Charting the Future for the

National Academic Research Fleet

A Long-Range Plan for Renewal

Draft Plan

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A Report from the Federal Oceanographic Facilities Committee (FOFC) of the National Oceanographic Partnership Program (NOPP)

Artist's rendition of the new SWATH ship, R/V *Kilo Moana*, an Ocean Class vessel.

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Wearing safety lines, researchers aboard R/V *Endeavor* wrestle with a rosette water sampler in the souther Labrador Sea. Photo courtesy of P. Landry.

Many thanks to the UNOLS Council, Fleet Improvement Committee, UNOLS Office, and the many members of the scientific community who provided input to FOFC.

Contents

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1. Executive Summary

This Plan defines a federal interagency renewal strategy for the national academic research fleet. The Plan addresses renewals, retirements, and technology upgrades for those vessels within the fleet that are over 40 m long. At present (CY 2001), this includes all but one of the federally owned vessels. Larger vessels are expected to be predominantly federally owned, owing to their higher capital costs. Smaller private and state-owned vessels will remain vital to the academic research fleet's capabilities, but their replacement is not specifically detailed in the Plan as traditionally they have not been built with federal funds.

The Plan defines four basic vessel classes for the current and future fleet:

- **Global Class** ships will continue to be high-endurance vessels, operating worldwide.
- **Ocean Class** ships will fulfill a critical need in fleet modernization by replacing the aging "Intermediate" ships with vessels of increased endurance, technological capability, and number of science berths. These will be ocean-going vessels, though not globally ranging.
- **Regional Class** ships will continue to work in and near the continental margins and coastal zone, but with improved technology and more science berths than in current, comparably sized vessels.
- **Local Class** ships will fulfill nearshore needs that do not require larger or higher-endurance ships. These vessels will be built primarily using non-federal dollars but will continue to receive federal operational and outfitting support.

Figure 1. The R/V *Oceanus*, an Intermediate Class ship built in 1976, is one of several that will reach 30 years of service within the next decade. Ocean Class ships will replace them as key elements of the future national academic research fleet.

Figure 2. The Seaglider is one of several autonomous underwater vehicles that will permit oceanographers to measure hydrographic, chemical, and biological fields across the ocean. Seagliders can be launched from small boats and operate for a year without servicing. Instruments such as these free ships from routine sampling chores, permitting them to undertake tasks requiring special capabilities. Photo courtesy of C. Eriksen, University of Washington.

The renewal strategy presented in this report is based on projected operational life spans for existing vessels and a nominal 30-year life span for new vessels. The fleet's current geographical distribution is consistent with the anticipated future demand for federally funded academic research. Federal funds for ship construction and operation will be awarded on the basis of open competition.

The baseline assumption for the Plan is to maintain fleet capacity (expressed as total operational days averaged over the most recent five years) at current use levels while increasing capability over the next 20 years and beyond. The rationale for this baseline assumption rests on historical trends of stable to slightly increased federal funding for academic oceanographic research, combined with a modest fleet overcapacity and a consistent trend towards more oceanographic data acquisition from nontraditional platforms. The growing trend towards larger, interdisciplinary, seagoing science teams using increasingly sophisticated research tools demands greater capability.

Over the next two decades, at least ten new ships, including one Global Class ship, six Ocean Class ships (one of which is currently under construction), and three Regional Class ships are required to maintain capacity and reinvigorate the fleet as aging and less-capable ships retire. If optimistic budget scenarios permit new scientific thrusts outlined in this plan to go forward, fleet size and composition might need to increase to up to 13 new ships.

Ships will undergo continuous and significant technological upgrades over their lifetime to ensure that new technological innovations are available in the fleet. Building a portfolio of ship-concept designs and identifying science mission requirements (SMRs) will also be important functions undertaken to maintain a modern, technologically viable fleet capable of supporting evolving science needs.

This Plan must be reviewed and updated by the Federal Oceanographic Facilities Committee (FOFC) at least every five years, based on evolving science requirements and funding trends, to determine whether additional ships will be required before the end of the second decade, and to plan their timely introduction where necessary.

2. Introduction

The Plan responds to a recommendation in the "Academic Research Fleet" report (Fleet Review Committee, 1999), which was received in May 1999 by the National Science Foundation's (NSF) National Science Board:

The Federal agencies funding research in oceanography should prepare and maintain a long range plan for the modernization and composition of the oceanographic research fleet which reaches well into the 21st century. This will avoid the high cost of obsolescent facilities and provide the Congress with a unified roadmap for out-year allocations for vessels to support oceanographic research.

The Plan presents a vision for the larger ocean-going vessels in the national academic research fleet, defined here as those exceeding 40 m (130 ft). The 16 existing vessels account for about 85% of the total federal fleet operating expenditures, and all except four were built or acquired with federal funds. The Plan adopts projected service life retirement dates determined for each ship by the University-National Oceanographic Laboratory System (UNOLS) in 2001, and calls for a schedule of new ship construction. While the Plan addresses the role of vessels in the fleet that are smaller than 40 m, it does not offer a replacement plan for them. Traditionally, most smaller ships have not been built with federal funding. The smaller ships will continue to be an integral component of the facilities needed to support the science of the future.

The Plan recognizes that the demand for more research, education, and exploration in the ocean sciences is well documented and is greater than can be supported by current federal-agency budgets. The Plan's goal is to be flexible enough to provide the ship-support needs of the ocean sciences community at the levels required by demand as tempered by funding constraints. The acquisition of new ships, from design through construction, takes several years. Consequently, the Plan proposes an essential baseline of renewal with expansion appropriate to potential budgetary increases that would facilitate additional science requirements. To accommodate changing circumstances, the Plan will be reviewed and updated at least every five years by the Federal Oceanographic Facilities Committee (FOFC) of the National Oceanographic Partnership Program (NOPP). The Chair of FOFC will report annually to the National Ocean Research Leadership Council (NORLC) on progress towards implementing the Plan.

The Plan only peripherally refers to submersibles, remotely operated vehicles (ROVs), ocean observatories, drifting or navigated sensor packages, or other facilities used in support of academic oceanographic research. These other "facilities" will be addressed in the future because they will also have a major impact on our nation's ability to continue to conduct ocean sciences research.

Figure 3. The Global Class R/V *Melville*, built in the 1969 and re-engined, stretched, and upgraded in 1991, will be retired in 2014.

3. A Historical Perspective of the National Academic Research Fleet

Ship Acquisition: Building a Fleet

Oceanography in the United States grew rapidly after World War II, largely guided by the Office of Naval Research (ONR), which was established in 1946. NSF was established in 1950 with Alan Waterman, formerly Chief Scientist of ONR, as its first Director. The 1957-58 International Geophysical Year marked the first major NSF involvement in oceanography, with responsibility for administration of Congressionally appropriated funds for this significant program. During this period, academic oceanographic ships either belonged to the institutions themselves, or were provided by the Navy. NSF-funded researchers usually gained access to ships through ONR omnibus contracts.

In 1959, two landmark reports were issued which set the tone for the upsurge of academic oceanography for the 1960s: the Navy's "Ten Years in Oceanography (TENOC)" Report (Lill et al., 1959) and the National Academy of Sciences' "Oceanography 1960 to 1970" report (National Academy of Ocean Sciences Committee on Oceanography, 1959). The latter called for a doubling of research over 10 years, and recommended that the Navy, Maritime Administration, and NSF finance new research ship construction. The two reports and subsequent national attention resulted in the passage of the Marine Resources and Engineering Development Act of 1966, which established what has long been referred to as the Stratton Commission. The Commission's report, "Our Nation and the Sea," (Commission on Marine Sciences, Engineering, and Resources, 1969) shaped oceanography through the 1970s and beyond, and lead to the establishment of the National Oceanic and Atmospheric Administration (NOAA), the third major builder of oceanographic research vessels.

