PMEL Science Review
Implementation Plan

Pacific Marine Environmental Laboratory's Response to the Recommendations from the August, 2008 Science Review

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1. Rationale and outline of the Implementation Plan

The PMEL Review Team developed a list of 46 separate recommendations in their report. We are grateful for the Team's thoughtful consideration of PMEL's programs and needs, based on the material presented at the review. Rather than respond to all 46 recommendations sequentially as they were listed in the report, we categorized the recommendations and, in so doing, have adopted a strategy to utilize them to their fullest value.

We have identified issues that fall into the following five categories: 1) a summary recommendation, 2) recommendations that PMEL can use to move our research objectives forward within NOAA, 3) recommendations which PMEL has already put into motion and, in some cases, has already completed, 4) recommendations that are primarily outside of PMEL's control, but will be offered to the most appropriate NOAA offices, and 5) recommendations that were made concerning the conduct of the review, or for which we judged were made rhetorically. In this way, we account for all the recommendations, even those for which there is no action required on PMEL's part.

It should also be noted that the recommendations of the reviewers are numbered from 1 to 40, with two recommendations having more than one part. (There is a Recommendation 12, 12.2, and 12.5; there is also Recommendation 40, 40.1, 40.2, 40.3, and 40.4, for a total of 46 recommendations.) In this Implementation Plan, we retain the reviewers' original numbering scheme for consistency with the reviewers' report.

Consistent with OAR's guidance stated in the Implementation Plan, PMEL intends to implement action on all applicable recommendations within six months of the acceptance of this implementation plan by OAR.

2.0 List of Reviewer Recommendations

Reviewer Recommendation	Addressed in Section…
1. PMEL should be more aggressive in mounting long-term observation programs of the ocean water column	3.2.1
2. NOAA should consider a more deliberate effort to measure currents and fluxes in selected areas.	3.2.1
3. PMEL climate and carbon cycle groups should have systematic ties to external (modeling) groups and some internal hires with modeling experience.	3.2.2
4. NOAA/PMEL needs to continue communicating with NOAA headquarters on ship time	3.2.4
5. PMEL would greatly benefit from a formal seed-fund to support pilot studies for technology development and higher-risk concepts.	3.2.4
6. PMEL should invest in data management to keep up with existing and anticipated demands for increasing demands for data and for stakeholders.	3.4.3
7. A strong, explicit mentoring program and base of upcoming mid-career leaders needs to be in place within the laboratory for a successful transition plan (succession plan) when the current crop of senior people retire or move.	3.3
8. Whatever you do, don't break it!	3.1
9. It would be useful to present PMEL's roles and responsibilities within NOAA/OAR for purposes of evaluating the Lab's effectiveness.	3.5.1
10. Provide statistics and budgets by research area rather than for the lab at large.	3.5.1
11. PMEL management should reinforce with scientists and technical editors that salinities should not be published in units of PSU.	3.5.1
12. Provide time for writing by the review team and establish an expectation that draft comments be provided before the review team departs.	3.5.1
12.2 PMEL's tsunami program needs to dedicate effort to publishing its research in the scientific literature as well as developing operational products to improve the Tsunami Warning Program within NOAA.	3.2.3
12.5 PMEL's tsunami program needs least one or two additional PhD level scientists.	3.2.3
13. Transfers of climate observation technologies should be followed by institutional cultural and scientific adjustments enabling new technology initiatives (e.g., glider program).	3.4.2
14. PMEL should consider a more aggressive instrumentation activity including a heavier focus in monitoring the water column, for programs such as the Ocean Climate Station program.	3.2.1

15. The Live Access Server should have greater visibility and attention.	3.4.3
16. Bridge across PMEL research groups by connecting the water chemistry studies to ecosystem impacts and the discovery-exploration of CO2 release by underwater volcanic systems.	3.3
17. The PMEL review team should have met with Mike Johnson.	3.5.1
18. PMEL should play a lead role in an OAR determination of how to scale up efforts to operationalize NOAA Climate program activities.	3.4.1
19. PMEL should better demonstrate the importance and utility of the tropical oceanographic data products.	3.3
20. The TAO transition should have involved PMEL in developing a strategy for maintaining climate quality data.	3.4.2
21. PMEL needs an appropriate role in any NOAA Climate Services organization, with clear boundaries between research and operations, prioritization of field efforts and two-way information exchange to translate field observations into decision support tools.	3.4.1
22. The PMEL CLIVAR and carbon programs should be given high priority for NOAA ship time on the Ron Brown or for NOAA funds to charter an equivalent Class I research vessel.	3.2.4
23. The recent ocean carbon survey along the US West Coast should be integrated into the NOAA observational network, with observational rather than research funding, and be repeated on a regular basis.	3.4.1
24. PMEL instrumentation to autonomously measure two components of the ocean carbonate system should be incorporated into a wider network of moorings.	3.3
25. PMEL should have a performance metric to track obtaining and providing ocean observations data to the larger external community (in addition to publications).	3.2.5
26. PMEL's engineering innovation and the science-engineering partnership should continue to be strongly supported.	3.2.4
27. FOCI should consider a more proactive use of Lagrangian techniques to explore, chart and understand the mesoscale dynamics of the Bering Sea/Gulf of Alaska region.	3.3
28. FOCI should consider gliders and/or AUVs for insight into the structure of the circulation, the eddy field, mixing processes and the role of topography to define advective and dispersive processes, which play a major role in fixing the water properties.	3.3
29. NOAA should continue to support FOCI long-term time series for assessing changes in ocean climatology and fisheries.	3.2.1
30. The successful FOCI partnership between PMEL and the National Marine Fisheries Service should be highly commended as an example of strong within-agency cooperation and coordination to address societally relevant goals.	3.5.2

31. Research efforts, such as EcoFOCI, need to build on the approaches developed by program with a single species focus to a broader ecosystem-wide orientation.	3.3
32. FOCI should determine if the current mooring network is adequate through a more thorough observational network design study.	3.2.2
33. EcoFOCI would benefit from greater contact with regional climate modeling groups, for projections of future climate change, climate downscaling products and boundary conditions (atmospheric and lateral) for local numerical models.	3.2.2
34. EcoFOCI should set priorities and research directions to meet the emerging focus on IEAs in support of ecosystem approaches to management.	3.3
35. Base funding should support a higher fraction of FOCI activities. One possible avenue to enhanced base funding is a commitment to shaping IEAs in the Gulf of Alaska and the Bering Sea.	3.2.4
36. PMEL should assure funding for maintenance of the four Bering Sea moorings.	3.2.1
37. FOCI must decide what is planned for transition and what will be supported in the long term, specifically with regard to the four Bering Sea Moorings, which probably should not be transitioned.	3.4.2
38. Why not put the output of an ocean hydrophone on the net?	3.3
39. Consider a hydrophone offshore of a harbor.	3.3
40. In the case of tsunamis, a performance measure other than publications should be used to measure the success of the program.	3.2.5
40.1 PMEL should consider expanding server capability to provide access to tsunami buoy data and forecasts during large earthquake events.	3.2.3
40.2 PMEL tsunami group should publish a paper with the details about FACTS and maintain both FACTS and ComMIT servers.	3.2.3
40.3 PMEL'S tsunami group must maintain the 'branding' of its MOST code vs. other less capable codes marketed by newcomers.	3.2.3
40.4 PMEL should be more assertive in debunking invalid claims made for less capable tsunami models.	3.2.3

3. Responses to the Recommendations

3.1 Summary Recommendation (to NOAA Leadership) (Recommendation 8)

- Recommendation 8 (Whatever you do, don't break it!)

Response: Thank you! We'll take that as a compliment!

