Report Summary

Sea Change

2015–2025 Decadal Survey of Ocean Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

New observational and computational technologies are transforming the ability of scientists to study the global ocean with a more integrated and dynamic approach. This enhanced understanding of the ocean is becoming ever more important in our economically and geopolitically connected world, enabling informed decisions on vital ocean policy matters.

In the United States, the National Science Foundation (NSF) is the primary funder of the basic research that underlies advances in our understanding of the ocean. This study addresses the strategic investments necessary at NSF to ensure a robust ocean scientific enterprise over the next decade.

Scientific Advances from Ocean Research

The ocean science community has undertaken the challenge of exploring the ocean domain and over the past few decades has produced a remarkable surge in understanding the physics, biology, and chemistry of the ocean, and the geology and geophysics at and beneath the seafloor. Technological advances have fueled much of the increase in knowledge, as ocean scientists have rapidly adopted, developed, and employed new computational and modeling capabilities, robotics, and technological innovations such as genomics. Satellites and autonomous sensor systems have revealed a dynamic global ocean system on unprecedented temporal and spatial scales; chemists have detected significant declines in ocean pH, and biologists have studied the impact of this change in ocean chemistry on marine species and ecosystems. Geologists have documented eruptions on the deep seafloor and discovered microbial communities beneath the seafloor. Also, ocean research has improved scientific understanding of global climate change, one of the defining issues of the twenty-first century.

Beach erosion near homes in North Carolina. *Credit: iStock*

These exciting developments in ocean science have been made possible by investments in a portfolio of funds for research, development and application of new technologies, and oceanographic infrastructure such as ships, gliders, and submersibles; in situ and remote observing systems; and other facilities such as marine laboratories, cyberinfrastructure, and sample and data repositories. In addition, substantial advances have arisen from programs that cut across traditional disciplinary boundaries, bringing together scientists from many fields, federal agencies, and other countries. Such programs have yielded insights into the global ocean and have informed policymakers, the private sector, and the general public about both the future opportunities, and limits, of the ocean as a resource.

Ocean Sciences at the National Science Foundation

Although many other federal agencies contribute to ocean science and technology, the Division of Ocean Sciences at NSF (OCE) provides the broadest base of support for the field, including funding for research in physical, biological, and chemical oceanography and marine geology and geophysics, and the development, implementation, and operational support for ocean research infrastructure. Within NSF, OCE encompasses a broad portfolio of diverse interests and

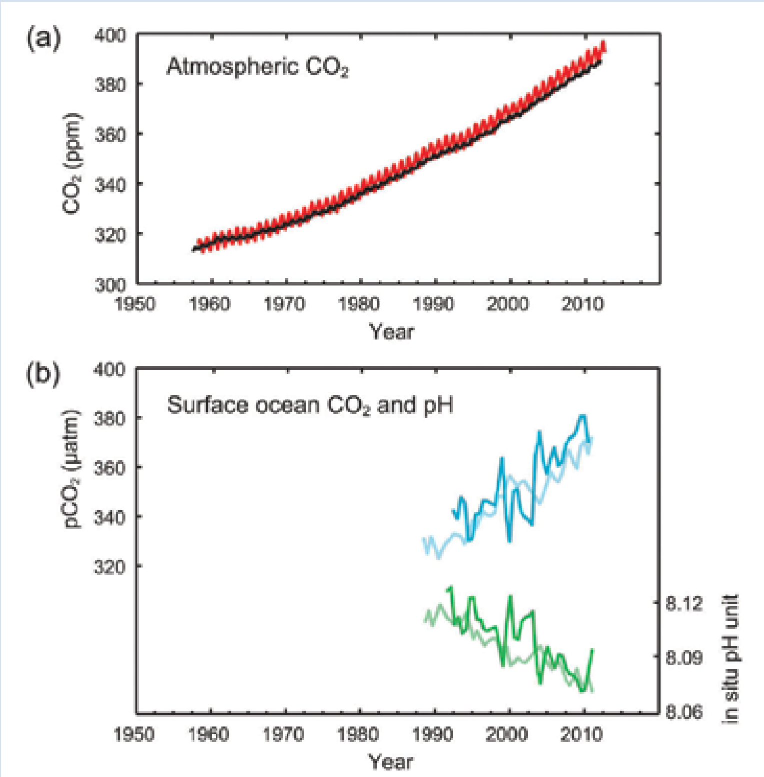


Figure S–1. *Observations of increasing CO2 in the atmosphere (Mauna Loa 19°32′N 155°34′W- red and South Pole Station - black) and surface ocean (BATS 31°40′N 64°10′W – blue and green, and HOT 22°45′N 158°00′W – light blue and light green) and decreasing surface pH (ocean acidification). The oceanic stations have been occupied at monthly intervals since the late 1980s/early 1990s, and include a host of physical and biogeochemical measurements. SOURCE: IPCC5 and references therein; Dore et al., 2008.*