By the early 1960s, NSF support for academic ocean research had become a significant fraction of the total, to the point where the NSF Associate Director for Research needed to establish a panel on Grants and Contracts for Ship Construction. This resulted in NSF funding the construction of three ships during that decade: R/Vs *Eastward* (1962), *Atlantis II* (1963), and *Alpha Helix* (1966).

At about the same time, the Navy funded the construction of several AGOR-3 class research vessels, three of which, R/Vs *Conrad* (1962), *Washington* (1965), and *Thompson* (1965), were operated as part of the national academic research fleet. Other vessels of this class, such as the USNS *Davis, Lynch, De Steiguer* and *Bartlett* were operated until the last decade for the Naval Research Laboratories. The academic fleet now covers some of the work once done from these vessels. In addition, during the 1960s several WWII-vintage and newer freighters were converted to research vessels with funding from various institutions and federal agencies. These included, among others, the R/Vs *Agassiz* (1962) at Scripps Institution of Oceanography, the *Trident* (1963) at University of Rhode Island, the *Alaminos* (1964) at Texas A&M University, and the *Yaquina* (1964) at Oregon State University. In 1970 three more intermediate- to large-size vessels joined the academic fleet: the R/Vs *Gilliss* at University of Miami; the *Kana Keoki* at University of Hawaii; and the *Moore* at the University of Texas. These ships are all examples of conversions made with institutional funds.

Towards the end of the 1960s, the Navy built two new Global Class vessels for the Fleet, the R/Vs *Knorr* and *Melville*. In the 1970s NSF undertook the construction of six ships over 40 m (130 ft). These included four Intermediate Class ships (R/Vs *Iselin, Oceanus, Wecoma,* and *Endeavor)*, all of which were in service by 1978, and two Regional, or Cape, Class ships (R/Vs *Cape Hatteras* and *Cape Florida*, later renamed *Point Sur*), which were in service by 1981. The Navy built the R/Vs *Gyre* and *Moana Wave*; both were operating by 1973 and 1974, respectively. The State of California built the R/V *New Horizon* and began operating that vessel by 1978.

Recognizing that the 133-ft R/V *Alpha Helix*, which had been transferred to the Alaska region in 1980, was not adequate in either size or ice strengthening to the rigors of those waters, NSF commissioned a study for a new 220-ft ship (Elsner and Leiby, 1980). A second study funded in 1994 (University of Alaska, 1994) called for a much larger and more ice-capable vessel. Despite the fact that the R/V *Alpha Helix* was approaching its 30-year design life, neither plan was implemented and a new ship was not built. NSF is now funding a new design study based on updated SMRs.

The other Intermediate and Regional Class ships built with NSF funds in the 1970s are also aging and will reach their 30-year design life over the next few years. The R/Vs *Iselin* and *Moana Wave* were retired in 1995 and 1999 respectively.

Global Class ships began reaching design life during the 1980s, and the Navy initiated a major program to re-engine, stretch, and upgrade two vessels (R/Vs *Knorr and Melville*) and construct three new vessels, which entered service during the last decade (R/Vs *Thompson*, *Atlantis,* and *Revelle*). The aging R/V *Conrad*, used primarily for specialized marine seismic research, was replaced in 1983 by a relatively new ship originally built for oil exploration. Supported by NSF funds, the replacement vessel was purchased from the oil industry, renamed the R/V *Ewing*, and outfitted to perform general oceanographic and seismic work for the fleet.

Figure 4. The Global Class vessel R/V *Roger Revelle*, built in 1996, has a projected retirement date of 2026. Photo courtesy of Scripps Institution of Oceanography.

Figure 5. The R/V *Atlantis* being launched. This global class ship, built in 1997, operates the deep-submergence vehicle, *Alvin*. Photo courtesy of Woods Hole Oceanographic Institution.

University-National Oceanographic Laboratory System

Recognizing the need for coordinated use of federally supported oceanographic facilities, the community of academic oceanographic institutions which use and operate these facilities approved a charter in 1972 for an organization named the University-National Oceanographic Laboratory System. UNOLS also acts as an advisory body for the federal agencies that support oceanographic research. Byrne and Dinsmore (2000) documented the history of the UNOLS establishment; the continuing history and most recent version of the UNOLS Charter can be viewed at www.unols.org.

A major UNOLS objective is to coordinate and review access to and use of facilities for academic oceanographic research, and to assess the match of facilities to the needs of academic oceanographic programs. Another objective is to foster federal, state, and private support for academic oceanography, thereby continuing and enhancing the excellence of our nation's oceanographic program. UNOLS currently has 61 member institutions, including 21 ship-operating and 40 non-ship-operating institutions, whose scientists use the ships of the national academic research fleet.

The UNOLS fleet includes the federal, state, and privately owned vessels that make up the national academic research fleet. The Navy owns five of the six largest vessels; NSF owns the sixth. The intermediate and regional vessels are a mix of federal, state, and privately owned vessels. NSF owns all six of the federally owned vessels in the Intermediate and Regional Classes. Except for one NSF-owned vessel and one owned by the Smithsonian Institution, the local/near-shore UNOLS vessels are state or privately owned.

Vessels within the fleet are a composite of different ship sizes, designs, and capabilities and serve both general and specialized purposes. All UNOLS vessels are equipped for multidisciplinary science. Two of these vessels have been equipped for specialized science operations: the R/V *Ewing* conducts seismic reflection surveys and the R/V *Atlantis*, and its submersible *Alvin*, conduct deep-submergence surveys and experiments. The current vessels of the national academic research fleet are listed in Appendix A.

Ocean Sciences Funding History (1980-2001)

The scientific justification for research and education in the ocean sciences is strong and the potential importance of this research to the public is far reaching. Despite these factors, we cannot assume increased funding for oceanographic research over the next 20 years. The competition for public funds within the federal budget is significant, and the priorities of society, Congress, and the federal agencies change with time.

An examination of trends over the past 20 years, however, may provide useful insight. Although there appears to be a strong upward trend for federal ocean science funding during this period, when converted to constant dollars to account for inflation, the trend is essentially flat from 1982 to 1999, according to data compiled by the Ocean Studies Board of the National Research Council (Figure 6). Overall, the proportion of the budget allocated for ship operations has progressively fallen both at NSF and Navy, traditionally the two largest federal funders of UNOLS vessels.

The fleet renewal strategy set forth in this report calls for a fleet structure capable of accommodating the average demands placed on it in the recent past. The Plan also recognizes the increased facilities requirements described in the science plans being generated by the ocean sciences community. If budgets increase significantly over the next few decades, the Plan's flexibility will permit necessary adjustments to be made.