3.2 Recommendations Actionable by PMEL

3.2.1 Enhancements to observing/monitoring/research (Recommendations 1, 2, 14, 29, 36)

- Recommendation 1 (PMEL should be more aggressive in mounting long-term observation programs of the ocean water column.)
- Recommendation 2 (NOAA should consider a more deliberate effort to measure currents and fluxes in selected areas.)
- Recommendation 14 (PMEL should consider a more aggressive instrumentation activity including a heavier focus in monitoring the water column, for programs such as the Ocean Climate Station program.)
- Recommendation 29 (NOAA should continue to support FOCI long-term time series for assessing changes in ocean climatology and fisheries.)
- Recommendation 36 (PMEL should assure funding for maintenance of the four Bering Sea moorings.)

Response: PMEL concurs with these recommendations and will continue to pursue funding support through NOAA's PPBES process as appropriate. Observation and monitoring of the ocean and atmosphere have been the mainstay of PMEL research since its inception. The oceans, especially, have been historically undersampled, and as the significance of the ocean's role in climate, and, more recently, climate change, is understood, there is an increasing interest in collecting high-quality scientific data over all ocean regions in support of numerous programs to accelerate our understanding of the oceans' roles in sustaining the planet. As the Nation has expanded its thirst for knowledge, NOAA has tasked its ocean scientists to develop innovative methods in addition to conventional means to collect observations in support of research and PMEL has answered the challenge for many years.

While funding for research has allowed PMEL scientists to engage in cutting edge research in the climate, ecosystems, and weather and water areas, PMEL scientists have identified several research gaps which, heretofore, have not been supported by

NOAA.

Based on the review recommendations, PMEL supports four research themes that are at various points in the NOAA budget process: 1) Ocean Acidification is on track for a 2010 start; its future is now dependent on the outcome of Congressional budget action this year; 2) a budget alternative will be prepared supporting the Pacific Upwelling and Mixing Physics (PUMP) program, to be submitted to the Climate Observations and Monitoring (COM) Program for the 2012-2016 PPBES process, which begins in April-May, 2009; 3) an alternative will be prepared which requests long-term NOAA funding for the Bering Sea biophysical moorings. This will be submitted either to the Ecosystem Observing Program (EOP) or the Climate Services Development Program (CSD); and 4) PMEL is involved in the Passive Acoustics Ocean Observing Systems (PAOOS) alternative that was considered "above core" in the 2011-2016 PPBES process. PMEL will work with program managers to determine appropriate next steps for this activity. In the meantime, PMEL staff will continue to pursue innovative ideas to improve the efficiency and effectiveness of observing systems as project budgets permit.

3.2.2 Modeling (Recommendations 3, 32, 33)

- Recommendation 3 (PMEL climate and carbon cycle groups should have systematic ties to external (modeling) groups and some internal hires with modeling experience.)
- Recommendation 33 (EcoFOCI would benefit from greater contact with regional climate modeling groups for projections of future climate change, climate downscaling products, and boundary conditions (atmospheric and lateral) for local numerical models.)

Response: We agree with these recommendations and plan to pursue adding two numerical modelers to PMEL to address these deficiencies. One modeler will have experience in numerical model development with an emphasis on application to PMEL climate interests while the second modeler will focus on applications of ocean models to support PMEL climate research. We envision the modelers will have close connections with the relevant modeling communities within and outside of NOAA, including the Modular Ocean Model (MOM) and the Hybrid Coordinate Ocean Model (HYCOM). Funding to support the two modelers will come from a combination of project and base funds. We estimate that, if approved, the modelers could be hired by the end of FY10.

- Recommendation 32 (FOCI should determine if the current mooring network is adequate through a more thorough observational network design study.)

Response: The existing Bering Sea mooring array design in not optimum; EcoFOCI plans to conduct a thorough array design study using the ROMS model .PMEL will utilize the outcome of the Buoy Recap Plan to request funding for a mooring design

study of the Bering Sea array.

3.2.3 Tsunami Research (Recommendations 12.2, 12.5, 40.1, 40.2, 40.3, 40.4)

- Recommendation 12.2 (PMEL's tsunami program needs to dedicate effort to publishing its research in the scientific literature as well as developing operational products to improve the Tsunami Warning Program within NOAA.)

Response: PMEL's primary mission is to serve NOAA and the nation. Recent advances made by the PMEL tsunami research team has resulted in eagerness to upgrade NOAA's tsunami warning capabilities in the shortest amount of time possible. PMEL has responded to this need by focusing its tsunami resources on developing the models and delivery system. With funding support to the NOAA Tsunami Program provided through the Warren Act from 2009 through 2012, PMEL will enhance its research capability, which will lead to an increase in publications. Looking beyond 2012 and the expiration of funds made available through the Warren Act, PMEL has submitted an alternative through the Tsunami Program to continue the research program initiated in 2009.

- Recommendation 12.5 (PMEL's tsunami program needs at least one or two additional Ph.D. level scientists.)

Response: The PMEL Tsunami Program currently has 12 Ph.D. scientists on board, approximately half of the program total staff. The funding of a Tsunami Research Program by NOAA will allow PMEL to reapportion its scientific talent so that NOAA's operational needs and the publication of research results will benefit the broader tsunami community.

- Recommendation 40.1 (PMEL should consider expanding server capability to provide access to tsunami buoy data and forecasts during large earthquake events.)

Response: This capability will be available to the research community through the National Center for Tsunami Research (NCTR) as a result of the Tsunami research funding

- Recommendation 40.2 (PMEL tsunami group should publish a paper with the details about FACTS and maintain both FACTS and ComMIT servers.)

Response: The functionality of FACTS, run under PMEL's Live Access Server, is being replaced by a new application called WebSIFT. WebSIFT will be phased in over time and will support the needs of the tsunami modeling research community. ComMIT will continue to be maintained as before to access the pre-computed

propagation model database. User manuals are available for the MOST model and ComMIT software. FACTS has a user manual and a similar support documentation is envisioned for WebSIFT.

- Recommendation 40.3 (PMEL'S tsunami group must maintain the "branding" of its MOST code vs. other less capable codes marketed by newcomers.)

Response: The newly established research test bed will help maintain high standards for modeling accuracy.

- Recommendation 40.4 (PMEL should be more assertive in debunking invalid claims made for less capable tsunami models.)

Response: Publications using the NOAA tsunami forecasting models will continue to establish the accuracy and performance of the models. We cannot control other publications, but we hope the peer review process will filter out unfounded claims.

3.2.4 Resources (i.e., Laboratory funding, Shiptime funding) (Recommendations 4, 5, 22, 26, 35)

- Recommendation 4 (NOAA/PMEL needs to continue communicating with NOAA headquarters on ship time.)

Response: The NOAA fleet's support for ocean and climate research (principal OAR activities) has decreased dramatically in the past 15 years. Three Class I vessels which were dedicated to OAR activities were retired in the 1990s and were replaced by the *Ronald H. Brown* and the *Ka'imimoana*; the latter is now supporting National Weather Service (NWS) requirements. A charter fund was intended to replace the loss of Class I time with UNOLS charters; however, this fund has become inadequate as the size of the charter fund in real dollars has decreased; it has now been made available to address non blue-water research carried out by Sea Grant, NURP, and GLERL; and the cost of shiptime has risen dramatically. PMEL management and researchers continue to work within NOAA to voice concern about our deteriorating ability to conduct at sea operations and, at the same time, we have heavily leveraged our associations with foreign nations and other partners to make up for NOAA's lack of support for shiptime. Although we will continue to pursue shiptime through the traditional NOAA ship request process, and use the NOAA budget planning process to push for additional fleet funding, we will also develop technology to reduce PMEL's dependency on large, expensive ship time. Current and projected research requirements for ship time, including those of PMEL, will be considered in the next phase of the NOAA Ship Recapitalization Plan. PMEL is actively participating in the NOAA Buoy Recapitalization Plan and is investing in the development of advanced mooring technologies that hold promise for reducing the need for shiptime in the future.

