Summary Report

Pacific Marine Environmental Laboratory Review

September 9-11, 2014

Review Panel

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Overview

The review was over three days at the Pacific Marine Environmental Laboratory (PMEL) Sand Point Lab in Seattle, WA. The panel heard presentations on the management and demographics of the lab, was taken on tours of the engineering and lab facilities, and given opportunity to talk with senior staff, management and stakeholders. The panel reviewed PMEL activities since 2009 in four research areas: Climate, Marine Ecosystems, Research Innovation, and Oceans & Coastal Processes. Prior to the review, the panel was briefed on the review process, and provided with the many helpful read ahead documents. These included strategic plans of the National Oceanic and Atmospheric Administration (NOAA), NOAA's Office of Oceanic and Atmospheric Research (OAR) and PMEL, the 2008 PMEL review with responses, and stakeholder survey responses. The panel appreciates the effort that went into the review planning, the review itself, and for the web site that provided a single point of access for information and documents associated with the review.

As instructed, panel consensus was not sought in preparing this report. Individual ratings of the research areas are provided and recommendations are underlined throughout the report and summarized in the last section of this report. The Chair would like to thank the panel members for sharing their expertise and time, their thoughtful review comments and for making the process collegial, focused and efficient.

Summary of Laboratory-Wide Findings

Each of the Panel members indicated that PMEL is conducting outstanding scientific work, supported by an impressive engineering team. It is clear that the work helps fulfill the NOAA, OAR and PMEL strategic plans and takes advantage of the unique strengths of a federal lab. PMEL is having a powerful impact in the community, as measured by traditional measures such as number of scientific publications, H-index and awards, but also by community leadership, outreach, partnerships, and engineering innovation. Panel comments included:

- "The portfolio is extremely strong, internationally renowned, and of the highest quality".
- "The quality of the researchers and their science is excellent"
- "PMEL has an excellent reputation in the field for important, influential science and for partnering effectively with other organizations"
- "I am very impressed with the dedication of scientists, staff, and engineers at PMEL and the quality of their research products and publications"
- "The large number of international programs in which PMEL scientists either participate or lead [is impressive]. Even more impressive, it is evident from the use of technology developed by PMEL scientists/engineers by the international community"
- "Innovation is prevalent within all the defined research areas. Besides innovative science, [there is] an impressive array of national and international partnerships and academic collaborations, and leveraging resources on a global scale"
- "The degree of clever engineering was to me, simply stunning"

Three important factors appear to be responsible for the success of the lab: (1) the culture, (2) support of scientific independence and (3) engineering-enabled, end-to-end science.

The culture of the lab is one of respect, innovation, excellence and excitement. It was palpable as researchers gave their presentations and as tour leaders described the lab and its work. Scientists celebrated the engineers. Engineers celebrated the scientists. Everyone respected the administrative staff. Panel comments included:

- "The respect that the engineers have for the scientists and the scientists for the engineers is remarkable, and is connected with the general well-being of the group and of the lab."
- "The working atmosphere [is] excellent. The review gave a very strong impression of collegiality, teamwork, and mutual respect throughout the lab. This appears to foster great interactions and advancement of science."
- "The partnership between PMEL scientists and engineers/techs is remarkable".
- "Critical in achieving high levels of performance in innovation is close collaboration between scientists and engineers. PMEL has done an exemplary job of integrating science and engineering"
- "The marrying of engineering with science is unique and a highlight/strength of the lab."

Kudos to the lab founders for creating this culture, and to past and current management for maintaining it. NOAA should be very proud of this culture but should not take it for granted.

It seems that research at PMEL occurs in groups often driven by a single PI and their interests. A few members thought this was a problem, that the research could be more top-down, responsive to prioritized needs of NOAA. Most thought, however, that this bottom-up independence was critical for attracting top-notch researchers and conducting excellent research. Panel comments included:

- "[A] quality that I think is most important is that over the years PMEL research has been bottom-up, that is, scientists were allowed to work on projects that interested them. In my view, there is no better way to ensure quality results."
- "Achieving a high level of research innovation [depends on] attracting and retaining talented people. Providing opportunities to pursue new ideas within a research organization has proven to be an important factor in maintaining a competitive advantage in recruiting and retention."
- "I applaud PMEL leadership for realizing that a large degree of scientific freedom is critical for attracting top notch researchers and conducting excellent research."
- "It seems clear that the researchers are optimizing their scientific contributions by picking research pathways that best utilize their own skills as well as the federal resources of the lab."