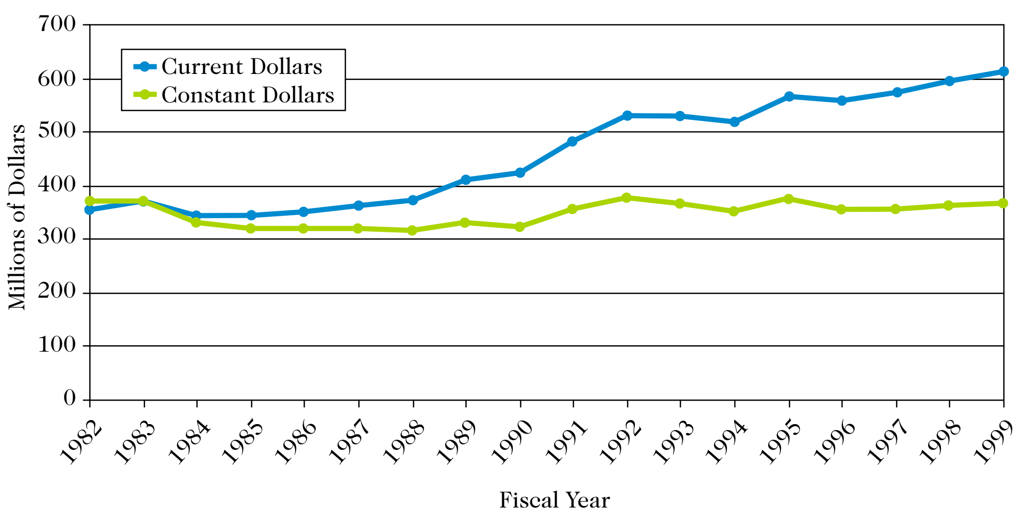


Figure 6. Total funding for ocean sciences in current and constant 1983 dollars for fiscal years 1982-1999. Compiled by the Ocean Studies Board, National Research Council.

4. Fleet Capacity and Usage

Fleet capacity has been defined in a variety of ways by different stakeholders. In general, "fleet capacity" within the Plan refers to the ability of the fleet to support federally funded projects in a timely manner. Defined as such, a multitude of factors affect fleet capacity. Some of the factors and their impacts are included in Table 1.

All of these factors affect scientists' ability to perform their research at sea. For example, the number of available science berths can limit the number of scientists who can participate on a cruise. For simplicity, throughout the report "ship operating days" has been used as the principal metric for quantifying capacity.

UNOLS vessel use varies from year to year, depending largely on the amount and mix of federally funded research that requires ship support. Generally, research programs are funded one or more years prior to the year(s) ship resources are needed. Some reserve capacity in the system is necessary to meet fluctuating ship demand, but it is also costly to maintain.

Defining the extent to which the fleet approaches full use depends on having an accepted definition of a full operating year (FOY) for each ship class. The Plan follows the FOY definitions in the "Academic Research Fleet" report (Fleet Review Commit-

Table 1. Fleet Capacity

Factors	Impacts
Number of vessels in the fleet	• Determines how many ship operating days are available for scheduling science days at sea • Affects the number of cruises that can be scheduled concurrently
Vessel design, size, range, and endurance	• Determines ship operating area • Affects ability to support general and specialized science, such as seismic and deep submergence • Dictates maximum cruise lengths
Number of science berths and available scientific and storage places	• Limits the number of available science slots aboard the vessel
Geographic distribution of vessels	• Affects ability to reach research sites efficiently
Ship-operation budgets	• Serves as a boundary for funding fleet support

tee, 1999), which are 300 days for Global Class, 275 days for Intermediate Class and Ocean Class (discussed below), and 200 days for Regional Class vessels. The standard UNOLS definition of an "operating day," which includes all days away from home port in an operational status incident to the science mission, is used in this report. Although not absolute measures for any one vessel, the FOY estimates are roughly comparable within classes, and are based on historical evaluations of ship capabilities, size, design, operating profiles, and associated costs. Figure 7 illustrates average UNOLS ship-operation days by class, in relation to FOY.

The average use of Global Class ships increased sharply from the early to mid 1990s, and then declined over the next five years coincident with the termination of the sea-going phases of the large Joint Global Ocean Flux Study (JGOFS) and World Ocean Circulation Experiment (WOCE) programs. Most recently, this trend has reversed due to an increase in science demand and the Navy's increased use of the fleet (additional surveys and other applied military research). NOAA has also increased its use of the fleet over the past several years. Use of Global Class ships has averaged about 90% of available capacity in the 1990s. There is usually some overcapacity in the Global Class, but it oscillates within tolerable limits.

In most years, there are a few projects not accommodated within the desired time frame. This is either because of difficulty of scheduling the appropriate facility at a peak period within the year, or at the desired geographical location. Funding for research and ship operations typically comes from the same fixed resource. Reducing the ratio of transit to total operational days and maximizing the number of actual science days on cruises can produce savings that can be used for funding more research grants or ship improvements. Wherever possible, meeting science priorities remains the uppermost goal of federal managers and ship operators.

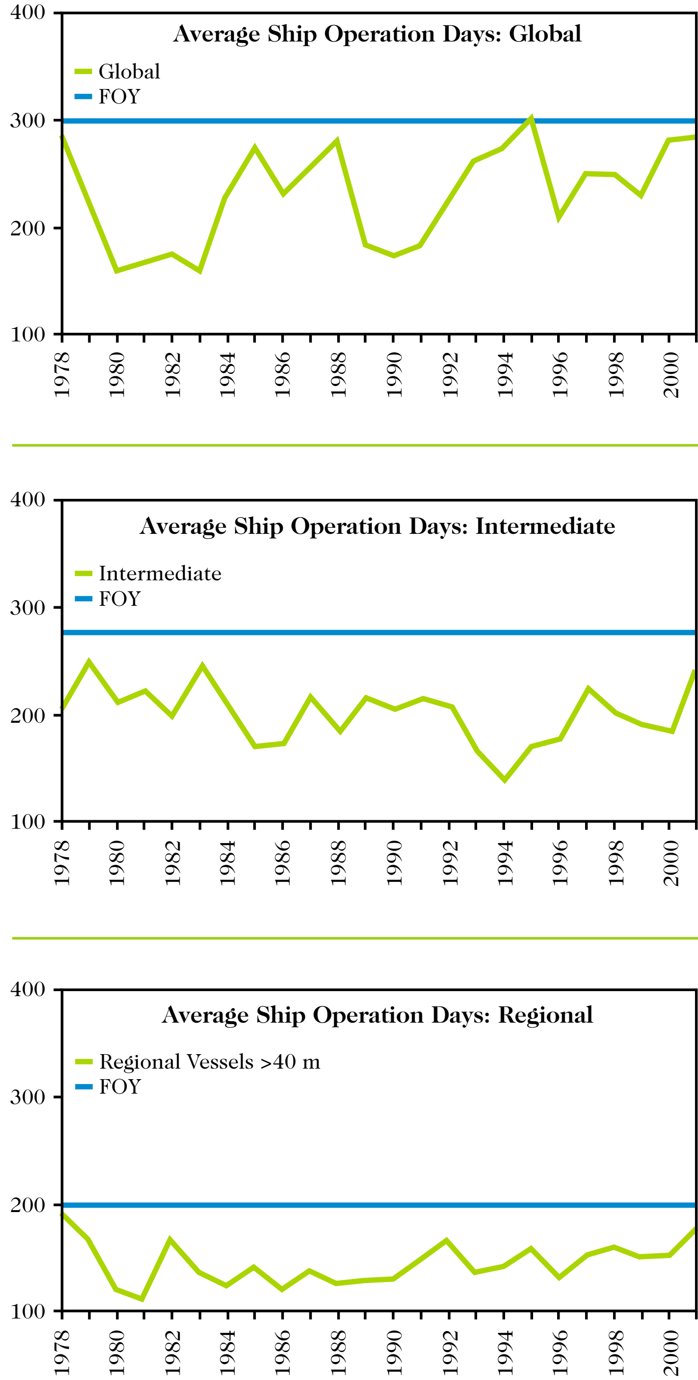
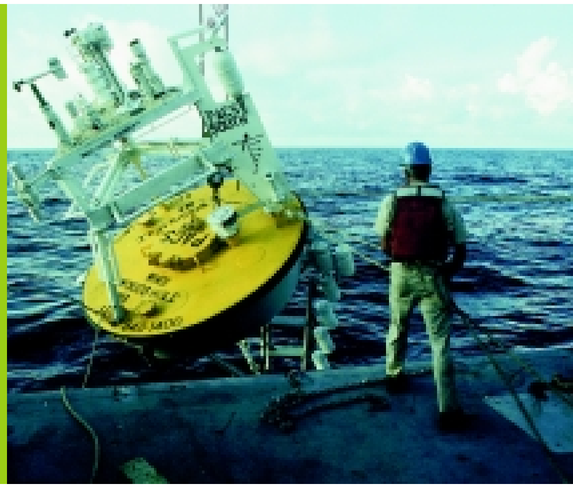


Figure 7. Average Ship Operation Days by Class (current UNOLS ship classes).

