October, many of the individuals involved in the outstanding effort to install the cabled observatory on time and budget were stunned to receive "pink slips" as the cabled observatory now moves to a status of sitting in limbo with a skeleton staff waiting for the cyberinfrastructure to catch up. NSF left clear instructions through COL that none of the data coming to shore can be shared with interested scientists until the data management system is ready, supposedly next May. Indeed the UW IO is not even allowed to start the process of looking at the sensor data to verify that instruments are functioning properly since that task has now been transferred to the new cyberinfrastructure group. In response to some community pressure, NSF has agreed to allow the data from 13 cabled seismometers to be placed in the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC) if this can be accomplished at minimal cost. However, this still leaves most of the data gathering dust.

The UW cable team has been reduced to 2 technicians at the shore station, 4 engineers at the Applied Physics Lab and 2½ people in the School of Oceanography. Under the MREFC, the UW IO still has responsibility for generating very extensive documentation and they should be verifying that the sensors are returning good quality data and planning to correct problems that are found. When the data management system gets off the ground, the UW IO will have to provide the metadata for each sensor and help the new Cyberinfrastructure group develop interfaces and control procedures for the cabled sensors and platforms. The UW group will also have to respond to the teething troubles that are bound to occur early in the life of such a sophisticated system, which includes novel cutting-edge technologies. As the system moves into O&M, they have to prepare for an extensive cruise next summer when >100 sensors will need to be swapped and 3 shallow and 3 deep mooring must be serviced. Prior to the cruise, these objectives require extensive procurement, testing and integration of sensors and the construction of replacement mooring pods and profilers. While the Cyberinfrastructure group now has responsibility for quality control, a task that will apparently be performed by only 4 Masters-level scientists for >800 OOI sensors, the troubleshooting of any data problems for the cabled sensors will also presumably involve the UW group.

It is pretty clear that the reason for the drastic contraction of the UW group is that all available funds in the MREFC are being redirected by COL, under the direction of NSF, to fund Rutgers and Raytheon for the cyberinfrastructure rescue effort. It is not only inherently unfair to punish the parts of the program that work well to support those that have failed, but also extremely short sighted. The cabled observatory has about $120M worth of infrastructure in the ocean and leaving this in a dynamic and corrosive environment without an adequate team to maintain and operate it is foolhardy. For much less than the Raytheon is charging the OOI, I am pretty certain the UW could partner with existing NSF-funded data centers to handle its own data as I am equally certain that WHOI and OSU could do the same for theirs – conveniently for COL and NSF the redirection of the cyberinfrastructure funds was not competitively bid or subject to peer review.

When the OOI is commissioned and moves to O&M, I would hope that some funding would be restored to the UW but as I understand it, the current plans call for a reduction from 8½ to 7 permanent OOI-funded employees with additional staff being temporarily recruited for the summer field season. The OOI is constrained to work with an annual budget of $55M/yr which at first seems to be quite generous. However, the costs of maintaining and servicing the system, and in particular the global buoys, are high. It is possible that the ridiculously low staffing levels currently being applied to the cabled observatory are a result of a complete lack of planning and understanding within COL and NSF of the OOI's needs for O&M. However, after 5-years spent managing the installation I find this hard to believe. I suspect instead that the staffing levels reflect an effort by the COL and NSF to make the drastic cuts necessary to fit the real requirements for O&M into a prescribed budget. NSF's secretive decisions to add the South Atlantic global buoy and to get deeper into bed with Raytheon may have come back to bite.

So how can the OOI get out of this mess? Nothing will happen until the community speaks up, but when it does there are a number of steps that can reinvigorate the program.

- First, the funds that have been cut from the UW and possibly elsewhere, that support personnel with critical knowledge, experience and expertise to operate the physical infrastructure, need to be restored while the program comes up with a credible plan for how to proceed. If there are no funds available within the MREFC, then O&M funds should be released to those components that are now operating.
- Second, as painful as it might be, the problems in the OOI have to be made public. Transparency will not make the project immune to bad decisions, but only secrecy creates an environment in which repeated bad decisions are ignored and allowed to compound.
- Third, the OOI has to commit to a serious plan for scientific oversight and engagement because its operation is only worthwhile if it serves the needs of scientists. The NSF Division of Ocean Sciences needs to listen to the scientists it supports.

- Fourth, there needs to be a realistic assessment of costs of operating the various components of the OOI to the high standards that would make them useful and a decision made based on community input as to which components are affordable and worthwhile. The National Academy of Science's Ocean Studies Board's Decadal Survey for Ocean Sciences might be the right forum for such deliberations, but only if the committee is accurately briefed about the status, challenges and finances of the OOI. Whatever happens, downsizing of the facility should not be based on abandoning the equipment that breaks down first which at least according to some rumors is the current plan at NSF.
- Fifth, the approach to data management needs to be rethought. We do not need Raytheon to do it for us at significant added cost. The Geoscience Directorate at NSF already supports many outstanding data centers including the IRIS DMC adjacent to the UW campus, the Marine Geoscience Data System at Lamont Doherty Earth Observatory and National Center for Atmospheric Research's data services and archives in Boulder. NOAA supports several others including the National Oceanographic, National Climatic and National Geophysical Data Centers all of which are willing repositories for data collected with NSF funds. Ocean Networks Canada which oversees the NEPTUNE Canada and VENUS cabled observatories has developed a capable database for ocean observatory data. The OOI should tap into existing data expertise in our community and where appropriate utilize existing data centers to solve its data management problem. The Geoscience Directorate also funds a program called Earthcube that seeks to "create effective community-driven cyberinfrastructure" to "transform research and data management practices"[3]. In stark contrast to the cyberinfrastructure effort of the OOI, Earthcube is based on building an extensive community of users. More ambitious plans for data integration and assimilation into models within the OOI should be implemented incrementally and in concert with broader efforts such as Earthcube as the user community for the OOI develops and its needs become clear.
- Sixth, the institutions operating the physical infrastructure need to be set free of the poor management at COL and the dysfunctional relationship between COL and NSF and allowed to operate these facilities under collaborative agreements with NSF, just like they currently operate ships.

[3] About Earthcube, web page http://earthcube.org/page/about, accessed on October 30, 2014.