A third factor in PMEL success was viewed to be the end-to-end scientific workflows that are enabled by the strong connection to engineering. PMEL has a history of developing the sensors and engineering solutions to conduct the science, making the measurements, interpreting the results, publishing the science and delivering data to the community using standardized approaches. It is clear that this approach leads to the collection of higher quality data and more effective use of data, as evidenced by the high data return rates of PMEL floats relative to the general Argo community floats, and high data return rates of the PMEL-maintained TAO array relative to the NWS-maintained TAO array. It makes sense that higher quality data are collected when one's research depends on it and when engineers are on staff to assist before, during and after deployments. It is also clear that PMEL's commitment to data management results in more effective and efficient use of data not only at PMEL but within the larger geoscience community. Panel comments included:

- "It was clear that end-to-end science workflows enabled by the infrastructure of the lab plays a large role in its success. Striking examples were (1) the collapse of data return from the TAO array after it left PMEL maintenance and oversight, and (2) the amazing longevity of the PMEL Float compared to Argo as a whole (70% active after 6 years for PMEL, 20% active for Argo as a whole)."
- "An exceptional aspect of PMEL's Argo floats is that they last much longer than the average lifetime of the other (non-PMEL) floats in the array. Why? Apparently because of the quality control that is carried out before deployment, which ensures that each float is working properly."
- "[The] full-life-cycle approach allows for meaningful improvement of strategy and methods and yields a high quality product. I strongly encourage PMEL to continue this model."
- "Software and data visualization (Ferret and LAS) developed by PMEL have been widely used in ocean and climate communities."

PMEL is not without issues, of course. As common with federal labs, PMEL has an aging workforce, a strongly white male demographic, issues with permanent vs. temporary staff, and some challenges for early career personnel. Management is aware of all of these issues, but it is important to emphasize that they need to be addressed to ensure the future success of the lab.

The demographics show that 47% of the federal employees are eligible for retirement in the next 5 years. <u>A documented strategy is recommended for succession planning.</u> <u>It would be advantageous to have a phased retirement program that would allow a period of overlap between outgoing and incoming group leaders and thus mentorship for a new generation of PMEL research drivers.</u>

Although numbers on gender and racial diversity were not provided, it was clear that the leadership and senior scientific staff were mostly white males. Part of this demographic is likely historical, reflecting the pool of available candidates at the time of hire, but this is changing rapidly, at least with respect to gender: 50% of graduating oceanographers are women. If PMEL is to create a scientific workforce whose diversity is comparable to that of the student population (and of course the US population as a whole) it will need to actively work to attract, mentor and retain women scientists. <u>As a first step to addressing this issue, PMEL should compile statistics on diversity in the lab, including salary equity; investigate/correct any biases and inequities found; investigate possible reasons for lack of diversity, and put into place policies to address deficiencies found in this area.</u>

About half the employees are non-federal, many working for the University of Washington through the cooperative institute JISAO. Some panel members thought that more staff should be permanent federal employees to help ensure the stability of the organization, while others thought that having a large fraction of non-permanent staff allows the lab to be more nimble and efficient in responding to research opportunities or budget cut-backs. PMEL should assess the frequency of meetings between the heads of PMEL and JISAO to ensure that communication is optimal. There should be a plan in place to ensure good Fed/JISAO relationships and prevent building an "us and them" division in the lab.

Since many of the PMEL projects are long-term and led by senior staff, it was not clear how early or mid-career scientists could effectively advance their own ideas. As such, the current policy may be losing the creative ideas of those not high in the management ladder. PMEL should consider setting money aside for competitive seed ideas that might, if successful, turn into larger programs. A corollary to a mechanism for starting new programs would be a plan for ending older programs. Existing programs should be evaluated periodically to make sure they are still as effective and efficient.

Since PMEL prides itself on collaboration, work should be done to ensure that access to the PMEL campus is as easy as possible while still obeying federal laboratory requirements. During the review, paperwork available at security suggested new regulations would exclude all foreigners from the site, including US green card holders. PMEL should be active in ensuring that proposed new regulations contain sufficient routes for non-US citizens visiting the PMEL.

Panel comments include:

- “PMEL needs to develop a clear plan to replace its older staff. The problem is now critical.”
- “Very surprisingly, no statistics on diversity were presented during the review. I encourage the lab to compile these statistics and assess diversity balance not just in the lab as a whole or JISAO as a whole, but also in relevant subsets, (e.g., science management, administrative management, engineering, students), each split also into PMEL/Fed and JISAO.”
- “More discussion should have been had on [the JISAO/PMEL] relationship, including differences in remuneration, CI people being “first out the door” with fiscal cuts, CI people unable to run the finances of a PMEL program, etc. Whilst the relationship appears to be working, I felt there was tension in that relationship. PMEL senior management should hold regular meetings with JASIO senior management to better enable lines of communication to discuss salient issues.”
- “Some disquiet was expressed by non-federal employees, who didn’t feel they had the same opportunities as federal employees. At the same time, some JISAO scientists are quite happy being non-federal. It is not clear to me if this is really a serious issue at PMEL.”
- “Innovation is critical to the continued success of PMEL. Is the procedure for starting new initiatives clear at PMEL? In this regard, is it possible for younger scientists to start new programs? How are funds allocated at PMEL for new initiatives?”
- “Connection with modeling groups outside PMEL is important, but these collaborations are more ad hoc and project driven, often lacking in continuity. For future initiatives and projects, PMEL needs to consider modeling as an important component either through targeted hiring of modelers and/or designating PMEL scientists to be a liaison to work with outside modeling groups.”