Figure 8. The meteorological sensors on buoys like this one, being launched from the R/V *Roger Revelle*, for a Pan-American Climate Studies mooring, are vital to programs such as Climate Variability and Predictability (CLIVAR). One of CLIVARS' predecessors, the World Ocean Circulation Experiment (WOCE) used over 2200 days of ship time between 1990 and 1999. Photo courtesy of R. Archibald.



Use of the Intermediate and Regional Ship Classes for the past twenty years has remained below the FOY capability for these size vessels. For the past decade use has averaged about 70% of capacity. Overcapacity causes partial and full-year lay-ups, creating various problems such as crew layoffs and additional expenditures (lay-up and start-up costs), which otherwise would have been used to support research.

During periods of low use, efforts have been made by both individual operators and federal agencies to increase fleet use by supporting projects not associated with the federal agencies' core research programs or "nonacademic customers." Examples of this include the completed commercial charter in 1998 of the R/V *Ewing,* and operation of the Naval Oceanographic Office's (NAVO) survey programs on several academic research fleet vessels. Such use can be important to maintain facilities through temporary funding shortfalls, as discussed by the Fleet Review Committee (1999). The Plan recognizes that such activities can and will be carried out on academic fleet vessels on occasion, however, this aspect of fleet use is less predictable and is not taken into consideration when evaluating optimal fleet size and composition.

Following the lead set by the Federal Oceanographic Fleet Coordination Council (FOFCC) in 1984, the Plan takes the service life of an oceanographic vessel to be 30 years as a goal, while recognizing that, "the factors which define ship obsolescence have no set values." Mid-life refits and upgrades are assumed to be necessary over time to ensure habitability, maintain efficiency of operation, and upgrade technological capabilities to extend the ship's service life to 30 years and beyond. Modern ships are more fuel efficient due to advances in engine, hull, and propulsion design. Automation, modern equipment, and safety technology will lead to a reduction in crew necessary to operate and maintain a vessel. New ships built with modern habitability and safety standards established by USCG, ABS, and SOLAS increase morale and reduce liability from workplace injury and the potential loss of life.

5. Science Trends
and the Changing Mix of Tools

The ocean sciences community is vigorous, full of ideas, and anxious to implement many new programs of discovery, exploration, and education. Many of these themes are showcased in several reports stimulated by the beginning of the new millennium. These reports include "Ocean Sciences at the New Millennium" (Brewer and Moore, 2001), "Illuminating the Hidden Planet" (National Research Council, 2000b), "Earth, Oceans and Life: Scientific Investigation of the Earth System Using Multiple Drilling Platforms and New Technology" (Moore et al, 2001), and "Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration" (McNutt et al, 2000).

Advances in understanding the ocean environment have nearly always been preceded by observations. The national academic research fleet is the primary tool by which such observations have traditionally been obtained, and it will continue to be central. The ocean sciences are entering an era of new needs and new capabilities. The direction for both research and operational oceanography over the next two decades will be towards using new technology to make continuous, long-term observations and gather increasingly large data sets. Researchers require data that permit exploration of the time domain. Operational predictive capability, which enables various kinds of publicly useful forecasts of oceanic conditions, likewise requires such continuous, long-term information. These dual requirements of "continuous" and "long-term" cannot be met using conventional ships alone, but require unattended, automated observing systems. Rapid advances in technology, including speed and miniaturization, are revolutionizing data collection and these trends will continue at an ever-increasing pace.

Figure 9. The Argo float program involves the deployment of several thousand freely drifting PALACE floats, which profile the oceanic temperature and salinity while moving with the circulation deep beneath the surface. In large numbers they are yielding a global picture of the evolving density structure of the ocean. Photo courtesy of S. Riser, University of Washington.

While continuous observations of all aspects of the ocean will increasingly be from nontraditional platforms, ships will still be needed to deploy and service observing systems. Ships will become more important in supporting focused experiments in the context of ongoing observations, as well as in the early development and testing of sensing systems and observatories.

Deploying and Servicing Observing Systems: Within the next five years the goal of the Argo Project, which arose out of WOCE-funded technology development, will be to continuously monitor global temperature and salinity to a depth of 2,000 meters using 3,000 autonomous profiling floats (Figure 9). Most floats will be deployed from aircraft or volunteer ships, but in certain regions and times only research vessels will be available to sustain the global network. Another global-scale observing effort, which is set forth in a National Research Council report (2000b), calls for increased emphasis on long-term monitoring of the seafloor and below. Ships will be required to deploy and maintain instruments throughout the life of that program.

There are other implemented or planned semiautonomous data collection systems. The well-established LEO-15 shallow-water observatory on New Jersey's coast has demonstrated the capabilities of an unattended array that collects continuous multiparameter data (Figure 11). The National Oceanographic Partnership Program (NOPP) has established the OCEAN.US Office to coordinate efforts of federal agencies in building a national operational and research ocean observing system.

Figure 10. MARLIN, the research instrument deployed here from the R/V *Wecoma* off the coast of Oregon, is a sophisticated towed body capable of making measurements of velocity shear, turbulence, and fine structure to depths of 3400 m. The purpose of the instrument is to investigate physical processes that lead to mixing of the deep ocean near topography such as seamounts, submarine canyons, escarpments, and mid-ocean ridges. Photo from http://mixing. oce.orst.edu/Photogallery/Marlin/start.htm.

Both domestically and internationally, observing systems such as these are expected to proliferate over the next three decades, and will supply an ever-increasing quantity of oceanographic data to operational organizations and academic researchers. The classical deep-sea oceanographic station measurement from a ship will no longer be the only source of direct observation of any variable within the ocean. In this respect, some areas of oceanographic data collection are following the path of meteorological science two or more decades earlier, where technological advances allowed for the remote collection of data. As data collection technology continues to evolve, so will the fleet-support requirements. The fleet's role in collecting observations will diminish, but it will take on a greater role in deploying, servicing, and maintaining new observing systems.

A recent workshop supported by NSF (Cowles and Atkinson, 2000) asked the academic community to consider the future trends in oceanographic research and their implications for a changing mix of tools. The workshop report noted the ongoing revolution in observing methods made possible by autonomous vehicles of various kinds, new modes of data exchange among vehicles, ships and shore, satellite observing systems, moored or seafloor installations, and other techniques. The vast increase in data volumes, and their assimilation into models, leads to an increasing need for a new era of interdisciplinary hypothesis testing, requiring a new generation of ships serving as highly capable sea-going laboratories. Workshop attendees noted that there may be an increased need for ship time.