activities. Managing this enterprise has been made more challenging with the continued increase in operations and maintenance costs for the ocean research facilities, especially the academic research fleet, scientific ocean drilling through the International Ocean Discovery Program (IODP), and the launch of the Ocean Observatories Initiative (OOI). Infrastructure expenses have risen over the past decade (about 18% in 2014 dollars), even as the total NSF OCE budget fell by more than 10%. With no significant budget increases anticipated by NSF in the near future, strategic decisions are required to ensure that key programmatic elements are supported to maintain the overall health of the ocean sciences community.

Traditionally, NSF seeks community input on long-range research priorities and strategies to optimize scientific investments. A decadal survey process that establishes research priorities, and then identifies the investments necessary to achieve those priorities, has been used by several scientific disciplines and science agencies to develop community-based plans. In 2013, OCE asked the National Research Council's Ocean Studies Board to undertake a decadal survey of ocean sciences to provide guidance from the ocean sciences community on research and facilities priorities for the coming decade. OCE requested this guidance to address the community's priorities in the context of funding constraints imposed by the current trend of flat or declining budgets. The research portfolio includes investments in infrastructure, individual investigator-based science, multi-investigator large research programs, and cross-directorate initiatives like NSF's Science, Engineering, and Education for Sustainability. The study committee was asked to place NSF's ocean science activities in the context of activities undertaken by other federal ocean agencies. The committee also examined the role of international cooperation and collaboration in advancing ocean science.

Priority Science Questions and Infrastructure for the Next Decade of Ocean Research

Selection of Priority Science Questions

The committee was asked to select no more than ten ocean science priorities with the goal "to identify areas of strategic investment with the highest potential payoff" for the coming decade (2015–2025). NSF, the Ocean Studies Board, and this committee viewed community involvement as an essential element in the process of identifying priorities. To encourage participation, the committee held town hall meetings at the 2013

American Geophysical Union Fall Meeting (San Francisco, CA) and the 2014 Ocean Sciences Meeting (Honolulu, HI). In addition, the committee solicited input through a web-based virtual town hall that collected over 400 responses from November 2013 to March 2014. The community responses were supplemented with research topics identified in more than 30 reports and publications, presentations by scientists from both academic and government institutions, letters from institutions, and discussions with colleagues. Additionally, the committee actively sought out opinions from early career scientists whose futures will be influenced by decisions made over the next decade.

The committee devoted a major effort to distill the many topics gathered through these sources down to 10 or fewer priorities. The process began with sorting the input into three dozen diverse, high-level, disciplinary and interdisciplinary scientific questions. Similar questions were then clustered to yield high-level scientific questions, to which four criteria—transformative research potential, societal impact, readiness, and partnership potential— were applied, listed in order of relative importance. These criteria were derived from previous NRC and interagency reports related to ocean science research priorities, and from suggestions by NSF program managers.

Eight priority science questions emerged from this process, each representing an integrative and strategic research area. The questions cover topics appropriate for OCE core programs, cross-cutting NSF programs, or in partnership with other federal agencies or international programs. A synopsis of the eight priorities is provided below, ordered from the ocean surface, through the water column, to the seafloor:

1. ***What are the rates, mechanisms, impacts, and geographic variability of sea level change?***
2. ***How are the coastal and estuarine ocean and their ecosystems influenced by the global hydrologic cycle, land use, and upwelling from the deep ocean?***
3. ***How have ocean biogeochemical and physical processes contributed to today's climate and its variability, and how will this system change over the next century?***
4. ***What is the role of biodiversity in the resilience of marine ecosystems and how will it be affected by natural and anthropogenic changes?***
5. ***How different will marine food webs be at mid-century? In the next 100 years?***
6. ***What are the processes that control the formation and evolution of ocean basins?***
7. ***How can risk be better characterized and the ability to forecast geohazards like mega-earthquakes, tsunamis, undersea landslides, and volcanic eruptions be improved?***
8. ***What is the geophysical, chemical, and biological character of the subseafloor environment and how does it affect global elemental cycles and understanding of the origin and evolution of life?***

Each of these high level questions encompasses many sub-topics that are described in much greater detail in the report. Most of the questions will require interdisciplinary research across the sub-disciplines of ocean science as they are managed within OCE, within the disciplines of the Geosciences Directorate (GEO), and across Directorates. Because interdisciplinary research across the subfields of ocean science will be essential to achieve many of the decadal science priorities, it is particularly important that the ocean science community does not encounter or perceive barriers to obtaining funding for interdisciplinary research.