Summary of Individual Ratings

(1 = Highest Performance; 2 = Exceeds Expectations; 3 = Satisfactory; 4 = Needs Improvement)

	Reviewer #1	#2	#3	#4	#5	#6	#7	#8
Climate	1		1					
Quality	1		1					
Relevance	1		1					
Performance	2		1					
Marine Ecosystems	2	1		1				
Quality	1	1		1				
Relevance	2	1		1				
Performance	2	1		1				
Research Innovation	2	1			1	1		
Quality	1	1			1	1		
Relevance	2	1			1	1		
Performance	2	1			1	1		
Ocean and Coastal	2						1	1
Quality	2						1	1
Relevance	1						1	1
Performance	2						1	1

Findings and Recommendations by Research Area

1. *Climate Research*

The PMEL climate group studies the state of the climate system and causes of climate variability and change. To address these issues it undertakes a variety of projects, which collectively measure a broad range of climate variables in geographic regions from the tropics to the Arctic. The group has been productive, with 464 climate papers published over past 6 years that have an average H-index of 39. The panel was impressed by the quality, relevance and performance of the climate research program. The two reviewers who rated it gave it the top mark of "highest performance" and it's clear that PMEL is having a large impact on this field.

Global Tropical Moored Buoy Array:

PMEL made a critical contribution to climate research beginning in the mid 1980s with the conception and implementation of the TAO array, which helped move PMEL into the international spotlight. The real-time data stream from TAO improves initialization of ENSO forecasting models around the world, and it helps to advance and increase forecasting skills of various models. These ENSO forecasts have been used by decision-makers at regional and local levels range from adjusting water usage for agriculture to reducing fish catch along California and Peru coasts. The success of the TAO array in the eastern tropical Pacific was later expanded into the TRITON array in the western Pacific, the PIRATA array in the Atlantic and the RAMA array in the Indian Ocean. In 2006, NOAA transferred the management and operations of TAO from PMEL to NDBC, with the idea that these measurements would be more effectively managed by an operational center. There are different ideas about what happened, but there is no disputing that data return rate has dropped from over 80% under PMEL management to about 40% under NDBC management. Loss of ship time is one contributing factor, with the retirement of the NOAA ship Ka'imimoana. Yet surely another is that this work is not truly operational, and benefits from the end-to-end research chain that PMEL can supply. To make matters worse, the Panel heard that JAMSTEC has reduced its support of the far-western-Pacific Triton array. This is a huge loss. NOAA explicitly states that it wishes to entrain international partners into its activities. The future of these mooring systems *should* be bright, as newer sensors and technologies are allowing more efficient measurement of physical parameters as well as new measurements of biological and chemical parameters. However, to ensure success in the future, PMEL needs to play a major role again in controlling the design and operation of the TAO array. It looks there is a way for this to happen: the Panel heard that PMEL is co-leading an international committee that is charged with reinventing the TAO array and incorporating new platforms such as gliders to conduct more efficient sampling, and incorporate modeling requirements in the design. PMEL needs strategically at the lab level to consider more integrated ocean measurements by incorporating reliable bio-optical and chemical sensors. The integration of biological and chemical measurements should also be considered for more Argo floats and the Arctic observing initiative. PMEL management should provide strong support for getting the tropical observing system back on course.

Thermal Modeling and Analysis Project (TMAP):
The TMAP group seeks to understand sociological important air-sea climate patterns, focused on ENSO. The group has investigated a number of different patterns, including multi-decadal ENSO variability, Central Pacific (CP) versus Eastern Pacific (EP) El Ninos, new indices for forecasting El Nino, La Nina events and ENSO impacts on CO2 rise. The realization of these different ENSO types and potential drivers has emerged in the last decade and gives new insights into climate, directly addressing NOAA climate goals. <u>The TMAP work is important and should continue.</u>

<u>Pacific Western Boundary Currents</u>
This project seeks to determine ENSO's role in the meridional distribution of warm water. An equally important, second goal is to provide a test bed for glider technology: Can gliders be used to obtain measurements in swift western-boundary currents? In this project, gliders are used to measure directly the transport of the New Guinea Coastal Undercurrent (NGCUC), which was previously determined only as a residual from other flows. To date, the program has carried out 26 missions, covering 46,000 km, and has lost no gliders. One interesting finding is that interannual variability of the NGCUC resembles that of ENSO, except lagged by about 3−4 months, so that the NGCUC reacts to (but doesn't predict) ENSO. An as yet unresolved question is whether broad-scale tools can be used to predict the directly measured WBC, which is filled with eddies? With several more years of data, the glider measurements should provide the information needed to answer this question. The success of the study supports the idea that gliders are a cheap and feasible way to measure western-boundary currents. <u>PMEL should attempt an approach similar to the NGCUC studies with gliders in another WBC region.</u>