- Recommendation 5 (PMEL would greatly benefit from a formal seed fund to

support pilot studies for technology development and higher-risk concepts.)

Response: In the past, such seed funding was provided by various sources: PMEL itself, AA discretionary funds, NOAA Ecosystem Goal Team, and Ocean Exploration, to name a few. There is currently no regular NOAA funding source available for such high-risk, high reward projects, particularly for longer than one-year terms, although the OAR AA and DAA/LCI considers the availability of such funding a high priority. PMEL will continue to pursue opportunities as the funding climate allows.

- Recommendation 22 (The PMEL CLIVAR and carbon programs should be given high priority for NOAA ship time on the *Ron Brown* or for NOAA funds to charter an equivalent Class I research vessel.)

Response: The inadequacy of funding for vessel operation (NOAA fleet or charter) is apparent across all NOAA programs, but perhaps most acutely seen in the ocean research community. There is currently only one NOAA vessel to support a large and growing research demand, and as charter funds for replacement vessels shrink, shiptime costs increase dramatically. PMEL makes its needs known and is supported to the extent possible by the Climate Program Office in fleet and charter fund allocation discussions. As pointed out above (Recommendation 4), NOAA goal teams need to recognize the importance of shiptime to their portfolios and make it a priority to bolster funding for the fleet and charter operations. Current and projected research requirements for ship time, including those of PMEL, will be considered in the next phase of the NOAA Ship Recapitalization Plan.

- Recommendation 26 (PMEL's engineering innovation and the science-engineering partnership should continue to be strongly supported.)

Response: PMEL will continue to challenge the Engineering Development Division to develop new and innovative methods for measuring ocean parameters. Furthermore, PMEL will leverage project funds with possible other funding sources, such as those addressed in Recommendation 5 above.

- Recommendation 35 (Base funding should support a higher fraction of FOCI activities. One possible avenue to enhanced base funding is a commitment to shaping IEAs (Integrated Ecosystem Assessments) in the Gulf of Alaska and the Bering Sea.)

Response: An alternative in NOAA's FY10 planning budget increases funding to conduct IEAs for several large marine ecosystems, including Alaska. If this alternative is ultimately funded at its requested level, PMEL and NOS will receive a funding increase of approximately $1M per year to support ecosystem assessments.

3.2.5 Performance Management (Recommendations 25, 40)

- Recommendation 25: (PMEL should have a performance metric to track

obtaining and providing ocean observations data to the larger external community (in addition to publications).)

Response: NOAA's performance measurement system currently allows for the recognition of data collection as a valid metric in evaluating performance. Several PIs in the Climate, FOCI, and Vents programs have included continuation and expansion of various data collection efforts in the annual tracking of milestones within OAR and NOAA. Data access, per se, has not been used as a performance metric by PMEL to date. Certain projects, particularly the tropical ocean climate observations systems (TAO, PIRATA, RAMA), have a strong data access program and server statistics that could provide quantitative performance metrics. PMEL will work with OAR's Program Planning and Evaluation Office to develop appropriate performance metrics..

- Recommendation 40: (In the case of tsunamis, a performance measure other than publications should be used to measure the success of the program.)

Response: This recommendation complements Recommendation 12.2 (see section 3.2.3, above). In the case of the Tsunami Program, performance measures at the program level focus on the completion of forecast models and the implementation of the operating system, which supports the model forecasts. Publication totals are important measures for the lab as a whole, but variances between programs within the lab affect publication totals. PMEL does not use publications alone to judge how individual programs are performing.

3.3 Recommendations Already Implemented (in various stages of completion) (Recommendations 7, 16, 19, 24, 27, 28, 31, 34, 38, 39)

- Recommendation 7 (A strong, explicit mentoring program and base of upcoming mid-career leaders needs to be in place within the laboratory for a successful transition plan (succession plan) when the current crop of senior people retire or move.)

Response: There are a number of junior level scientists within the lab who are being mentored by senior staff. PMEL views the scientific staff like a pyramid: a small number of senior scientists, with a larger number of junior scientists (some federal, but more from the Cooperative Institutes), and a still larger number of technicians. PMEL has produced two PECASE (Presidential Early Career Awards for Scientists and Engineers) junior scientists in the past 10 years, and has had several junior scientists depart for opportunities at other institutions and universities.

- Recommendation 16 (Bridge across PMEL research groups by connecting the water chemistry studies to ecosystem impacts and the discovery-exploration of CO_2 release by underwater volcanic systems.)

Response: PMEL's CO_2 scientists are actively engaged with both the PMEL Vents program and the EcoFOCI programs: a research proposal has been accepted to conduct CO_2 monitoring studies in the Bering Sea in the summer of 2010 and funding for CO_2 research at the Vents NW Eifuku site in the Marianas Arc has been proposed.

- Recommendation 19 (PMEL should better demonstrate the importance and utility of the tropical oceanographic data products.)

Response: PMEL believes that the utility of the tropical oceanographic data products has been demonstrated adequately. As an illustration of this point, through 2008, 676 peer-reviewed publications have appeared in the scientific literature utilizing tropical oceanographic data from the TAO-TRITON, PIRATA, and RAMA Arrays. In 2008 alone, 28.8 million web hits were registered on PMEL's and NDBC's tropical moored buoys web sites, indicating that these datasets are being heavily used by the research and operational communities.

- Recommendation 24 (PMEL instrumentation to autonomously measure two components of the ocean carbonate system should be incorporated into a wider network of moorings.)

Response: The PMEL mooring established at Ocean Station Papa, supported by the National Science Foundation, the Canada Department of Fisheries and Oceans, and NOAA is the first (and only) "ocean acidification" mooring deployed where two components of the ocean carbonate system are being measured: pCO_2 and pH. PMEL has requested funds from the Climate Program Office for addition of pH sensors to other pCO_2-equipped moorings, but a better solution would be to replace the pH sensor with an instrument capable of measuring total CO_2 at the ocean-atmosphere interface. PMEL has requested support from CPO to begin development of such a sensor through the "add task" mechanism in its FY2008 annual progress report and will again in its FY2009 submission.

- Recommendation 27 (FOCI should consider a more proactive use of Lagrangian techniques to explore, chart, and understand the mesoscale dynamics of the Bering Sea/Gulf of Alaska region.)

Response: Surface drifters and ARGO floats have been used in the Gulf of Alaska and Bering Sea regions in the past (focused studies were supported by NOS/GLOBEC, the Steller Sea Lion research effort, and other programs in the early 2000's), and they have been very useful in describing transport, especially in the vicinity of the Aleutian passes. Lagrangian methods are a valuable tool in the EcoFOCI toolbox and will continue to be utilized as observing requirements demand.

- Recommendation 28 (FOCI should consider gliders and/or AUVs for insight into the structure of the circulation, the eddy field, mixing processes, and the role of topography to define advective and dispersive processes which play a major role in fixing the water properties.)

Response: Gliders have been employed successfully in the Gulf of Alaska basin, in partnership with Dr. Charles Eriksen of the University of Washington. Funding is no longer available, similar to the Lagrangian measurements referenced above. Geographical focus for EcoFOCI has shifted to the Eastern Bering Sea, where the shallow depth (approximately 70 meters) and a very active fishing fleet most of the year in this region make glider operations problematic.

- Recommendation 31 (Research efforts, such as EcoFOCI, need to build on the approaches developed by the program with a single species focus to a broader ecosystem-wide orientation.)

Response: EcoFOCI began the shift from a single-species research effort based on Pollock to a multi-species ecosystem focus in 1999-2000, when NOAA was directed to address the Steller Sea Lion population declines in the Aleutian Islands. Since that time, PMEL and the Alaska Fisheries Science Center (AFSC) of NOAA's National Marine Fisheries Service have become increasingly focused on ecosystem approaches to management of the Alaska fisheries issues.