Credit: NOAA

The OCE core programs will likely address many aspects of the scientific priorities identified above, but the committee recognizes that it would be counterproductive to constrain the core programs to fund only those proposals directly related to these priorities. To advance ocean science and technology, the core programs require a high degree of flexibility to fund basic research and promising new ideas and approaches, respond to infrequent events that present opportunities to understand key phenomena, incorporate advances from other areas of science and technology, and encourage the training and professional development of the next generation of scientists.

Because the eight priority questions have broad relevance to societal issues, other federal agencies may also be interested in devoting resources to addressing these research topics. Collaborations between U.S. basic research and mission agencies could hasten both research advancements and transition to operational products by taking advantage of complementary skills, resources, and expertise among organizations. Industry, foundations, international organizations, and non-governmental organizations could also be engaged to assist in addressing these questions, due to their global reach.

Alignment of Infrastructure to the Priority Science Questions

One purpose of identifying priorities in this report is to ensure alignment between the next decade's foremost topics in ocean science and the National Science Foundation's (NSF) investments in ocean research infrastructure. The committee assessed how well the current portfolio of NSF-supported ocean research infrastructure matched the decadal science priorities and focused on three major infrastructure assets—the academic research fleet, IODP, and OOI—which together comprise over 50% of the total OCE budget and over 90% of the infrastructure budget. In addition, the committee evaluated a few smaller facilities and programs supported by OCE, such as the National Deep Submergence Facility and field stations.

The committee identified categories of alignment between infrastructure and each decadal science question. Critical refers to infrastructure assets without which the science priority question cannot be addressed effectively and important infrastructure is useful but not essential to address the question.

Academic Research Fleet

The strongest match between current infrastructure and the decadal science priorities is the academic research fleet. Research vessels, especially Global class ships, support a broad swath of oceanographic activities and are essential to achieve all of the science priorities. Global class ships have greater deck loading, berthing, and sea state capacities, and are critical to or important for the multidisciplinary, multi-investigator types of research identified in all of the science priorities. Regional class ships strongly contribute

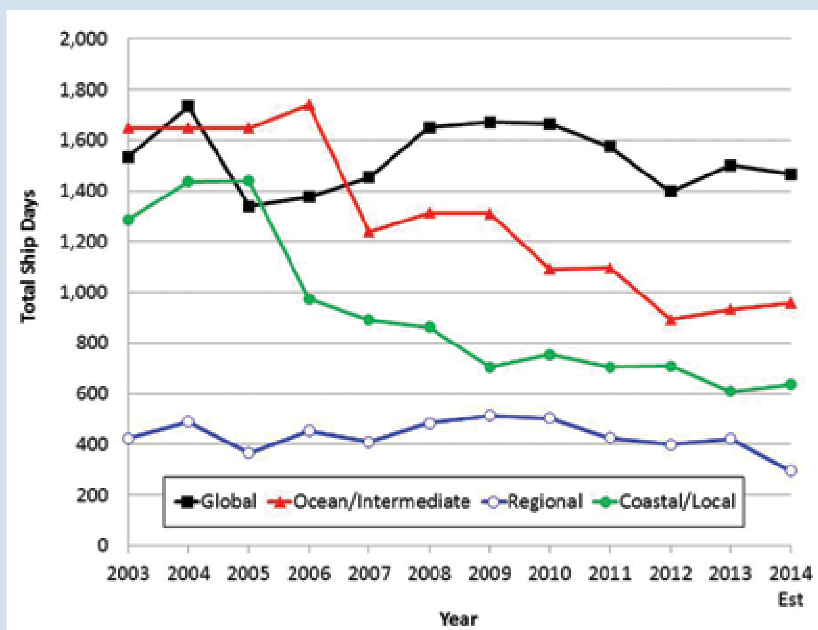


Figure S–2. *Ship usage for the UNOLS fleet, broken out by class. Data from NSF and UNOLS, October 2014.*

to societally relevant questions in coastal environments, being critical to or important for topics such as sea level rise and biodiversity of marine ecosystems. Ice-capable ships are requisite for answering a number of questions related to understanding climate change, ocean-ice interactions, and polar marine food webs.

NSF is currently considering the acquisition of up to three new Regional class research vessels (RCRVs). Under current plans, the new RCRVs will have a length and berthing capacity comparable to the larger Intermediate class and are expected to have day rates that are substantially higher than the regional ships that are being replaced. This expansion in capability and cost, combined with the restricted geographical range and days at sea associated with the RCRV's regional status, raises the question of whether the current design and estimated day rates of the RCRVs are well matched for expected future use.