Ships for Multidisciplinary Hypothesis Testing: New technologies and emerging global observation data sets will lead to new insights and new questions about ocean processes. During the ship-intensive, decade-long WOCE program, for instance, profiling floats were developed and over 200 of these were deployed in the North Atlantic as a demonstration of the concept of automated, continuous near-real-time collection of temperature and salinity data with depth. This has led to the concept of the Argo program (see above). Data collection from 3,000 Argo floats worldwide for operational purposes will surely be used by the research community. The availability of these data will, in turn, stimulate new ship-intensive research experiments, and the demand for finer time and space resolution than the existing global network can provide. A ship in this case is likely to be a center of activity or "mission control" for a mix of local data gathering systems such as floats, moorings, AUVs (autonomous underwater vehicles), and ROVs.

One kind of experiment that often requires unscheduled and rapid access to ship support responds to sudden, natural events. Despite the difficulty in providing immediate ship resources, agencies have long incorporated rapid funding mechanisms to permit quick scientific response to events such as rapid El Niño onsets, hurricanes, and submarine volcanic eruptions. Future ability to have short-term alerts of unanticipated events through automated, continuous observing systems assures an increasing demand for fast-response ship time.

Ships as Test Platforms: To date, the most successful, long-term, unattended instruments have primarily measured temperature and salinity. The capture of most important chemical and biological variables has yet to be automated for long-term, unattended deployment. For some measurements, this is likely to remain true for the foreseeable future, and scientists taking measurements from ships will be essential. New analytical techniques, and new systems to automate them, will be devised continually, and ships will be required to evaluate and test these new systems.

Summary: During the last two decades significant progress has been made in unraveling the physical, chemical, and biological interactions that connect oceanic processes to Earth systems. Basic interdisciplinary understanding has arisen from several large oceanographic field programs such as WOCE, JGOFS, and Global Ocean Ecosystems Dynamics (GLOBEC), with strong U.S. leadership, as well as from field studies conducted by individual investigator-driven research programs. U.S. oceanographers are now poised to apply this basic knowledge to large regions of the ocean through effective combinations of remote sensing, autonomous vehicles and platforms, and shipborne studies.

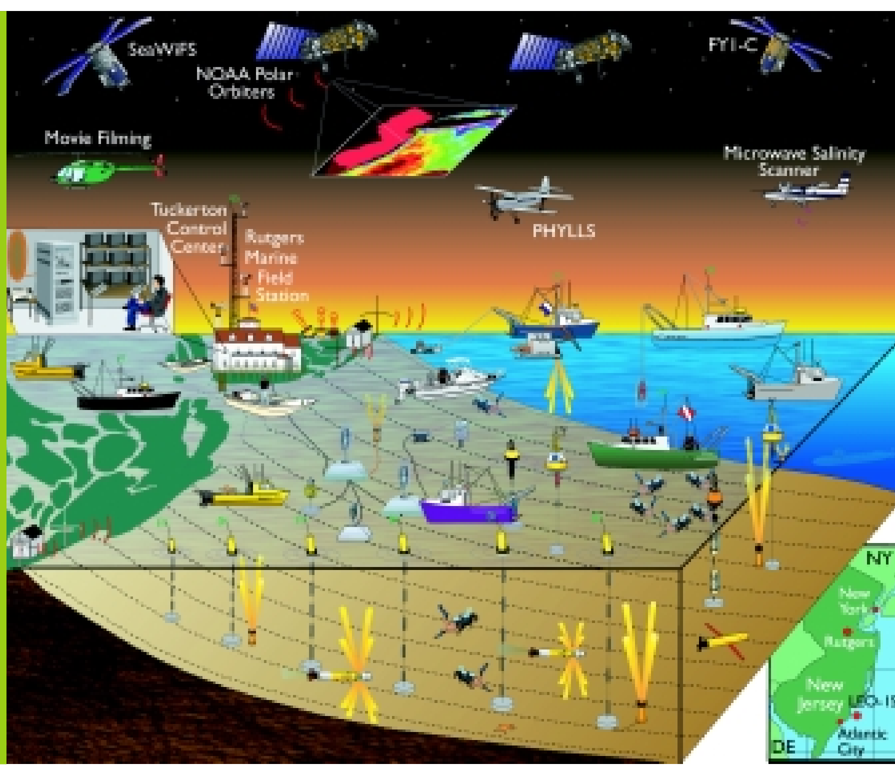


Figure 11. Coastal ocean observation networks are now operating or are being constructed at numerous locations around the United States. This schematic diagram of Rutger's LEO-15 coastal observatory, occupies a 30 km by 30 km region in the New York Bight. Several types of research vessels are required to carry out the integrated physical, chemical, bio-optical research program. Figure courtesy of Dale Haidvogel, Rutgers University.

6. Evolution of the Fleet

Over the Next Two Decades

Terminology: Ship Classes (Present and Future)

The UNOLS Fleet is currently divided into five classes (UNOLS Fleet Improvement Committee, 2000) based roughly on vessel length. UNOLS Class I and II ships (70-85 m or 230-280 ft) are usually considered together and referred to as the Global Class vessels. UNOLS Class III ships (51-62 m or 168-204 ft) are normally called Intermediate Class vessels. UNOLS Class IV, Regional Class ships, are 32-41 m or 105-135 ft; Class V, Local Class ships, include all vessels below 30 m or 100 ft.

The Plan focuses primarily on vessels larger than 40 m (130 ft), many of which are federally built and owned. This includes the larger of the existing UNOLS Regional Class vessels (the Cape Class vessels). The smaller UNOLS regional and local ships are also an important part of the national academic research fleet, although most of them were acquired with non-federal funds. This will probably hold true for the future.

The Plan advocates establishing four general categories of vessels for the future. As in the recent past, the largest are called Global Class vessels—those vessels over approximately 70 m (230 ft). A new term, Ocean Class, is introduced to describe ships in the length range of 55-70 m (180-230 ft). The term Regional Class is retained, but used only to refer to vessels in the 40-55 m (130-180 ft) range. Vessels less than 40 m (130 ft) long would be considered Local Class. Appendix A lists current vessels in the national academic research fleet.

Figure 12. High-resolutions studies of Earth's past climate rely on long, undisturbed records from ocean sediments. Oregon State University's long coring facility, here being deployed from the R/V *Melville*, can provide researchers with cores up to 20 m long, appropriate for studies of ice-age climate change over the last few hundred thousand years. Site selection was made based on seismic and swath bathymetric mapping just prior to coring. Photo courtesy of A. Mix, Oregon State University and M. Lyle, Boise State University.

Global Class

Global Class vessels are highly capable, able to work worldwide in ice-free waters with endurance of 50+ days, and able to carry more than 30 scientists and technicians. They have extensive deck space and equipment, as well as a broad and diverse complement of laboratory space and outfitting. They are equipped to handle a wide array of instruments, and to deploy suites of moorings, autonomous vehicles, large complex sampling tools, and sophisticated acoustical equipment. Some vessels within this class support specialized services such as operating deep-submergence vehicles or multichannel seismic equipment. The global range of this vessel class makes the home port location less important to their mission when compared to other vessel classes.

Ocean Class

This is a new class of vessel proposed by the Plan. Designed to support integrated, interdisciplinary research, Ocean Class ships will be ocean-going, with many of the capabilities of modern Global Class vessels, though not globally ranging. They will be somewhat smaller and more efficient to operate than the Global Class vessels. However, they will substantially expand the existing capabilities provided by most of the older, Intermediate Class UNOLS ships. They will be able to carry more scientists, will have increased laboratory and deck space and improved equipment handling, and will be able to operate sophisticated instrumentation such as ROVs and AUVs. Some may be configured to accommodate ice-margin research, fisheries-related oceanography, or other specialized missions.