- Recommendation 34 (EcoFOCI should set priorities and research directions to meet the emerging focus on IEAs in support of ecosystem approaches to management.)

Response: As indicated above, EcoFOCI research has migrated towards an ecosystem-based approach, even before NOAA adopted this approach. The Alaska large marine ecosystem has been identified for Integrated Ecosystem Assessment (IEA) funding beginning in FY10 and PMEL and its academic, federal, and local community partners have a plan in place to implement immediately if the planned funding is made available.

- Recommendation 38 (Why not put the output of an ocean hydrophone on the net?)
- Recommendation 39 (Consider a hydrophone offshore of a harbor.)

Response: Data from a cabled hydrophone established on the Pioneer Seamount in 2001 was made available on the web in real time until its failure in September, 2002. PMEL also established a hydrophone in Yaquina Bay, Oregon (Newport) as part of an exhibit on underwater sound at the Hatfield Marine Science Center in Newport in 2008.

While there are obvious outreach and education benefits from making these sounds available, PMEL does not have a requirement to provide these data on line in real time. Rather, PMEL's approach is to include samples of sounds in the sea from geophysical events, marine mammals, and ambient ocean noise which have been extracted from recovered moored hydrophones on our acoustics web site (http://www.pmel.noaa.gov/vents/acoustics.html).

3.4 Recommendations Outside PMEL's Sphere of Influence

3.4.1 Climate Services (Recommendations 18, 21, 23)

- Recommendation 18 (PMEL should play a lead role in an OAR determination of how to scale up efforts to operationalize NOAA Climate program activities.)

- Recommendation 21 (PMEL needs an appropriate role in any NOAA Climate Services organization, with clear boundaries between research and operations, prioritization of field efforts, and two-way information exchange to translate field observations into decision support tools.)

Response: This is a part of the discussion surrounding the evolution of the present day Climate Program within NOAA to a NOAA Climate Services organization. A great deal of discussion has occurred over the past year or so at several levels inside and outside of NOAA as to how to make Climate Services more relevant to the American people. Selected PMEL scientists and leaders have and will continue to be involved in this discussion.

- Recommendation 23 (The recent ocean carbon survey along the U.S. West Coast should be integrated into the NOAA observational network, with observational rather than research funding, and be repeated on a regular basis.)

Response: Shiptime funds are not allocated based on an operational vs. research delineation. NOAA ship time and charter funding decisions are made based on the line office and program recommendations. As the development of a NOAA Climate Services capability evolves, the distinction between climate research and climate operations may become more distinct and this issue can be resolved at that time. Alternately, other technology, such as gliders, may prove to be suitable alternatives to an extended cruise in this region. PMEL has recently acquired two gliders for test and evaluation purposes related to this and other PMEL research efforts.

3.4.2 Transition from Research to Operations (Recommendations 13, 20, 37)

- Recommendation 13 (Transfers of climate observation technologies should be followed by institutional, cultural, and scientific adjustments enabling new technology initiatives (e.g., glider program).)

Response: PMEL has “let go” of transitioned projects and is focused on other research goals. The TAO Array, for instance, was transferred to the National Data Buoy Center (NDBC), operated by the NWS. PMEL continues to provide the sensors for the array while NDBC procures and integrates new sensors into a replacement buoy system.

PMEL has moved forward to addressing scientific issues in the Indian Ocean. NOAA Management determines the process and schedule of transition activities.

- Recommendation 20 (The TAO transition should have involved PMEL in developing a strategy for maintaining climate quality data.)

Response: PMEL was involved with the development and implementation of the TAO Transition Plan following NOAA's decision to transfer the TAO Array from PMEL to NDBC. As part of the transition, PMEL transferred its entire software suite used to quality control and manage the data stream. PMEL remains closely involved with TAO today, providing all the sensors for the Array until such time as NDBC is able to provide a "refreshed" sensor suite. As users of the data, PMEL remains highly attentive to data quality issues and shares any concerns with NDBC personnel.

- Recommendation 37 (FOCI must decide what is planned for transition and what will be supported in the long term, specifically with regard to the four Bering Sea Moorings, which probably should not be transitioned.)

Response: We agree. Within NOAA, decisions on whether or when to transition research projects to operational status are made by the relevant Line Office Transition Managers. PMEL would not be supportive of transitioning the Bering Sea moorings or the EcoFOCI program to another organization at this time. We believe that EcoFOCI is a research effort and the Bering Sea moorings are research moorings. The parameters measured continue to evolve as knowledge is gained on the indicators of ecosystem health in the region. If and when NOAA considers transitioning these moorings to an operational status, PMEL will be involved in the development of a transition plan to ensure that the transition is successful.

3.4.3 Data Management (Recommendations 6 & 15)

- Recommendation 6 (PMEL should invest in data management to keep up with existing and anticipated increasing demands for data and for stakeholders.)
- Recommendation 15 (The Live Access Server should have greater visibility and attention.)

Response: Data management activities are supportive of the research environment of PMEL. Activities such as LAS that have been developed here are the result of specific projects that are the outgrowth of research activities. Because of PMEL's obvious interest in maintaining access to high quality oceanographic datasets, PMEL will continue to provide data management and visualization support for NOAA's data managers.

3.5 Recommendations Not Part of the Scientific Program

3.5.1 Recommendations related to the Conduct of the Review (Recommendations 9, 10, 11, 12, and 17)

- Recommendation 9 (It would be useful to present PMEL's roles and responsibilities within NOAA/OAR for purposes of evaluating the Lab's effectiveness.)

Response: A description of the OAR Laboratories' planning and priority setting activities will be included in future lab reviews.

- Recommendation 10 (Provide statistics and budgets by research area rather than for the lab at large.)

Response: This could be attempted for future reviews; however, a significant portion of staff and resources support all the Lab's programs generally and as such, it would be arbitrary to define the level of support to any particular research area. This is particularly true with respect to the lab's base funding. Attribution of publications by program area is much more clear-cut and could be easily accomplished.

- Recommendation 11 (PMEL management should reinforce with scientists and technical editors that salinities should not be published in units of PSU.)

Response: Agreed.

- Recommendation 12 (Provide time for writing by the review team and establish an expectation that draft comments be provided before the review team departs.)

Response: We will pass this recommendation on to OAR Headquarters for future reviews.

- Recommendation 17 (The PMEL review team should have met with Mike Johnson.)

Response: We will pass this suggestion on to OAR Headquarters. Other laboratories might benefit from similar arrangements in forthcoming reviews.

3.5.2 "Recommendations" that are not Recommendations (Recommendation 30)

- Recommendation 30 (The successful FOCI partnership between PMEL and the National Marine Fisheries Service should be highly commended as an example of strong within-agency cooperation and coordination to address societally-relevant goals.)

Response: We agree. Thank you.