Scientific Ocean Drilling

Based on the committee's analysis, scientific ocean drilling facilities and analysis of core collections are critical for the decadal science priorities related to subseafloor exploration, geohazards, and formation and evolution of the ocean basins. They are also important for issues related to climate and sea level variability. Scientific ocean drilling has also proven to be an effective vehicle for science diplomacy through building long-term international partnerships.

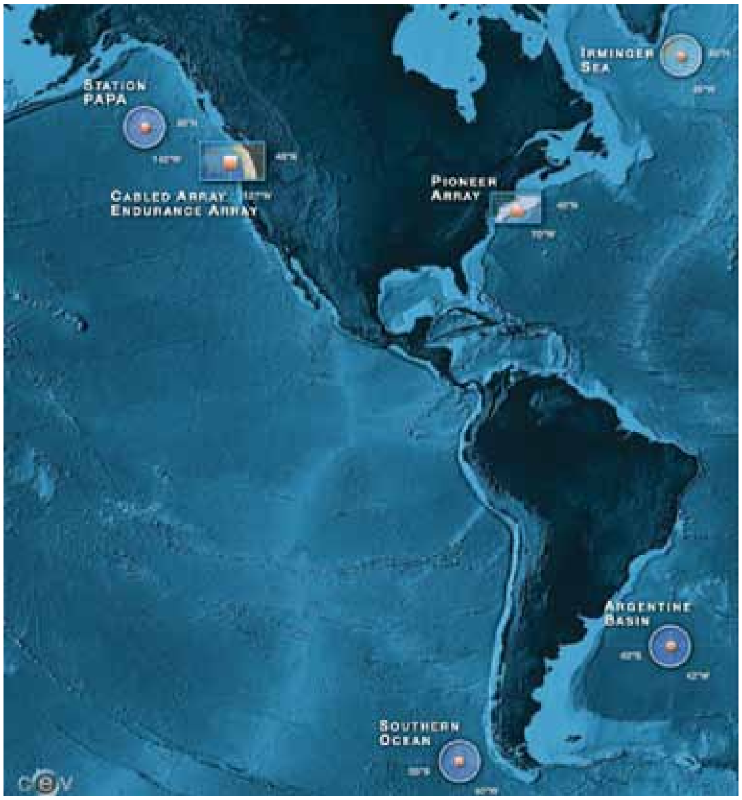
JOIDES Resolution drill ship. *Credit: William Crawford and IODP*

NSF has supported an ocean drilling program for over 45 years and, as part of IODP (2013–2018), currently covers the majority of costs for the JOIDES Resolution drill ship. Although scientific ocean drilling is necessarily an "infrastructure-heavy" undertaking, requiring a high proportion of funding for operations relative to research, IODP has implemented many cost-savings measures in recent years to decrease operating costs and improve efficiency. Nevertheless, the United States still carries a heavier financial burden than many of the other contributing countries to cover scientific ocean drilling facilities and operations costs. Moreover, the international community as a whole appears overextended in scientific ocean drilling facilities. NSF has the ability to renegotiate its contribution to the IODP consortium and is strongly urged to pursue a more cost-effective partnership. If additional revenue cannot be found, one budget solution could include a reduction in the total number of platforms operated by members of the consortium, which would allow more efficient utilization of the remaining assets. NSF plans to fund IODP (2013–2018) at a total of $250 million over the next five years, providing for four JOIDES Resolution expeditions annually.

Ocean Observatories Initiative

The different OOI components—global moorings, coastal arrays, and the regional cabled observatory—are not all at the same level of alignment with the science priorities. The coastal arrays are important for sea level rise, coastal processes, and climate variability; the global moorings are important for climate variability. The regional cabled observatory is important for solid earth and subseafloor biosphere questions.