Large-Scale Ocean Physics:
The large-scale, ocean-physics group analyzes global ocean measurements (from Argo, repeat hydrography, etc.), with estimates of ocean heat content one of their most important products. Regarding Argo floats, PMEL deploys about 60 floats per year, and has provided a total of 660 floats, about 1/7 of the total global array. Further, PMEL has developed salinity sensor response correction and calibration systems for Argo. An exceptional aspect of PMEL's Argo floats is that they last much longer than the average lifetime of the other (non-PMEL) floats in the array: after 6 years, 70% of PMEL floats are active, compared to only 20% for Argo as a whole. The reason given was the quality control that is carried out before deployment, which ensures that each float is working properly. Group scientists have found different warming patterns of deep waters in the global ocean. Remarkably, AABW is warming at about 1/3 the rate of the surface warming, whereas NADW hasn't changed much at all. Plans are underway to allow some Argo floats to profile to the ocean bottom (6000 m), which should greatly improve our knowledge of the variability of the deep ocean circulation. Knowledge of heat content in the abyssal ocean plays a huge factor in understanding global warming, as global warming is mostly about ocean warming. Unfortunately the deep ocean is dramatically under sampled, and error bars are so large on direct estimates of heat content that we can't even tell if the abyssal ocean is heating or cooling. <u>Deep Argo measurements are critically important and must be expanded if the community is to have enough data to accurately understand where the heat due to climate change is being absorbed</u>.

Ocean Climate Stations

Ocean climate stations are heavily-instrumented, surface mooring sites. PMEL currently has two such stations: the Kuroshio Extension Observatory (KEO), and an observatory at Ocean Station Papa (OSP). The moorings have physical, biological, atmospheric, and CO2 sensors, and also measure bottom temperature and salinity. They are among the few surface moorings deployed outside the tropics. The oceanic, surface heat flux is difficult to measure globally, and so it is determined in large part using bulk algorithms. A usefulness of the moorings, then, is that they provide ground truth for the heat-flux products. The KEO mooring is the first climate mooring in the region, and it is being used to help improve weather and hurricane forecasts. The OSP Papa mooring is the first mooring to look at ocean acidification. The ocean climate stations provide comprehensive, oceanic and atmospheric measurements at specific locations, complementing the ARGO measurements. <u>The ocean climate stations are an important member of NOAA's climate array and should continue being supported.</u>

Ocean Carbon

Through its carbon program, PMEL has been a national and international leading group in contributing to understand the role of ocean uptake anthropogenic CO2 from atmosphere. Without contributions of ocean carbon measurements from PMEL, many global and regional ocean carbon models would be delayed in their advancement by several years or longer. During the past two and half decades, the carbon measurements throughout the world ocean made by PMEL scientists and staff are one of the largest sources in both ocean surface (SOCAT) and interior carbon database (GLODAP). Data is collected using ships of opportunity, by adding CO2 sensors to moorings, and through the development of new technology like the carbon wave glider. Presently, PMEL's ship-of-opportunity program contributes about 50% of CO2 data, and its mooring data account for 75% of "alternative" (non-shipboard) platform data in SOCAT. Future plans are to fill gaps in the array with measurements from autonomous systems (wave glider). <u>PMEL's carbon program clearly supports NOAA goal to acquire information about the impact of atmospheric CO2 on the ocean and should continue being supported.</u>

Arctic Climate Dynamics

Arctic warming (sea-ice decline, warming temperatures, permafrost melt, shifts in ecosystems) over the last decades is now well documented by the science community. Perhaps most dramatically, summer minimum Arctic sea-ice extent has decreased dramatically, faster than predicted by the IPCC forecasting models. The mechanisms of sea-ice loss are still poorly understood and quantified, and the fundamental work done by PMEL is contributing greatly to our understanding of the role of the atmosphere and anthropogenic forcing in this process. Arctic warming has profound impact on US coastal regions, climate and industry (e.g., Arctic resource exploitation, resource management, shipping, etc.). Areas where PMEL is well positioned to excel include Arctic atmospheric drivers, Arctic Ocean Acidification, Bering Sea Arctic fisheries (and change in the Bering Sea). <u>There is a clear need to continue measurements of Arctic climate change, and to communicate results and understanding to society.</u>

Arctic-related efforts are distributed across a number of PMEL programs including climate dynamics, marine ecosystems and acoustics. There are also synergies with current efforts at the UW Polar Science Center. The Navy's current Arctic Roadmap includes the proposed establishment of an "Arctic Center of Excellence", yet to be defined. A coherent Arctic-focused partnership between PMEL and APL/UW would be an excellent foundation for such a Center.