Appendix A.
Responses to OAR-highlighted text in Reviewers' Final Report

PMEL Research Review Final Report comments highlighted by OAR HQ.
(Accompanying text included where necessary to provide context)

I. "There was no clear sense of whether the laboratory plans to move into new areas of research (which could also be strongly relevant to NOAA's overall objectives), how priorities are set across the laboratory, and how (if) the decision would be made to phase out one of the existing research themes to support other areas." **(HQ)**

Response: PMEL sets research priorities by evaluating three factors: NOAA opportunity (support in the Strategic Plan or interest in the problem expressed by a Program Office or Line Office), the availability of the scientific expertise to address the research problem, and the availability of necessary technology/support to assist the research effort.
While PMEL can provide limited funding to a high priority research effort from its base funds, PMEL does not have the capacity to sustain a meaningful research effort on its own for the long term. Eventually, NOAA Program or Line offices will need to provide funding for the research effort or the effort will end. PMEL's Tsunami research effort, carbon dioxide/ocean acidification research, and Ocean Climate Stations are programs that PMEL initially supported until NOAA Line or Program Offices assumed that responsibility; allowing PMEL the opportunity to support other research.
Currently, there are two new areas of research on the horizon; Ocean Acidification and Ocean Climate Stations are on the cusp of regular funding from CPO, and ETD buoy technology is also still being largely supported from lab funds. When those projects are successful, PMEL will be open to supporting new research projects, such as ocean acoustics.
Phasing out a research effort is a more difficult task. It is fairly obvious when NOAA is no longer supportive of a particular research effort; i.e. demonstrated through the decisions of its funding organizations or, if timely, in new versions of the Strategic or Research Plans. The more difficult task is to redirect scientific staff that has supported a program which is no longer funded. Some more recent examples where PMEL has spun down areas of research are the Gulf Stream transport measurements using abandoned telecommunications cables and transitioning of construction of in situ CO_2 sensors to industry.

II. "The overall strategy and purpose for the ecosystem forecasting was not clear." **(HQ)**

Response: The purpose for the ecosystem forecasting research in Alaska is to provide

NMFS and fisheries managers with integrated ecosystems management tools they need to make assessments and forecasts of ecological conditions that will sustain viable commercial fisheries, protect marine mammal and bird populations, provide economic opportunity for coastal residents and stakeholders.

III. "In the final wrap up, a vision was presented for buoys everywhere in the world ocean, but for what purpose?" **(HQ)**

Response: Buoys are not the goal, rather an efficient and affordable technology to provide ocean observations for a myriad of NOAA products. Presently, buoys play a large role in providing information because oceanographic ships are expensive to operate and few in number. In addition to buoys, PMEL is developing means to exploit smaller, less costly vessels of opportunity and is aggressively experimenting with AUVs such as gliders and autonomous floats to augment our ocean observing capabilities to further mitigate the research vessel cost and availability issues,

IV. "The thinking behind the Tsunami Test Bed does not seem to be as well developed or as consistent with the other test beds within NOAA." **(HQ)**

Response: Reference the attached NOAA Tsunami Research Plan that was vetted with OAR's Senior Research Council in May 2007. This plan is guiding the development of a tsunami test bed at PMEL using Spectrum funds for FY09-12.

V. "There seemed to be little attempt or interest in being cognizant of present and future satellite systems and how PMEL's activities could benefit or contribute." **(HQ)**

Response: In the course of a 20-minute science talk, it is difficult to include all aspects of scientific work associated with a particular project. PMEL routinely utilizes and integrates satellite data in its research (e.g. SST, wind fields, ocean color, SAR). Satellites are also used extensively for data communication to and from PMEL buoys and ships for ocean observations. PMEL collaborates with NASA to use buoy-based observations for calibration/validation activities of various satellite sensors, including SST, rainfall, and ocean-atmosphere fluxes.

PMEL is also partnering with the NOAA Office of Ocean Exploration and Research (OER) to pioneer the use of broad-bandwidth, satellite communications in the laboratory's Exploration Command Center to receive real-time data from expeditions aboard the NOAA Ship *Okeanos Explorer*. This capability also will enable PMEL scientists to lead *Okeanos Explorer* expeditions from the Command Center.

VI. Referring to transitioning Argo to NDBC: **"**But this is something I would 'hurry slowly' with because there is still a lot of learning going on, including the addition of more sensors. Of course, there is absolutely nothing that says that NDBC can't run the main program and various groups continue to explore Argo for more focused research initiatives." **(HQ)**

Response: PMEL is aware that there are discussions within NOAA regarding the possible

transition of ARGO operations to NDBC. At this time, we do not favor a transition due to the research nature of the program. There is also the fact that the bulk of the U.S. Argo program is being carried out by non-NOAA research entities: SIO, WHOI, and Univ. of WA.

VII. "The TAO Transition Plan was written in 2004. Four years have passed and it does not seem that there has been an objective or independent assessment of how well the transition process is working." **(HQ)**

Response: This is an issue for the Climate Goal, OAR and NWS Transition Managers, the NOAA Observing Systems Council, or Science Advisory Board to consider.

VIII. "Although beyond the control of PMEL, the labs efforts suffer to some extent in that NOAA as an agency does not have an operational or routine ocean data assimilation system for state estimation of the ocean climate. While NOAA has some work directed toward the initialization of coupled ocean-atmosphere prediction models, it does not have a dedicated effort for monitoring the ocean climate. The impact of this is that the sustained demand or pull for the observations that PMEL provides is not as defined as they could or should be at this point, nor are these observations being taken advantage of to the extent possible." **(HQ)**

Response: Over the past several years, PMEL has discussed the benefits (and indeed we have gone so far as to exploring space requirements with the Western Regional Center managers) of hosting an International Center for Climate Observations, with Mike Johnson of the Climate Program Office's Ocean Observation System. Such a center would be viewed as a NOAA contribution to the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology and be co-located with PMEL at the Western Regional Center in Seattle. While this vision has been through several iterations since its inception and has not been implemented, this type of center would provide the focal point for PMEL's (and other's) ocean climate observations that is addressed in this comment. The addition of a climate modeling capability (addressed in section 3.2.2 of this Implementation Plan) with linkages to operational and research modeling communities, would further address the issues raised here.

IX. "The performance metrics we were presented with were rather weak. **(HQ)** All the metrics we received were presented in an absolute context, but there was no relative comparison or context with peer institutions be they other NOAA labs, other government labs, or academic institutions. For a mission-oriented agency such as NOAA the number of peer reviewed publications need not be the overriding metric. Even though the number of publications is going up, are these numbers significant? For a total of 140 scientists, 81 publications do not come across as a particularly strong total absent other performance measures. During the period 2004-2007 covered by this review, 83 PMEL authors published 323 journal articles in the refereed literature. They also published 22 book chapters and one book. These authors include 40 federal employees and 43 joint institute employees. Moreover, given the strong role PMEL has for obtaining ocean

observations, there does not seem to be any performance metric to track and recognize those individuals involved in obtaining ocean observations and making them available to the larger community. Given that the main metric is publications, a danger exists that this could work against free and timely access to the data by the larger external community if the provision of data is not assessed and recognized by a formal performance measure **(recommendation #25)**."

Response: We agree that performance measures can be strengthened, but this needs to be developed within OAR. PMEL will bring this issue to the attention of OAR's Office of Policy, Planning, and Evaluation.

X. (Re: FOCI) "Subsurface floats (below the wind-forced Ekman layer), on the other hand, tell us exactly how fluid moves about in space. Dispersion of clusters gives us insight into scales of motion, displacement of clusters tells us about circulation. Multiple clusters allow one to map out and distinguish between advective, dispersive and mixing processes. These technologies are highly developed for the open ocean, not yet for shelves. But PMEL has a very strong engineering group, and would be quite capable of developing corresponding techniques for shallow water applications." **(HQ)**

Response: Working with EcoFOCI scientists, the PMEL Engineering Group will evaluate the technical challenges, once the Lab has determined this to be a research priority and funding is available.

XI. "As the agency moves toward the definition and implementation of an ecosystem approach to management, the challenge will be to build on the approaches developed by program with a single species focus to a broader ecosystem-wide orientation **(recommendation #31)**. There is evidence that this is recognized at the program level and evolving research in the Bering Sea incorporates with broader ecosystem perspective. This direction is to be encouraged if PMEL is to play a leadership role in the transition to a full ecosystem approach to management." **(HQ)**

Response: EcoFOCI plans to continue moving towards an integrated ecosystem management approach in the Bering Sea.