Because OOI has not yet entered full operation, it lacks both a robust user community and a record of research accomplishments. Therefore, the committee determined that it was premature to make strong statements about potential success, failure, or the possibility



Ocean Observatories Initiative. *SOURCE: OOI Cabled Array program and the Center for Environmental Visualization, University of Washington.*

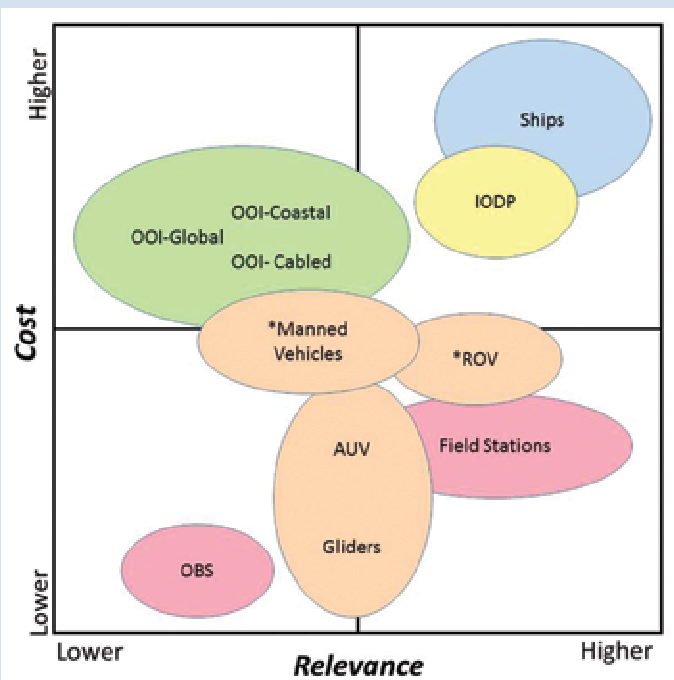


Figure S–3. *Relative cost versus relevance of the infrastructure—fleet and other ships (blue), IODP (yellow), OOI (green), vehicles (orange), other (pink). The asterisk next to manned vehicles and ROVs indicates that costs increase if the costs of necessary support vessels are included.*

for transformational research. However, comments from the virtual town hall and additional discussions with both early-career and established scientists suggest a lack of broad community support for this initiative, exacerbated by an apparent absence of scientific oversight during the construction process. OOI is an expensive new piece of infrastructure; estimated operational costs are at least $55-to-$59 million per year for the next five years.

Course Corrections

NSF asked the committee to "recommend a strategy to optimize investments that will advance knowledge in the most critical and/or opportune areas of investigation while also continuing to support core disciplinary science and infrastructure," and provide "guidance on the most effective portfolio of investments achievable at the current funding level that will support both the research infrastructure and programmatic science necessary to address the most significant priorities."

The committee undertook this assignment by first developing a vision for the ocean sciences in the next decade:

The ocean science community will undertake research and pursue discoveries that advance our understanding of the oceans, seafloor, coasts, and their ecosystems; foster stewardship of the ocean; reduce society's vulnerability to ocean hazards; and nurture and exploit the integration of the disciplines. A diverse and talented community of researchers will develop new technologies to study the ocean in novel and cost-effective ways and create innovative educational programs that will engage and inspire the next generation. Partnerships will be fostered across funding agencies, national borders, and the private sector to provide the greatest value for the nation's investment in ocean science.

With this vision in mind, the committee considered the balance of investments in ocean science funding and the research infrastructure. Since 1970, the total budget at OCE has seen an annual growth rate of roughly $3 million per year (2014 dollars), punctuated by spurts of growth and shrinkage in spending power. Over the past decade the OCE budget has declined by more than 10% (inflation-adjusted[1]). During times of budget increases, OCE was able to initiate new technologies and sustain research facilities in addition to maintaining a diverse research portfolio that took advantage of the new capabilities.

From 2000 through 2014, there has been a shift in investment from the core research programs to the operations and maintenance costs of infrastructure. In the last four years the overall budget has not grown; as a consequence, the continued increase in infrastructure costs (more than 16% in 2014 dollars) has resulted in a substantial decline (about 26% in 2014 dollars) in the amount of funding available for the core research programs and therefore less support for investigator proposals. The funding for Oceanographic Technology and Interdisciplinary Coordination (OTIC), the main source of support for technology development within OCE, has been particularly hard hit by this decline.

Since the committee was asked to assume that the OCE budget is unlikely to grow significantly over the next decade, and given that cost inflation will continue at recent historical rates (~2%/year), the only way to recover funding for core science and OTIC is to reduce the amount of money spent on infrastructure. Such reductions are not easy and will cause disruptions for parts of the ocean science community. However, restoring the core science budget and investing prudently in new technology will promote the vision presented above—a diverse community of scientists able to undertake research and pursue discoveries that will advance ocean science. During the next five years, the goal is to carry out necessary programmatic changes to prepare for full implementation of the vision during the second half of the decade.

[1] Inflation adjustments were based on the U.S. Bureau of Labor Statistics Consumer Price Index annual average, with the exception of 2014. 2014 was based on an average of January–November values.