Atmospheric Chemistry

The goal of the atmospheric-chemistry project is to understand the impact of aerosols on the atmosphere. More specifically, the project seeks to measure both anthropogenic (due to pollution) and natural aerosol sources, and to provide that data to atmospheric modelers. To date, project scientists have undertaken 19 cruises and 12 land-based experiments. In addition, as a proof-of-concept, they have carried out 19 flights (40 hours) using unmanned aircraft to measure aerosol profiles. <u>The project contributes to NOAA's goal to improve understanding of atmospheric composition (clouds, aerosols, precipitation) and should be continued.</u>

2. *Marine Ecosystem Research*

The goal of this program is to measure and understand factors that impact the marine ecosystem. Two of the reviewers rated this program "outstanding", and the third rated "exceeds expectations". A sample comment: "The quality of the PMEL Marine Ecosystems Research Program is impressive in its depth and breadth. From fisheries to noise in the ocean to acidification and the processes coupling the solid earth to the ocean, the Marine Ecosystems research is comprehensive and it is clear that the 4 research foci are strongly coupled together. The scientists are excellent, hard-working and productive as evidenced by their publications, participation on national and international committees, and both their internal and external record of recognition."

Acoustics

The Acoustics program addressed an impressive scope of societal concerns. Links to specific NOAA goals were very well laid out in their presentation. It was good to see this expertise used to address both established (e.g., impacts of increased shipping on marine mammals, marine mammal surveys) and the more novel (e.g., potential increase in sound from renewal energy; using sound to link to subsea eruptions) applications for acoustics in our oceans.

Besides investigating the spectrum of ambient noise, the acoustics efforts could very productively complement the global climate data (moorings, hydrography) by fielding some long range acoustic ocean thermometry experiments. Such integral measurements could provide a unique estimate of the volume heat content and flux. Also useful for seasonal and climate studies on moorings would be subsurface acoustic rainfall sensors (e.g., WOTAN), a difficult quantity to measure remotely at the sea surface. In addition, the acoustics work on hydrothermal vent CO_2 flux seemed like it should be connecting with the ocean acidification program. Also acoustics could play a role in early detection of land slides.

The plans to obtain "baseline sound levels in Arctic" and quantify variation in sound levels due to seasonal changes in sea ice cover should be put into the context of the decades of Arctic ambient noise data that have been measured, modeled and archived in many previous field expeditions. Such data mining would be as rewarding as the innovative effort to crowd source and digitize old ship logs for insight into long-term Arctic meteorological and oceanographic trends.

<u>PMEL should explore greater connections between the acoustics group and other projects such as ocean acidification, climate, tsunami and Arctic programs.</u>

Alaska and Arctic Marine Ecosystems

This project focuses on oceanographic issues relating to fisheries in Alaska. The project is clearly relevant to NOAA's fishery management responsibility: The Bering Sea provides more than 50% of US fisheries. The Bering-Sea project of the Pollock fishery undertaken by this group has been amazingly successful. Scientifically, it overturned an old paradigm for the impact of climate on the fishery, replacing it with a new one that works. The old paradigm suggested that in warm years the ecosystem expanded northward, thereby reducing the pollock population in the southern Bering Sea, but that expansion does not happen. In the new paradigm, warm conditions lead to fewer large zooplankton, which leads to the death of young pollock thereby impacting the fishery in subsequent years. Recently, based on a prediction from this group, the local fisheries reduced fishing quotas by one half, a remarkable example of end-to-end (basic science to societal application) research. It seems that a large factor that the Alaskan agencies and public were receptive to the PMEL pollock research because of the active engagement of PMEL researchers in public discussions. PMEL researchers speak once a year to the public, discussing how the system is changing, and organize well-attended symposiums. <u>It is recommended that this focus and approach be extended to the Gulf of Alaska and other high priority coastal areas.</u> A key aspect of the ecosystem dynamics is cross-shelf exchange. Although the program has identified processes involved in that exchange, there seems to be little effort to study the physics of the exchange in any detail. <u>It is recommended that PMEL conduct a modelling study and if needed an observational process study to understand the mechanisms of cross-shelf exchange.</u> <u>PMEL is well-positioned to play a leadership role in the Arctic, and that the time is right to make a significant investment toward this goal. Coordination with other artic research groups will be critical to ensuring success.</u>

Ocean Acidification

The overall ocean-acidification (OA) project is impressive, and critically needed. For example, the hazards of OA are clearly demonstrated in the disasters that occurred in the local oyster hatchery since 2005. The industry asked PMEL to help, and project scientists demonstrated that influx of subsurface, corrosive waters onto the shelf was the most important factor. Further, the source of the corrosive waters is the subduction of offshore surface waters that are anomalously acidic due to higher CO2 concentrations. The ocean acidification work is another noteworthy example of end-to-end research at PMEL. In addition, more transfer of observation results into modeling would be beneficial. For example, understanding the effects of ocean acidification today could be extrapolated incorporated in the modeling of past climate regimes on Earth. <u>PMEL should consider working with coastal ocean observing communities to design regional ocean acidification network.</u> <u>PMEL should also investigate whether high-resolution data now obtainable from Greenland and Antarctica ice cores could be combined with modern ocean acidification effects to compare and contrast similar episodes in the recent past for better understanding of the evolution of our climate.</u>