XII. "EcoFOCI has focused on highly visible problems [e.g. through its research on pollock (arguably the most important single species fishery in the nation) and on (newly classified) endangered species such as the polar bear]. Although not directly indicated as such in the review, I assume the priorities and research directions for the program have been shaped by consideration of potential impact on these high profile issues. This approach is appropriate within the context of broad agency goals and objectives in resource management." **(HQ)**

Response: EcoFOCI does indeed incorporate high profile issues into its research, starting with Steller Sea Lions back in 1999-2000; however, the "base course" of developing an integrated ecosystem assessment is the overall guiding principle of the program.

XIII. "Of all the programs at PMEL the Vents program has the strongest flavor of basic or curiosity-driven research. By this we mean that the studies and resulting outcomes, while of general and societal interest, do not appear to couple that tightly to immediate needs or issues." **(HQ)**

Response: VENTS is a perfect example of a program that conducts basic ocean ecosystem-focused exploration and research that provides means for discovering NOAA's future mission priorities. With these objectives, the program has become a functional element within the Ocean Exploration and Research program. The guiding rationale for both programs being that NOAA cannot fulfill its overarching mission of ocean stewardship without knowing what ecosystems, and processes that impact them, exist in the ocean.

Examples of important VENTS discoveries and accomplishments include:

1. Pioneered the development and utilization of acoustic event detection systems to detect, locate, and study ephemeral ocean environment events, including submarine volcanic eruptions. Acoustic monitoring has also led to fundamental discoveries associated with marine mammals, including highly endangered whale species.
2. Pioneered the development of low-cost, satellite-linked, two-way communicable *in situ* sensors that provide time series perspectives of ocean processes, including sensing and sampling potentially valuable microbes associated with extreme high-temperature and exotic chemical environments.
3. Discovery of major, heretofore unknown submarine sources of CO_2 and their impacts, through ocean acidification, on marine ecosystems.

XIV. "The deployment of hydrophone moorings around the globe is a solid start to gain measures of geophysical activity. Documenting how much ambient noise has increased over time in various areas should be of considerable interest. Shipping has increased, is there a commensurate (or measurable) increase in ambient noise as well? How much?" **(HQ)**

Response: VENTS has initiated a pilot effort, funded by both NOAA and, ad hoc by non-NOAA programs, to begin establishing a critically needed global acoustic monitoring network. For example, VENTS scientists are developing new acoustic glider-based technology and poised to begin using its deployable acoustic mooring assets to establish baseline data in regions where ambient ocean noise will be increasing due in encroachment by shipping traffic made possible by progressive loss of high latitude sea ice. These data will enable NOAA to quantify and understand likely resultant marine ecosystem impacts.

XV. "One question I have is whether the VENTS program includes biologists. If so, are the abyssal ecosystems studied after they are discovered?" **(HQ)**

Response: VENTS itself does not have any biologists on staff; however, there is a close working relationship with Verena Tunnicliffe at the University of Victoria, Victoria, B.C. The VENTS program has included funding for a biologist in its 100% program since the

beginning of PPBES and requested it again in the recent call to support the newly designated Marianas National Monument.

XVI. "In terms of collaboration with other groups, PMEL is as open as any other National Laboratory is. There is a parade of uninvited guests from around the world who consider a PMEL visit as a pilgrimage to the holly of hollies (sic) of tsunami research. There is active collaboration with Northwestern, Texas A&M, Hawaii and USC, which are the universities most heavily into cutting edge tsunami research. I would border on the conflict of interest to suggest that PMEL could be doing more here, there is always room for improvement. I can say without hesitation that its culture towards intramural and extramural collaboration and for interdisciplinary research puts most of academia to shame." **(HQ)**

Response: Thanks for the compliment. We hope the formation of a PMEL tsunami test bed will sustain this reputation and facilitate collaboration.[1]

[1]

Appendix B.
NOAA Tsunami Research Plan

Prepared by:

Eddie N. Bernard
NOAA/PMEL
4 May 2007

Janus image: Philosopher and anthropologist of science and technology Bruno Latour uses Janus in his *Science in Action* to explain the difference between "ready made science and technology" and "science and technology in the making."

Executive Summary

The Tsunami Act of 2006 outlines five research directives:

1. Develop detection, forecast, communication, and mitigation science and technology
2. Consider other appropriate research to mitigate the impact of tsunamis
3. Coordinate with the National Weather Service on technology to be transferred to operations
4. Include social science research to develop and assess community warning, education, and evacuation materials
5. Ensure that research and findings are available to the scientific community

The National Tsunami Research Plan identified six priorities:

1. Enhance and sustain tsunami education
2. Improve tsunami warnings
3. Understand the impacts of tsunamis at the coast
4. Develop effective mitigation and recovery tools
5. Improve characterization of tsunami sources
6. Develop a tsunami data acquisition, archival, and retrieval system

By merging the Tsunami Act research directives and the National Tsunami Research Plan priorities, a $2M/year NOAA Tsunami Research Plan was formulated to serve as a tsunami think tank and a tsunami test bed. Elements of the program are:

1. Develop detection, forecast, communication, and mitigation science and technology (think tank)
2. Coordinate with the National Weather Service on technology to be transferred to operations (test bed)
3. Conduct social science and mitigation research by contributing to an NSF tsunami research program that would accept and review NSF tsunami-related proposals

The research program would be coordinated with the other agencies conducting tsunami research and the National Tsunami Hazard Mitigation Program to ensure relevance and quality in research topics and productivity.

I. Introduction and the Tsunami Act

NOAA Tsunami Research is conducted within the Office of Oceanic and Atmospheric Research (OAR). As such, the NOAA Administrator has assigned responsibility for the NOAA tsunami research program to the Pacific Marine Environmental Laboratory (PMEL), one of the oceanographic laboratories within OAR. PMEL is a recognized world leader in tsunami research with an impressive list of research findings, development of pioneering tsunami measurement systems and models, and a distinguished set of transfers from research to NOAA operations since 1973 (see Appendix A for more details). PMEL, as the only federal tsunami research institution in the U.S., has also served as a catalyst and coordinator of tsunami research both domestically and internationally. The U.S. National Tsunami Hazard Mitigation Program (NTHMP) was formed and implemented within OAR/PMEL from 1996 to 2003. PMEL scientists have held key positions in the NTHMP as well as positions in international tsunami research organizations. PMEL hosted the 2001 International Tsunami Symposium, where over 100 international tsunami scientists participated in a 3-day scientific symposium. More recently, the PMEL Director led the development of the U.S. National Tsunami Research Plan in 2006.

Following the horrific Indian Ocean tsunami of 26 December 2004 that resulted in over 230,000 casualties and millions of displaced people, the world's outpouring of assistance was unprecedented. The U.S. contributed almost $1B in tsunami relief, restoration, and strengthening the U.S. tsunami warning program. NOAA, the agency with responsibility to issue tsunami forecasts and warnings, became the lead agency to strengthen the U.S. tsunami warning program. As such, NOAA embarked on an impressive upgrade of its warning system by expanding tsunami warning coverage to include all U.S. coastlines and territories, expanding staff so that the two NOAA tsunami warning centers could operate 24x7, upgrading coastal tide gauges to measure tsunamis, increasing tsunami detectors in the deep ocean, and implementing a tsunami forecasting capability. The tsunami forecasting capability requires both measurement and modeling technologies, both of which were developed at PMEL and transferred to operations within the National Weather Service.

The U.S. also passed a law, the Tsunami Education and Warning Act (see Appendix B), which calls for four activities: 1) tsunami forecast and warnings, 2) mitigation through the NTHMP, 3) research, and 4) international coordination. Section 6 of the Act is specific to research activities, while Section 8 provides funding levels authorized.

SEC. 6. TSUNAMI RESEARCH PROGRAM.