Regional Class

Regional Class ships are the smallest vessels for which federal funding is anticipated to be the primary source for construction. There is a projected need for vessels with greater capability than the existing Cape Class vessels to address the science of the inner shelf and coastal environments around the United States. The science mission of these ships is coastal oceanography in the broadest sense. Though range, science complement, and outfitting will be less than that for the larger vessel classes, the new ships in this class should have the ability to carry approximately 20 scientists for up to a month, and to provide suitable laboratory space and instrumentation to allow significant multidisciplinary programs. Their design and outfitting will emphasize the scientific priorities of the shallower, coastal regimes in which they will operate. It is likely they will have the capability to deploy, supervise, and recover autonomous systems.

Local Class

Local Class ships will continue to be an important component of the fleet. The numbers and sizes of these vessels will be determined mainly by the operating institutions and regional collaborators. The primary source of funding for the replacement and new construction of vessels in this class will continue to be from sources such as state funds, private donations, and academic institutions. SMRs and vessel design will be largely driven by local and regional requirements, but should include input from the scientific community through UNOLS and consultation with federal agencies to foster interoperability across the fleet.

Table 2 summarizes the broad concept of the four ship classes. Specifics for each ship may vary, especially in the Regional and Local class vessels. New types of ship designs such as the Small Waterplane Area Twin Hull (SWATH) may provide for vessels that are shorter in length but have capabilities equal to a larger class.

Table 2. General characteristics of new vessel classifications.

Ship Performance	Global Class	Ocean Class	Regional Class	Local Class
Endurance	50 days	40 days	30 days	20 days
Range	25,000 km	20,000 km	15,000 km	10,000 km
Length	70-90 m	55-70 m	40-55 m	< 40 m
Science berths	30-35	20-25	15-20	15 or less

Current Fleet Status and Future Needs

Three of the six Global Class ships are among the youngest in the current UNOLS Fleet, having been built in the past decade, and a fourth is at its mid-life. The other two are over 30 years old, but were substantially upgraded in 1989 and 1991, and will be nearing retirement by the middle of the next decade. The Intermediate and larger Regional Class vessels were mostly built in the 1970s and early 1980s, and although these have undergone major refits, most will be approaching the end of their useful lives by the end of this decade. None of the Intermediate Class vessels is younger than 15 years old, and five of the seven are well over 20 years. The three larger (>40 m) Regional Class vessels (R/Vs *Cape Hatteras*, *Point Sur,* and *Alpha Helix*) are 20, 20, and 35 years old, respectively. Many of the Local Class vessels are also nearing retirement and the institutions operating these vessels are preparing plans for upgrades or replacement vessels.

Global Class

The Plan calls for at least four Global Class vessels to be available beyond 2020, recognizing that some cruises will be accomplished on Ocean Class ships. As noted above, two of the Global Class ships (R/Vs *Knorr*, *Melville*) are over 30 years old, but having been extensively upgraded and enlarged a decade ago are considered by the operating institutions and the "Academic Research Fleet" report (Fleet Review Committee, 1999) to be serviceable through the middle of the next decade. By that time, some requirements that are currently being met by these two vessels will shift to the new Ocean Class ships as they come on line beginning in 2002. Consequently, the baseline renewal plan makes no specific recommendation regarding replacing them at this time, although the UNOLS Council (UNOLS, 2001) emphasized a potential strong scientific justification for two additional Ocean or Global Class ships in the next decade. The Plan recognizes an inherent uncertainty and thus retains flexibility to evaluate the needs for either specialized or general-purpose Global vessels over the next five to ten years.

Figure 13. R/V *Ewing* shooting multichannel seismic profiles in the Gulf of Corinth. Photo courtesy of Lamont-Doherty Earth Observatory.

Three of the remaining Global Class ships (R/Vs *Thompson*, *Atlantis*, *Revelle*) are sufficiently new that they have 20 or more years of productive service. The R/V *Atlantis* supports specialized deep-submergence science missions and is not extensively used for general-purpose oceanographic projects.

The sixth of the current Global Class ships, R/V *Ewing*, is anticipated to be retired sometime after 2010 (Figure 13). The R/V *Ewing,* which supports specialized multichannel seismic reflection surveys, can be operated until about 2018, but may require replacement earlier in that decade for technological and scientific reasons.

Ocean Class

Ocean Class vessels are viewed as a key element of the future national academic research fleet. Currently all of the Intermediate Class vessels are at least 15 years old, and five of the seven will have exceeded 30 years of service prior to the end of this decade. As these older vessels leave the fleet, federal agencies anticipate building at least six new Ocean Class vessels that are more capable, generally larger, and more technologically sophisticated. Their development, already begun with the construction of the R/V *Kilo Moana* (AGOR 26), is expected to encompass some capabilities of both the Intermediate and Global Class vessels that will retire over the next couple decades (Figure 14).

While the capabilities of the SWATH vessel R/V *Kilo Moana* may alter future ship design criteria and allow for better heavy-weather performance in a smaller vessel, missions requiring heavy lifting or mooring deployments may not be well supported by a SWATH. Regardless, the R/V *Kilo Moana* provides an excellent opportunity to evaluate these capabilities early in the planning process for the next generation of vessels in this class.

After delivery of this ship, the next Ocean Class vessel that will be required to meet existing science needs will be for operation in the North Pacific, Alaska coast, and the marginal ice zones of the Bering and Chukchi Seas. Although the U.S. Coast Guard Cutter (USCGC) *Healy* addresses scientific needs in the ice-covered Arctic with its heavy ice-breaking capability, the increasing research needs along the ice margin exceed the capabilities of the single, aging Regional Class R/V *Alpha Helix* stationed in Alaska. This places heavy costs in time and transit on other ships to come from ports further south. To meet these needs, design efforts are already underway for an Alaska-area research vessel that provides an ice-strengthened platform suitably quiet for fisheries bio-acoustic research, and large enough to work in open waters through the severe winter weather common to the region. Designs for such a vessel were first completed in 1980 (when a 220-ft ice-strengthened ship was called for) and again in 1994 (when a much larger 330-ft substantially ice-capable vessel was proposed). Neither vessel was built, though FOFC and the academic community believe it is now the highest immediate priority.

Figure 14. The SWATH ship, R/V *Kilo Moana*, under construction. This new Ocean Class vessel will join the academic research fleet in 2002. Photo courtesy of R. Hinton.

Looking beyond the AGOR 26 and Alaska regional needs, the Plan anticipates the need for at least four additional Ocean Class ships over about ten years to fill the research capacity that will be lost by the retirement of the remaining Intermediate Class vessels. As noted above, science community input (UNOLS, 2001) suggests a need for up to two additional Ocean or Global Class vessels (one each Atlantic and Pacific), to meet the anticipated needs for observatory science, multi-ship operations, peak sampling periods, and rapid responses.

With the early opportunity to evaluate the SWATH version of an Ocean Class vessel, and progress on the new Alaska Region Research Vessel (ARRV) design, the development of concept designs for the future Ocean Class vessels are well underway. Because a central element of the Plan is frequent review and update, changing patterns of funding and science will necessitate that distribution of the Ocean Class vessels be examined to determine whether more than the minimum of six will be required.