Recommendation 1: In order to sustain a robust ocean science community, holistic fiscal planning is necessary to maintain a balance of investments between core research programs and infrastructure. To maintain a resolute focus on sustaining core research programs during flat or declining budgets, infrastructure expenses should not be allowed to escalate at the expense of core research programs.

The committee identified two models to achieve balance—(1) maintaining a fixed ratio for infrastructure costs relative to the total budget and (2) maintaining a consistent long-term funding trajectory for core science. The applicability of these two approaches depends on the fiscal outlook. In periods of flat or declining budgets, using a fixed ratio as a target for guiding expenditures would ensure that one part of the budget does not increase at the expense of the other. In times of increasing budgets, maintaining a consistent long-term funding trajectory for core science, rather than a fixed ratio, may provide a better approach to achieve balance. This approach accommodates adjustments in the budget fraction dedicated to infrastructure costs to reflect short-term needs or long-term changes in the use of existing infrastructure assets, as well as development of new technologies and facilities.

The committee developed a strategy for improving the balance of the OCE budget over the next decade. To restore core science funding during these lean budget times, the immediate goal is to reverse the trend of increasing infrastructure spending at the expense of core science in the OCE budget. Assuming that OCE has a flat budget over the next 10 years, roughly 20% (about $40 million in 2014 dollars) of the infrastructure O&M budget would need to be reallocated to core science (including OTIC) to meet this goal. This would return core science funding to approximately the budget level in 2011, the last year before funding for core science began to decrease.

Recommendation 2: OCE should strive to reduce the O&M costs of its major infrastructure (OOI, IODP, and the academic research fleet) and restore

funding to core science and OTIC within the next five years. If budgets remain flat or have only inflationary increases, OCE should adjust its major infrastructure programs to comprise no more than 40–50% of the total annual program budget.

Recommendation 3: To implement Recommendation 2, OCE should initiate an immediate 10% reduction in major infrastructure costs in their next budget, followed by an additional 10–20% decrease over the following five years. Cost savings should be applied directly to strengthening the core science programs, investing in technology development, and funding substantive partnerships to address the decadal science priorities, with the ultimate goal of achieving a rebalancing of major infrastructure costs to core science funding within the next five years.

There are several options available to reduce infrastructure costs while sustaining research capabilities. These options include: de-scoping or terminating activities; lengthening the time horizon of programs; delaying the start of new or planned programs or facilities; and finding ways to lower costs. Based on the analysis of the infrastructure investment alignments with the scientific priorities, costs of operation, efficiencies that could be gained, and likelihood of community support, the committee determined that the distribution of initial cost reductions between OOI, IODP (2013–2018), and the academic research fleet should be as follows:

Recommendation 4: The immediate initial 10% cost reduction in major infrastructure should be distributed, with the greatest reduction applied to OOI, a moderate reduction to IODP (2013–2108), and the smallest reduction to the academic research fleet.

A suggested weighting is to initially and immediately reduce OOI by 20%, IODP by 10%, and the UNOLS fleet by 5%. OOI is recommended for the greatest cost reduction because fewer of its components align strongly with the science priorities, operation of the program can be scaled to fit the available budget, and because the separate components of the OOI structure provide flexibility to retain those components that align more strongly with the decadal science priorities and broad