"The (NOAA) Administrator shall, in consultation with other agencies and academic institutions, and with the coordinating committee established under section 5(b), establish or maintain a tsunami research program to develop detection, forecast, communication, and mitigation science and technology, including advanced sensing techniques, information and communication technology, data collection, analysis, and assessment for tsunami tracking and numerical forecast modeling. Such research program shall—

(1) consider other appropriate research to mitigate the impact of tsunami;

(2) coordinate with the National Weather Service on technology to be transferred to operations;

(3) include social science research to develop and assess community warning, education, and evacuation materials; and

(4) ensure that research and findings are available to the scientific community."

SEC 8. AUTHORIZATION OF APPROPRIATIONS.

The Act specifies that not less than 8 percent of the amount appropriated shall be for the tsunami research program. Given the authorization amounts for FY 2008–FY 2012, the research program should plan for 5-year funding at $2.00M, $2.08M, $2.16M, $2.24M, and $2.32M, respectively.

II. The National Tsunami Research Plan

The Office of Science and Technology released a report in 2005 that called for a review of tsunami research needed to reduce tsunami vulnerability in the United States. An Organizing Committee was appointed by the Chair of the U.S. National Tsunami Hazard Mitigation Program (NTHMP) to develop a Strategic Plan for tsunami research. The Committee assembled a group of tsunami experts to review the current state of knowledge in areas essential to tsunami risk reduction and a workshop was held 25–26 July 2006 to develop a consensus on priority research needs. The focus of the effort was to define the basic research in areas of technology, geosciences, oceanography, engineering, and social sciences needed to develop, promote, and institutionalize tsunami-resilient communities in the United States. The group agreed to 15 recommendations in tsunami hazard assessment, tsunami warnings, and tsunami preparedness and education. The Organizing Committee combined these recommendations into six synthesized high-priority areas for tsunami research. The final plan (Bernard *et al.,* 2007) was approved by the NTHMP Steering Committee on 1 November 2006.

The six synthesized high-priority areas for tsunami research are:

1: Enhance and sustain tsunami education

Research needs: understand how individuals process and respond to natural and official tsunami warnings, and how people behave and communicate when warned to evacuate. Assess the effectiveness of outreach programs and products.

2: Improve tsunami warnings

Research needs: assess and improve tsunami warning products, include projected water levels and duration at specific coastal locations. Design scalable, sustainable multi-purpose observational networks for both local and distant tsunami sources and tsunami dynamics, including existing seismic and non-seismic networks.

3: Understand the impacts of tsunamis at the coast

Research needs: implement a methodology for measuring the tsunami current regime in harbors and at the coast, improve hydrodynamic modeling, develop credible fragility models of the interaction of tsunamis with the built and natural environment, and validate models through benchmarking against modern events, tsunami deposits, and other paleoindicators of past tsunami events.

4: Develop effective mitigation and recovery tools

Research needs: understand the interaction of structures and the surrounding environment with high-velocity, debris-strewn water, determine response of buildings and structures to extreme waves, develop a framework for pre-event mitigation techniques and post-event tsunami response, recovery, and reconstruction that incorporates both sustainability and reducing vulnerability from future tsunami events.

5: Improve characterization of tsunami sources

Research needs: identify tsunami sources including earthquakes, subaerial and submarine landslides, volcanic eruptions, and impacts, develop a probabilistic framework for characterization of tsunami sources that includes thousands of years of recurrence.

6: Develop a tsunami data acquisition, archival, and retrieval system

Research needs: develop a web-based archival system for field and laboratory observations, scenarios, remote sensing, topographic and bathymetric data, numerical models, and mitigation products and projects.

Federal agencies were invited to the workshop to describe their current tsunami activities and needs for the future research. Table 1 provides a budgetary shapshot of federal tsunami activities, including research, by agency.

Five agencies spent $54.4M in FY 2005 to reduce the impact of tsunamis to U.S. coastlines. NOAA and the USGS contributed about 80% of the effort, while NSF contributed 12%. The agencies reported their expenditures in four categories: Research,

Table 1: FY 2005 Federal agency expenditures ($M) for tsunami risk reduction.

Agency	Research	Assessment	Warnings	Preparedness	Totals	% of Totals
NSF	6.3	0.0	0.0	0.0	6.3	**12**
NOAA	0.8	1.4	20.3	3.5	26.0	**48**
USGS	3.0	2.0	12.0	0.0	17.0	**31**
USACE	0.0	4.5	0.0	0.0	4.5	**8**
FEMA	0.0	0.5	0.0	0.2	0.7	**1**
Totals	10.1	8.4	32.3	3.7	**54.5**	
% of Totals	**19**	**15**	**59**	**7**		**100**

Hazard Assessment, Warnings, and Preparedness. About 60% of the effort went into warnings, while Research represented a respectable 19% of the total. Tsunami assessment was the third largest category, while Preparedness was the smallest category at 7%. Preparedness efforts funded at the State or local level were not included in the research plan. It is, therefore, incorrect to infer that Preparedness is the lowest priority in the total federal effort.

The U.S. Congress passed the Tsunami Warning and Education Act which President Bush signed into law on 20 December 2006. The Research Plan and the Tsunami Act are amazingly consistent and compatible and lay the foundation for a successful implementation of the Research Plan through a multi-agency effort.

One limitation of this authorization Act is that the research program described in the law is about $2M/year for FY 2008–2012, while the total FY 2005 federal research expenditures exceeded $10M (Table 1). The Tsunami Act research program would represent only about 20% of the national tsunami research effort. One approach for NOAA's research program would be as a contributor to a multi-agency research program that includes NSF, NOAA, FEMA, USGS, and other agencies concerned with the tsunami hazard. This National Tsunami Research Plan could serve as the starting point to establish an interagency research program that could be supported by multiple agencies. One option would be for NSF to serve as granting agency with other agencies providing annual contributions to support the six tsunami research priorities as identified in the National Tsunami Research Plan

III. NOAA Tsunami Research Program ($2.00M)

Taking the Tsunami Act as guidance, NOAA's approach to a tsunami research program is to become a tsunami test bed and a tsunami think tank. The think tank concept allows researchers to explore the universe of ideas and activities for possible application to the tsunami problem. In order to closely coordinate efforts, members from the think tank would serve on the NSF panel and the NTHMP technical advisory board. The test bed concept allows the testing and evaluation of promising ideas from the think tank into NOAA's tsunami program mission to provide reliable tsunami forecast products and to promote community resilience (Figure 1). Research activities described below are linked to the first year funding of $2.00M to provide a starting point for the next 5 years.

The Tsunami Act includes two sections, reproduced below, that imply that NOAA will assist in developing tsunami inundation maps (Section 4) and will set standards (Synolakis *et al.*, 2007) that must be met by inundation models used to develop such maps (Section 5).