Regional Class

Only three of the existing Regional Class vessels fit in the new definition of this class. One of these (R/V *Alpha Helix*) is expected to be retired when an Ocean Class vessel is available to undertake the work in the Alaska region. There is, however, a projected need for a new Regional Class vessel for the Gulf of Mexico, where three aging vessels (one Intermediate and two small Regional/Local vessels) combine to handle about two full operating years of work annually. Although one new, capable Regional Class vessel could potentially handle most of the current Gulf of Mexico federal agency requirements, there are also larger and smaller ships in the area available for deployment to the Gulf of Mexico if needed. This coastal research ship would be the first of the new Regional Class vessels to be built, and it may serve as a design standard for two or more additional vessels needed over the subsequent decade, with at least one each on the east and west coasts of the United States.

Depending on the number and capabilities of Local Class vessels developed during the next decade, it may be necessary to increase the number and modify the distribution of Regional Class vessels. Many of the new Local Class vessels will have capabilities comparable to the smaller regional vessels. The concept designs developed for the first few regional vessels will be used as a basis for developing concept designs specific to the various regional requirements and can be used to build additional Regional or Local Class vessels as needed.

Local Class

Many of the Local Class vessels are at or near retirement age while several others are recent additions to the fleet. R/V *Calanus* has already been retired and has been replaced with the catamaran R/V *Smith*. The R/V *Blue Fin* was retired in 2001 when the R/V *Savannah* was delivered for operation. The R/V *Link* (formerly the *Sea Diver*) will go out of service in 2002 without being replaced. By the middle of this decade, the R/Vs *Barnes* and *Cape Henlopen* will be at retirement age. The University of Michigan ceased to operate the R/V *Laurentian* in 2001.

The University of Delaware has begun planning for the replacement of the R/V *Cape Henlopen*. Their process is an excellent model for developing SMRs and concept designs that meet the needs of a broader scientific community.

By the middle of the next decade the remaining six Local Class vessels will be ready for retirement. Many of these replacement vessels, including those on the Great Lakes, may approach the size and capabilities of the smaller Regional Class vessels and fill the regional needs anticipated for supporting observatories, event response, and coastal-process studies. The R/Vs *Laurentian* and *Blue Heron* are stationed in the Great Lakes and their replacement should be considered as part of a strategic evaluation of needs in the area mentioned in the section on the Great Lakes below.

Funding for vessel design and construction in this class will come from a variety of sources, and the needs of all these interests, including the federal agencies, should be considered.

Figure 15. R/V *Cape Hatteras* is one of three existing vessels that fit the new definition of Regional Class. This ship, built in 1981, has an expected retirement date of 2011.

Other Vessels

- **Global Vessels:** There are seven other vessels, all of which would be classified as Global Class or larger, which contribute to academic ocean sciences research in the United States, but are not part of the UNOLS fleet. All of these vessels have specialized missions.

USCGCs *Polar Star* and *Polar Sea* are multi-mission icebreakers that support science missions in the Arctic and Antarctic and provide logistical support for the Antarctic Operation Deep Freeze. USCGC *Healy* is a new icebreaker operated by the U.S. Coast Guard (USCG) with the special mission of supporting basic research in the Arctic Ocean. The Arctic Icebreaker science mission is largely planned and supported by NSF's Arctic Sciences Section of the Office of Polar Programs (OPP) and is scheduled in coordination with the USCG and other funding agencies with assistance from UNOLS. USCGC *Healy* is expected to be used primarily in ice-covered regions of the Arctic, areas that are inaccessible to the UNOLS fleet. In addition to this ship, two chartered vessels are subcontracted by OPP in support of research by the U.S. Antarctic Research Program: R/Vs *Palmer* and *Gould*. These ships have ice-breaking capabilities, and serve as primary platforms for supporting U.S. science in Antarctic regions. R/Vs *Palmer* and *Gould* are not operated as part of the UNOLS fleet, but close communication is maintained between OPP's contractor for vessel support and UNOLS where needed, especially in the areas of operations and technicians.

Another vessel operating outside the UNOLS framework, but used heavily to support NSF-funded ocean science, is D/V *JOIDES Resolution*, a chartered drilling vessel that supports the international Ocean Drilling Program (ODP) led by NSF's Division of Ocean Sciences. This unique scientific ocean drilling platform is contracted from the oil industry by Texas A&M University (TAMU). TAMU holds a contract for ship operations from Joint Oceanographic Institutions, Inc. (JOI), the ODP prime contractor. ODP ends in 2003, and NSF plans to seek the resources to provide capitalization costs for one of the new primary drilling vessels for ODP's successor, the Integrated Ocean Drilling Program. The new drilling vessel should be ready for international program operations in 2005.

Finally, the Global Class ship, R/V *Brown*, is operated for oceanographic and atmospheric research by NOAA. Although scheduled with UNOLS and used collaboratively by university scientists, most R/V *Brown* programs are in support of NOAA scientists, and is not considered here in the context of the national academic research fleet.

Figure 16. The remotely operated vehicle, *Jason*, is being deployed. The fiber-optic cable permits the shipboard pilot to navigate *Jason*, and also to transmit data back from the seafloor in real time for analysis. Photo courtesy of Woods Hole Oceanographic Institution.

- **Fisheries Vessels:** NOAA's current specialized fleet of fisheries vessels is near the end of its useful service life. At this time, four Fisheries Research Vessels (FRVs) have been authorized and a contract for the lead ship was awarded in FY2001. Design features of the ships include: quieting to meet the International Council for the Exploration of the Sea (ICES) noise standards for research vessels; hydro-acoustic sensors mounted on a retractable center board; multi-gear (e.g., trawl, longline, oceanographic) capabilities; and speed, power, and endurance to permit acoustic and trawl surveys at the shelf edge. In addition, NOAA will collaborate with UNOLS to develop a means of meeting a growing proportion of its oceanographic ship needs with UNOLS ship support.

- **Great Lakes Vessels:** The requirements of the Great Lakes were considered, but are not specifically addressed in the Plan. It seems increasingly desirable that a modern Regional Class ship replace the current small- and medium-sized research vessels in the area (both UNOLS and non-UNOLS vessels). It is recommended that the agencies and scientists most involved in Great Lakes research address the specific issues and logistics of Great Lakes science to define mission requirements prior to planning a vessel design for the region. It is not clear whether having one substantially more capable vessel is a primary need or whether a distributed fleet of smaller vessels will better satisfy the research requirements.

7. Specific Recommendations

for Fleet Retirement and Renewal

The proposed schedule for new construction is shown in Figure 17. The schedule calls for 10 new ships, based on the science needs described in previous sections. The great potential for new research, requiring capable ships over the next several decades as highlighted by UNOLS and the wider academic research community (UNOLS, 2001), is also recognized and accommodated. If federal ocean agency budgets increase significantly, demands for greater capacity and hence new ships might increase the requirement for new ships up to 13 by 2020 (an additional Ocean or Global Class ship in the Atlantic and Pacific and a fourth Regional Class vessel.)

Figure 17.