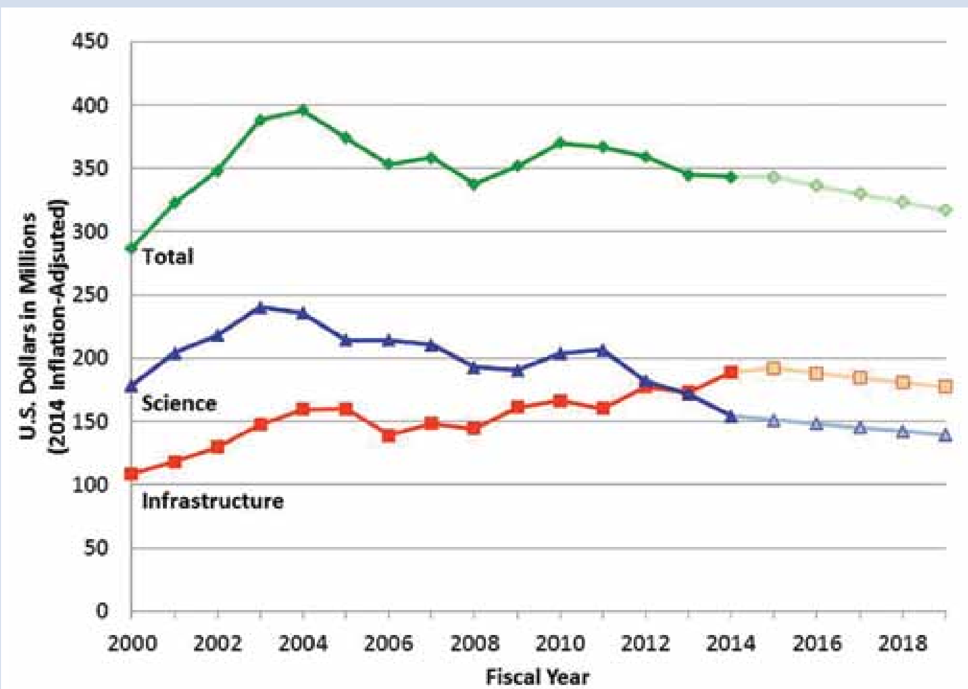


Figure S–4. *NSF investments in core ocean science (*blue*) and infrastructure (*orange*) since 2000, shown in inflation-adjusted 2014 dollars. Total funding for OCE is shown in green. Projections for FY2015–2019 (*lighter colors*) are based on the following assumptions provided by OCE—total future budgets are flat with no inflationary increases and ship operations, IODP, and OOI costs are held constant. OCE defines "infrastructure" as the academic research fleet, OOI, IODP, field stations and marine laboratories, the accelerator mass spectrometer facility, and miscellaneous smaller facilities. Facilities held in the core programs are included in core science, not in infrastructure. Data from NSF, December 2014.*

OCE research goals. For example, OOI might focus attention on one or two of the four global sites to minimize logistic costs and to demonstrate proof of concept. A moderate weighted cut recommended for the NSF-supported portion of IODP (2013–2018) reflects that IODP is important or critical for over half of the decadal science priorities. However, the JOIDES Resolution is an expensive facility and cost-sharing agreements within the consortium are not evenly distributed. The smallest cost reduction is recommended for the academic research fleet, because essentially all of the science priorities require ship-based access to the sea. Even a modest cut will require finding efficiencies to reduce the costs of the current fleet and to prevent an increase in overall O&M expenses with future ship acquisitions.

Recommendation 5: NSF should reconsider whether the current RCRV design is aligned with scientific needs and is cost-effective in terms of long-term O&M, and should plan to build no more than two RCRVs.

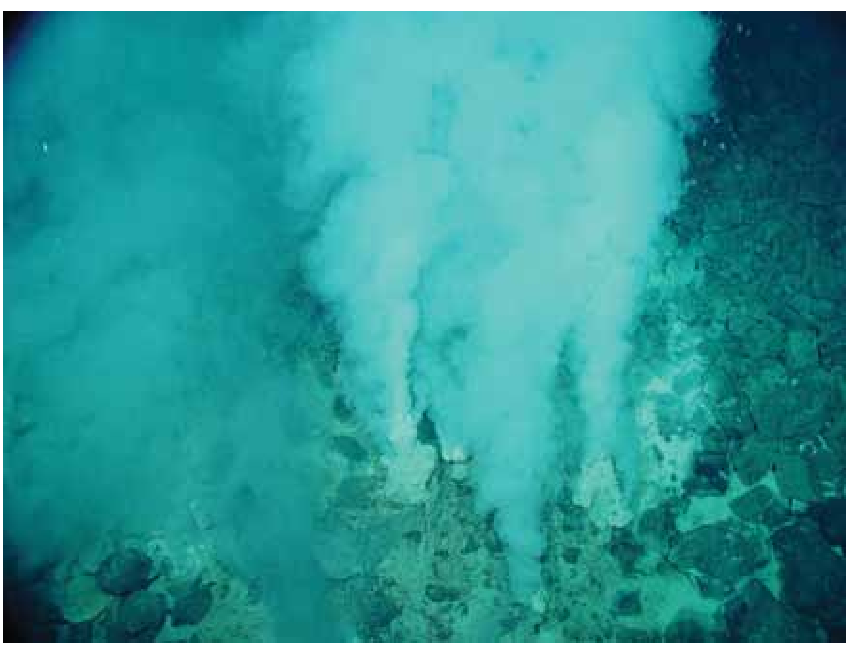
Decision Rules for the Future

The committee established the following strategic principles, to guide decision-making in an uncertain budget climate, which when combined with open communication and consistent actions will assist NSF in maintaining a balanced portfolio:

Promote a Decadal Budget Planning Outlook
A 10-year budget planning outlook can take into account both inflation and anticipated increased costs of doing business, while accounting for risks associated with unexpected costs.

Maintain Conservative Infrastructure Investment Strategies
Given the uncertain budget environment, it is prudent to assume budget cuts are permanent and increases are temporary. Strategies for controlling the overall costs of infrastructure have to be identified prior to the addition of any new asset. Assumptions that prove to be too conservative can be corrected in future budget cycles.