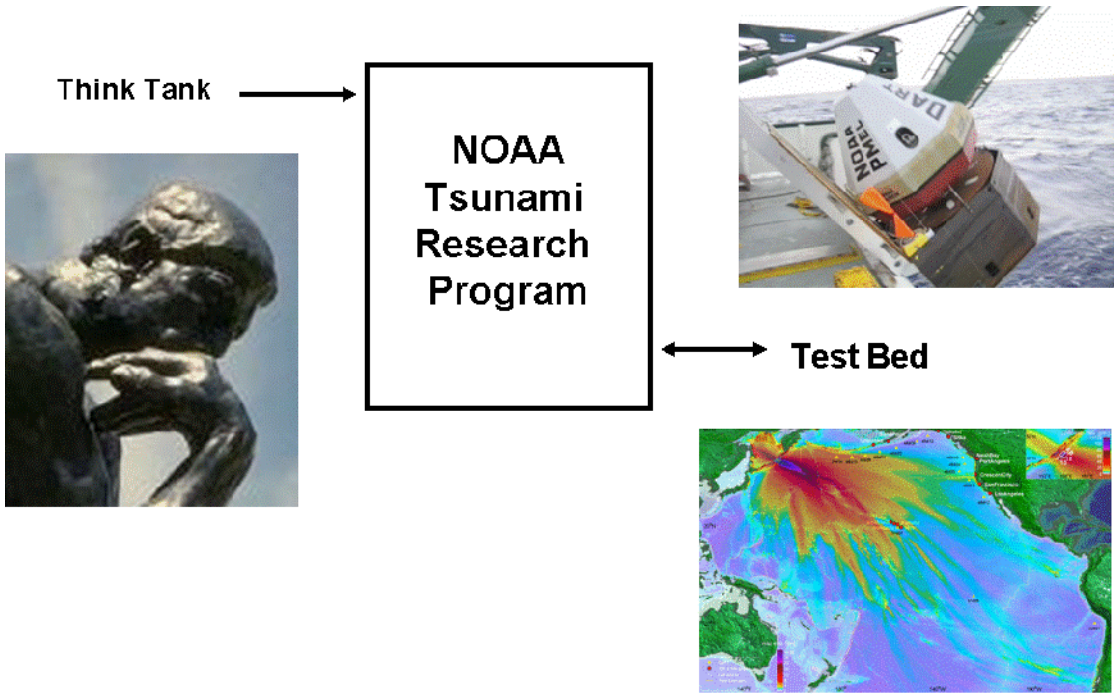

Figure 1. NOAA's Tsunami Research Program balances basic and applied research.

SEC 4. TSUNAMI FORECASTING AND WARNING PROGRAM.

(b) COMPONENTS.—"The program under this section shall—

(4) provide tsunami forecasting capability based on models and measurements, including tsunami inundation models and maps for use in increasing the preparedness of communities, including through the TsunamiReady program;"

This section implies that NOAA will assist in developing tsunami inundation maps.

SEC 5. NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM.

(c) PROGRAM COMPONENTS.—"The program under this section shall—

(1) use inundation models that meet a standard of accuracy defined by the (NOAA) Administration to improve the quality and extent of inundation mapping, including assessment of vulnerable inner coastal and nearshore areas, in a coordinated and standardized fashion to maximize resources and the utility of data collected;"

NOAA envisions a dual program focus of basic research that looks broadly at the universe of tsunami research ideas for use in forecasts and warnings (think tank) and applied research that serves to evaluate ideas and, in some cases, transfer technology for use in forecasts and warnings (test bed).

A. **Think Tank Activity:** Develop detection, forecast, communication, and mitigation science and technology ($1.5M)

1. Tsunami Detection: PMEL will continue to refresh and upgrade the DART technology invented by PMEL scientists and engineers to make more accurate measurements, develop multi-use of the surface buoy moorings, and contain the costs of maintaining the DART array. PMEL has developed a set of procedures to determine if a detection system can serve as a tsunami warning element. Several approaches will be explored to find the most cost effective combination of multiple sensor deployment, buoy operations, and maintenance. For example, a self-deploying buoy that requires a smaller vessel (such as a fishing boat) holds promise for reducing ship time costs. Another possibility is to connect tsunami detection devices to underwater research cables of opportunity. Evaluation of alternative technologies will be explored and documented through annual reports.
2. Tsunami Forecast: PMEL will complete the transfer of a tsunami forecast system to NOAA operations and embark on research for the next generation models to make the forecasts more reliable and accurate. Forecast models can also be applied to optimize DART array configurations. Evaluation of alternative technologies will be explored and documented through annual reports.

3. Communications: NWS operations will define research required in warning and dissemination communications. OAR/PMEL will assist NWS in identifying ways to facilitate the research. Evaluation of alternative technologies will be explored and documented through annual reports.

4. Mitigation: Inundation maps explicitly mentioned in Section 4 can be developed using tsunami forecast models, which meet the set of modeling standards developed by NOAA and required by Section 5 of the Act. NOAA has developed a set of modeling standards required by the Act (Synolakis *et al.*, 2007). The first-generation NOAA forecast models meet the standards. Research is needed to extend the use of the forecast models as tools for providing inundation maps (long-term forecasts). The use of the forecast tool should be standardized to ensure that all states and territories have inundation products that are state of the science. Evaluation of alternative technologies will be explored and documented through annual reports.

B. Test Bed Activity: Coordinate with the National Weather Service on technology to be transferred to operations ($0.2M)

PMEL would hire a technology transfer scientist to coordinate and assist in the transfer of technology into operations. Transfers will be guided by jointly developed transition plans between PMEL and the NOAA tsunami warning centers. PMEL will complete the development of forecast models for at least 75 U.S. coastal communities for use in the NOAA tsunami warning centers. Each transition plan will include a set of products, a schedule, and a budget.

C. Coordination Activity: Conduct social science and mitigation research to develop and assess community warning, education, and evacuation materials consistent with NTHMP goals and objectives ($0.3M)

NOAA/OAR/PMEL would provide NSF with an annual contribution to an NSF-administered, multi-agency tsunami program that included social science as described in the Tsunami Act. A NOAA researcher would serve on the NSF review panel to ensure research coordination between NOAA and other agencies. A NOAA researcher would also serve on the technical advisory committee of the National Tsunami Hazard Mitigation Program to coordinate research at both the federal and state levels, with the NSF research program, and within NOAA (Sea Grant, NOS, NESDIS).

D. **Communication Activity:** Ensure that research and findings are available to the scientific community

NOAA/OAR/PMEL has a long history of publishing scientific results in a timely manner. Other forums for scientific dissemination include workshops, scientific conferences, research reviews, training courses, and educational activities such as university courses and post-doc appointments. The NSF multi-agency program offers an opportunity to build a network of tsunami researchers through annual meetings and electronic networks. The National Tsunami Hazard Mitigation Program also offers an opportunity to distribute research findings to state and federal tsunami practitioners.

IV. Next Steps

After approval by the NOAA Research Council, the NOAA Tsunami Research Plan will initiate the following activities:

1. Establish a multi-agency National Tsunami Research Program within NSF

2. Hire a full time technology transfer scientist and three scientists to conduct tsunami research at NOAA's Center for Tsunami Research at PMEL

3. Appoint representatives from PMEL to serve on the NSF Panel and the NTHMP Technical Advisory Committee

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Appendices

A. OAR Outstanding Accomplishments in Research

B. Public Law 109-424, Tsunami Warning and Education Act

Appendix C.
Acronyms Used in this Implementation Plan

AA	Assistant Administrator (of OAR)
AFSC	NMFS Alaska Fisheries Science Center
AUV	Autonomous Underwater Vehicle
CLIVAR	Climate Variability Program
ComMIT	Community Model Interface for Tsunami
EcoFOCI	Ecosystem-Fisheries Oceanography Coordinated Investigations
FACTS	Facility for the Analysis and Comparison of Tsunami Simulations
FOCI	Fisheries Oceanography Coordinated Investigations
GLERL	OAR's Great Lakes Environmental Research Laboratory
HYCOM	Hybrid Coordinate Ocean Model
IEA	Integrated Ecosystem Assessments
LAS	Live Access Server
MOM	Modular Ocean Model
MOST	Method of Splitting Tsunami
NDBC	National Data Buoy Center
NMFS	NOAA's National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	NOAA's National Ocean Service
NURP	OAR's National Undersea Research Program
NWS	NOAA's National Weather Service
OAR	NOAA's Office of Oceanic and Atmospheric Research
OER	OAR's Office of Ocean Exploration and Research
PECASE	Presidential Early Career Award for Scientists and Engineers
PMEL	OAR's Pacific Marine Environmental Laboratory
PPBES	NOAA's Planning, Programming, Budgeting & Execution System
PUMP	Pacific Upwelling and Mixing Physics Program
TAO	Tropical Atmosphere Ocean Array
WebSIFT	Web-based Short-term Inundation Forecasting (System) for Tsunamis