Earth-Ocean Interactions

This project looks at some of the roles that vents play in influencing the global ocean. The exploration and pioneering aspects of the Earth-Ocean Interactions program are substantial, with many remarkable discoveries. This theme, however, could benefit from more linkage to NOAA goals. <u>The group should actively pursue linkages associated with natural acidification laboratories, drug discovery, and the future opportunities and challenges of deep ocean mining.</u>

3. *Research Innovation*

Common to most well-established research organizations is a periodic, new initiative competition to provide opportunities for staff to obtain funding for new ideas. This process is particularly important for new staff and provides a mechanism for bottom-up innovation. When budgets are expanding, this process is relatively easy to implement. When budgets are flat or declining, initiating and sustaining such a process is challenging. The imperative of establishing such a process is amplified and complicated by the age-related demographics of the Laboratory. Achieving a high level of research innovation in the future will depend on attracting and retaining talented people. Providing opportunities to pursue new ideas within a research organization has proven to be an important factor in maintaining a competitive advantage in recruiting and retention. In the current fiscal environment, meeting this challenge of renewal will require a high degree of innovation by corporate management.

This program encompasses the engineering and information technology infrastructure that provides core science support at PMEL. It is what allows PMEL to conduct its end-to-end science with efficiency and innovation. Two of the reviewers rated this program “outstanding”, and the third rated it as “exceeds expectations”. A sample comment: “The quality of the work performed in Research Innovation is reflected in the degree to which the PMEL research projects depend on this group for providing innovative measurement platforms, solutions to challenging engineering problems, and for data management and distributing PMEL science data to the research community as well as stakeholders.”

Engineering

It is clear that the engineering is highly valued and is vital to the lab, and the wide range of products is remarkable: from Dart buoys and Argo floats to wave gliders and aerial drones. The number of products and techniques exported to groups outside PMEL is impressive also – PMEL is clearly a leader in ocean engineering for the community. The projected number of PMEL moorings is not decreasing, and innovative upgrades are planned and being implemented. Building on the ATLAS to T-Flex evolution, the well-engineered Easy-to-Deploy (ETD) mooring is the logical next step, including incorporating the Prawler which provides additional cost saving and higher vertical resolution data. To decrease dependence on ship-time, which will likely be a persistent limiting factor in the future, other methods of deployment should be considered, including self-deployment. Such a capability would be a radical innovation.

A number of other platforms are in various stages of development and deployment, including:

Carbon waveglider
Saildrone
Slocum glider
Seaglider
Quasi-Eulerian float (QUEphone)

Roboat (Austrian Society of Innovative Computer Sciences)
EMILY (unmanned surface vehicle)
Winch mooring (under-ice recording)
MANTA UAV aerosol sampler

No plans to hire new engineers were mentioned in the review. Clearly PMEL has in- depth expertise in mooring technology that must be maintained to support the planned work. Moorings are autonomous systems, but not mobile. ARGO floats are autonomous systems, mobile but not navigable. Subsurface gliders, waveglider, saildrone, UAV's are autonomous systems, mobile and navigable. The latter class of platforms requires a different engineering and operating skill set than moorings. The current ratio of scientists to engineers is about 40/5. To maintain and continue to innovate mooring technology while expanding operations with the range of new platforms mentioned, without considerably increasing the engineering staff seems unrealistic and risky.

Many of the new platforms mentioned are immature, and will require substantial engineering and testing to achieve reliable operation. For example, the goal of increased spatial coverage via new autonomous technologies to lower uncertainties in air-sea CO_2 flux measurements using the carbon waveglider or the saildrone is laudable. However, comparing those platforms to the robustness of the Papa, KEO, ATLAS or T-Flex surface buoys, which have been engineered to survive in the ocean and provide reliable and accurate measurements, is sobering. The same can be said about UAV operations in the Arctic. Much work needs to be done before these are capable of producing cost-effective "routine observations of aerosol vertical profiles." Clearly these are innovative new technologies that should be pursued to advance science objectives. However, a realistic engineering strategy is preferable to an under-staffed, ad hoc approach. <u>PMEL should conduct an internal review of the engineering group with the primary aim of assessing and prioritizing core engineering competencies and staffing levels required to support projected science needs.</u>

Research IT, Data Management, Data Telemetry

It was heartening that PMEL takes cyberinfrastructure and data management seriously, realizing that it is fundamental to PMEL and community science. As a government agency, PMEL can play a unique role in providing sustained support to infrastructure that helps the entire community, and they have taken advantage of this in the development of tools such as the Live Access Server, their work on the Climate and Forecast Conventions, and leadership in multi-institutional programs like the Unified Access Framework. From the number of innovative cyberinfrastructure solutions presented, it is clear that the group has impressive technical capabilities. <u>The group should take advantage of the standardized framework it has been helping to develop and deploy it for the benefit of PMEL research, building tools, portals and clients that utilize standardized web services for search and access to PMEL data.</u> This should be done in partnership with the NOAA-led Integrated Ocean Observing System, which is on the same cyberinfrastructure and data management path.