Involve the Community in Setting Goals
Involving the scientific community in the development of strategic goals and objectives provides a broad base for identifying priorities and building community support for the enterprise into the future. The NSF Advisory Committee for Geosciences (AC-GEO) could serve as a link with the broader community. Involvement of AC-GEO could bolster support for difficult decisions that need to be made by OCE to adhere to the strategic plans.



Hydrothermal vent chimneys at the NW Eifuku volcano in the Mariana Arc. *Credit: NOAA*

Although NSF has undertaken reviews of individual programs and has established committees advising OOI, IODP, the fleet, and NDSF, at present there is no advisory body with broad oversight of major OCE infrastructure that can provide advice on the construction, maintenance, and operations of facilities in relation to the science priorities.

Recommendation 6: Program reviews for OOI, IODP, the academic research fleet, and NDSF should occur periodically (nominally every three to five years, with a 10-year outlook) and should be considered within the context of the broader OCE budget environment, rather than

independently. OCE should consider exit strategies for major acquisitions if funding is insufficient. OCE should seek periodic community input to help ensure infrastructure investments align with the science priorities.

Recommendation 7: OCE should initiate a high-level standing infrastructure oversight committee to evaluate the entire portfolio of OCE-supported infrastructure and facilities and to recommend proposed changes. The outlook should be for at least 10 years and should include discussion of the entire lifecycle of construction, operations and maintenance, decommissioning, and recapitalization. Committee membership should include professionals experienced in long-range budgeting and strategic planning.

Ocean research inevitably transcends national boundaries, with numerous opportunities for interagency and international collaboration. Such partnerships can leverage resources and maximize progress, and are expected to play an increasingly strong role for support of large, multidisciplinary programs to address complex, high-priority, ocean science questions.

Recommendation 8: The committee encourages OCE to expand its partnership capabilities with other federal agencies, international programs, and other sectors. Such partnerships can maximize the value of both research and infrastructure investments and may help spread the costs of major ocean research infrastructure beyond OCE.

Although the contributions of the ocean sciences community have been invaluable in guiding the work of the committee, the conclusions represent the deliberations of its members, who recognize the difficulty of the task and the reality that resolving current budget issues will impact existing programs. The committee focused on the long-term health of the ocean sciences with the goal of restoring a healthy balance among OCE's funding profiles and portfolios, while preserving the essential elements to sustain the research enterprise into the next decade. These strategic issues need to be examined regularly to make continued course corrections as necessary to steer ocean sciences toward a vibrant future.

Credit: kakisky/morgueFile

Committee for the Decadal Survey of Ocean Sciences 2015: Shirley A. Pomponi (*Co-Chair*), Harbor Branch Oceanographic Institution–Florida Atlantic University; **David W. Titley** (*Co-Chair*), Pennsylvania State University; **Edward Boyle** (NAS), Massachusetts Institute of Technology; **Melbourne Briscoe,** OceanGeeks, LLC, Alexandria, VA; **Russ E. Davis** (NAS), Scripps Institution of Oceanography; **Margo Edwards,** University of Hawaii at Manoa; **Mary (Missy) H. Feeley,** ExxonMobil Exploration Company (*retired*), Houston; **Donald Forsyth** (NAS), Brown University; **Peter Liss** (FRS), University of East Anglia, United Kingdom and Texas A&M University; **Susan Lozier,** Duke University; **Roberta Marinelli,** University of Southern California, Los Angeles; **James J. McCarthy,** Harvard University; **Alan Mix,** Oregon State University; **Steven A. Murawski,** University of South Florida, St. Petersburg; **Robert T. Paine** (NAS), University of Washington; **Charles Paull,** Monterey Bay Aquarium Research Institute, Moss Landing, CA; **Don Walsh** (NAE), International Maritime Incorporated, Myrtle Point, OR; **Bess B. Ward,** Princeton University; **James A. Yoder,** Woods Hole Oceanographic Institution; **William R. Young** (NAS), Scripps Institution of Oceanography; **Deborah Glickson** (*Study Director*), **Susan Roberts** (*Director*), **Payton Kalina** (*Senior Program Assistant*), **Stacee Karras** (*Research Associate*), National Research Council.

The National Academies appointed the above committee of experts to address the specific task requested by the National Science Foundation. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. For more information, contact the Ocean Studies Board at (202) 334-2714 or visit **http://dels.nas.edu/osb**. Copies of *Sea Change: 2015–2025 Decadal Survey of Ocean Sciences* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; **www.nap.edu**.