Almost all the long-term deployed sensor systems now rely solely on Iridium as the communication link. This is a single point of failure. There is much room for innovation to mitigate this risk. PMEL modular designs allow for adaption of new telemetry methods. Relatively low cost, low earth orbiting satellite communication technology (microsat) is rapidly advancing in other arenas, driven by the high cost of large communication satellites. Exploring communication alternatives to avoid reliance on a single network would be a wise investment.

4. Ocean and Coastal Processes

This program seemed a bit of catch-all for important but disparate projects, including analysis of ocean tracers, investigation of earth-ocean interactions (vents), and the tsunami warning system. Tracers help us to understand uptake of CO_2, changes in circulation, global climate, ecosystem, and therefore contribute to the other PMEL themes. Vent research studies the emission of trace metals and gasses (helium, iron, manganese, etc.), and seeks to understand their impact on ocean properties throughout the world ocean. The tsunami group develops tools to reduce tsunami hazard and protect life, including the design of optimal monitoring networks and rapid-response modeling. All projects address NOAA goals. Two of the reviewers rated this program “outstanding”, and the third rated it as “exceeds expectations”. A sample comment: “The ocean tracers group operates a world-class laboratory from which standards are distributed to other labs around the world. Similarly, the Tsunami Research and that of the Earth-Ocean interaction group have elements that are world class.” And another: “The deep ocean tsunami detection network based on the advanced DART sensors is simply the only globally operational network to facilitate tsunami early warning systems."

Ocean Tracers

CFC’s are a key metric for ocean models and provide insight into the uptake of anthropogenic CO_2 and to test numerical ocean model’s uptake of anthropogenic disturbance. The introduction of SF_6 monitoring as a tracer is innovative as the decline of CFC’s in the atmosphere continues. The tracer group should increase collaboration with modeling groups that use the tracer data.

Earth-Ocean Interactions

Conducting base line studies that would provide information on the value of seafloor mining and potential mitigation thereof presents an exciting niche for the Earth-Ocean group that is currently not being filled by any science agency in the US. This area of research clearly falls under the mission of NOAA considering its stewardship of the oceans. Seafloor mining is very likely going to happen. PMEL is ideally placed to be at the forefront of the research needed to inform policy makers, derive models on the likely impact to ecosystems, and the value of these resources to the nation. Some additional expertise, either through the hire of staff or collaboration with other institutions, is probably needed to complement existing expertise. <u>PMEL scientists are world leaders in seafloor hydrothermal systems, and should make the transition to enable them to be world leaders in understanding related mineral deposits and their possible exploitation.</u>

Tsunami

The Tsunami work was extremely impressive, and highly relevant. It is difficult to imagine something more relevant than an early warning system that could save many lives around the Pacific Rim. The accuracy of the forecast model for inundation of coastal regions is impressive and allows for more accurate warnings to be delivered to civil emergency groups. Several international competitors tried to challenge PMEL's leadership in the last decade, but NOAA has continually leap-frogged ahead and remains the only globally operational DART system. The operational DART sensors designed at PMEL are now being manufactured by SAIC and sold worldwide. The fact that even countries leading in tsunami research such as Japan have purchased DART sensors highlights the quality of the engineering performance. The tsunami forecasting through the MOST modeling suite developed at PMEL has proven invaluable for the tsunami warning centers PTWC and ATWC during numerous events worldwide. <u>The on-going technology and forecasting innovations at PMEL appear well-planned and should be completed. PMEL should study whether coastlines at high risk and vulnerability could benefit from shallower water sensors on deployed at depths of order a hundred meters to confirm incoming tsunami signals and facilitate more reliable model inundation forecasting for target coastlines.</u>

Comments on the Review Process

Panelists generally thought the review process was excellent: the pre-review web meetings and material on the web site gave the panelists a good idea of what to expect, the presentations were comprehensive in describing the research that goes on at PMEL. A few panel members thought that there could have been more detail, but most panelists thought that material was pitched at the right level of detail.

Many panelists applauded the attempts made to connect panelists with leadership, researchers, technical staff and stakeholders, but felt that the time was too short. Presentations often used the entire time period, leaving no time for questions, or even cutting into breaks, that, except for the excellent cookout, were the only time periods where one-on-one discussions between panelists and staff could take place. OAR should ensure there is sufficient time for reviewer questions and discussion during the presentations.

Panelists were a bit confused about the relationship between PMEL and JISAO, and given the importance of JISAO, the roles of the laboratory and its cooperative institute partner should be explained more at the very beginning of the review. The role of JISAO was clarified somewhat when the panel invited the Director of JISAO to join the leadership group discussion.

Panel interviews of the stakeholders should probably be extended from 12 minutes to 20 minutes each.

It would be useful to have a separate discussion with early career scientists.

A list of those attending the review would have been useful (names, positions, roles and photos) to facilitate Panel interaction.

The printed binder with all the talks and supplemental information was a lot of paper, but was felt to be useful, providing a place to take notes, and allowing quick referencing back to previous slides and talks as the review progressed.

Summary of Recommendations

1. A documented strategy is recommended for succession planning. It would be advantageous to have a phased retirement program that would allow a period of overlap between outgoing and incoming group leaders and thus mentorship for a new generation of PMEL research drivers.
2. As a first step to addressing [succession planning], PMEL should compile statistics on diversity in the lab, including salary equity; investigate/correct any biases and inequities found; investigate possible reasons for lack of diversity, and put into place policies to address deficiencies found in this area.
3. PMEL should assess the frequency of meetings between the heads of PMEL and JISAO to ensure that communication is optimal. There should be a plan in place to ensure good Fed/JISAO relationships and prevent building an "us and them" division in the lab.

4. PMEL should consider setting money aside for competitive seed ideas that might, if successful, might turn into larger programs.
5. Existing programs should be evaluated periodically to make sure they are still as effective and efficient.
6. PMEL should be active in ensuring that proposed new regulations contain sufficient routes for non-US citizens visiting the PMEL.
7. PMEL needs to play a major role again in controlling the design and operation of the TAO array
8. PMEL management should provide strong support for getting the tropical observing system back on course.
9. The TMAP [Thermal Modeling and Analysis Project] work is important and should continue.
10. PMEL should attempt an approach similar to the NGCUC [New Guinea Coastal Undercurrent] studies with gliders in another WBC [Western Boundary Currents] region.
11. Deep Argo measurements are critically important and must be expanded if the community is to have enough data to accurately understand where the heat due to climate change is being absorbed.
12. The ocean climate stations are an important member of NOAA's climate array and should continue being supported.
13. PMEL's carbon program clearly supports NOAA goal to acquire information about the impact of atmospheric CO2 on the ocean and should continue being supported.
14. There is a clear need to continue measurements of Arctic climate change, and to communicate results and understanding to society.
15. The [atmospheric chemistry] project contributes to NOAA's goal to improve understanding of atmospheric composition (clouds, aerosols, precipitation) and should be continued.
16. PMEL should explore greater connections between the acoustics group and other projects such as ocean acidification, climate, tsunami and Arctic programs.
17. It is recommended that the focus and approach [to investigating Alaska and Arctic Ecosystems] be extended to the Gulf of Alaska and other high priority coastal areas.
18. It is recommended that PMEL conduct a modelling study and if needed an observational process study to understand the mechanisms of cross-shelf exchange.
19. PMEL is well-positioned to play a leadership role in the Arctic, and that the time is right to make a significant investment toward this goal. Coordination with other artic research groups will be critical to ensuring success.
20. PMEL should consider to working with coastal ocean observing communities to design regional ocean acidification network.
21. PMEL should also investigate whether high-resolution data now obtainable from Greenland and Antarctica ice cores could be combined with modern ocean acidification effects to compare and contrast similar episodes in the recent past for better understanding of the evolution of our climate.
22. The Earth-Oceans Interactions group should actively pursue linkages associated with natural acidification laboratories, drug discovery, and the future opportunities and challenges of deep ocean mining.
23. PMEL should conduct an internal review of the engineering group with the primary aim of assessing and prioritizing core engineering competencies and staffing levels required to support projected science needs.

24. The [research IT, data management, and data telemetry] group should take advantage of the standardized framework it has been helping to develop and deploy it for the benefit of PMEL research, building tools, portals and clients that utilize standardized web services for search and access to PMEL data.
25. Exploring communication alternatives to avoid reliance on a single network would be a wise investment.
26. The tracer group should increase collaboration with modeling groups that use the tracer data.
27. PMEL scientists are world leaders in seafloor hydrothermal systems, and should make the transition to enable them to be world leaders in understanding related mineral deposits and their possible exploitation.
28. The on-going technology and forecasting innovations at PMEL appear well-planned and should be completed.
29. PMEL should study whether coastlines at high risk and vulnerability could benefit from shallower water sensors on deployed at depths of order a hundred meters to confirm incoming tsunami signals and facilitate more reliable model inundation forecasting for target coastlines.
30. The following recommendations are for OAR Headquarters to improve the review process:
    a. **OAR should ensure there is sufficient time for reviewer questions and discussion during the presentations.**
    b. The roles of the laboratory and its cooperative institute partner should be explained more at the very beginning of the review.
    c. The panel's interviews of the stakeholders should probably be extended from 12 minutes to 20 minutes each.
    d. It would be useful to have a separate discussion with early career scientists.