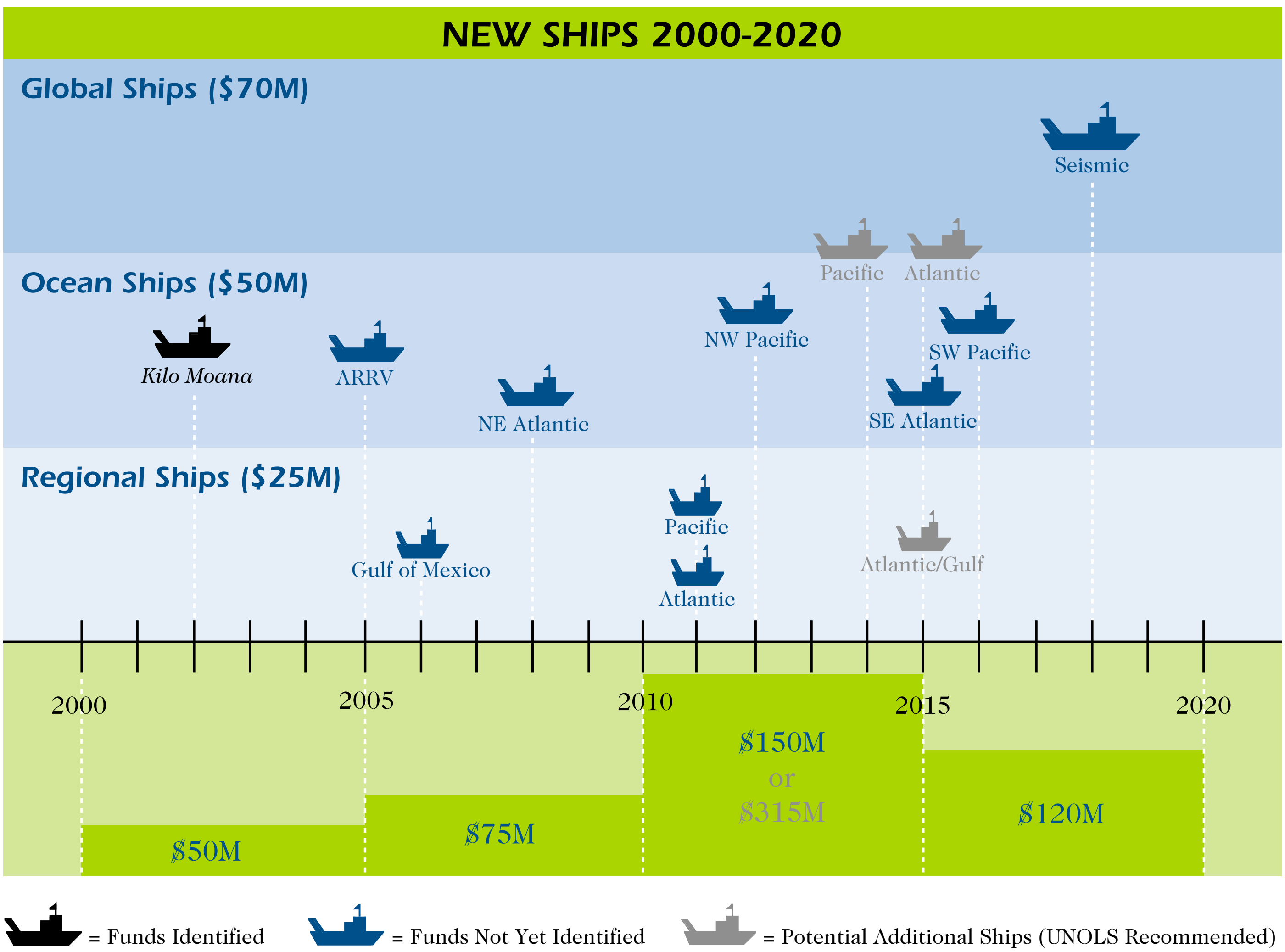
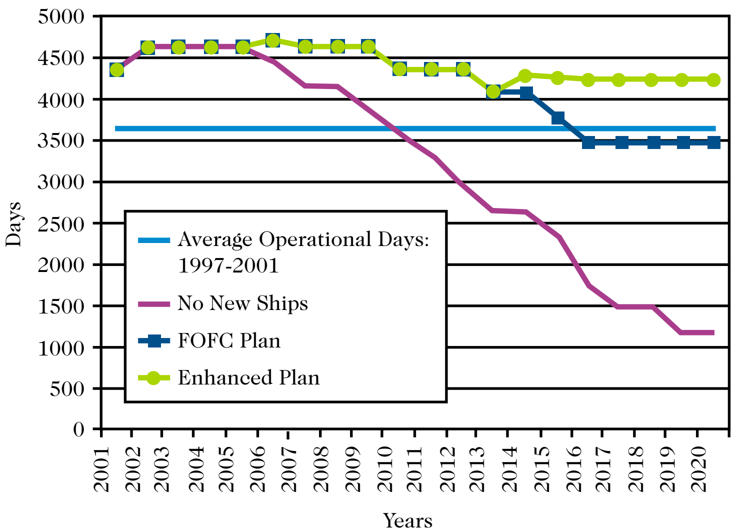


Figure 18. Ship Capacity (Ship Days)



The combination of new ships will maintain capacity, at approximately current use levels for at least the next 20 years. Figure 18 illustrates future ship capacity, expressed as ship operation days. The flat blue line projects the number of ship operation days needed based on the most recent five year average. The purple line, "No New Ships," represents the progressive reduction of available ship operation days as older ships in the fleet are retired over the next 20 years, assuming no new ships are built after R/V *Kilo Moana* (UNOLS Fleet Improvement Committee, 2000). The blue line, "FOFC Plan," projects available ship days assuming additions to the fleet proceed as scheduled in Figure 17. The green line beyond 2013, "Enhanced Plan," shows available days based on an expanded fleet, as recommended by UNOLS.

Year-to-year variability in ship-time can be handled by short-term increases in a ship's annual operating days or temporary lay-ups. Longer-term trends can be modulated by delaying or advancing retirement dates or construction dates. These adjustments will provide flexibility to maintain a fleet adequate to meet core demands, and capacity to permit scheduling flexibility, peak demand, and event-response capability. More capable Local Class vessels will contribute to this scheduling flexibility.

The following section describes a framework for retirements and construction of new vessels, shown in five-year increments (which is about the length of time required to design and construct a vessel if there are no delays between completion of designs and funds appropriated for construction). It should be noted that wherever terms relating to ocean regions are used below, they are relative to the U.S. coast (e.g., "southwest Pacific" refers to the Pacific Ocean region adjacent to the U.S. southwest coast).

2001-2005

Renewal: R/V *Kilo Moana* (AGOR 26), an Ocean Class vessel, will join the fleet by 2002. This vessel will provide service to the Pacific in the ice-free latitudes from its base in Hawaii. The vessel construction is being funded by the U.S. Navy.

Design studies funded by NSF are currently in progress for an Ocean Class vessel for the Alaska region (ARRV). This vessel's ice-strengthened hull would allow for high-latitude operations in seasonal ice conditions. Funding for the construction of this ship must be identified and construction started as soon as possible. Also, towards the end of this period, design studies for eventual construction of a Regional Class vessel to support science in the Gulf of Mexico would be initiated.

Retirement: The R/Vs *Alpha Helix* and *Gyre* will be retired as new vessels are constructed to operate in these regions by the end of this period or very soon after.

To move forward with the eventual design and appropriation of future Ocean Class vessels, a process of updating SMRs and completing concept designs will begin during this five-year period. This process will include a careful review of the actual operating experience of the AGOR 26 SWATH (R/V *Kilo Moana*), and also take into account lessons learned from the design of the ARRV and broad scientific community input.

2006-2010

Renewal: Using the concept designs and experience with the first two Ocean Class vessels, detailed design and construction phases would begin for at least two Ocean Class vessels for operation in the Northeast Atlantic and Northwest Pacific regions. Delivery of these vessels can be staggered and stretched into the early part of the next decade based on funding considerations and scientific demand.

Retirement: During this five-year period, two or three of the Intermediate Class ships, R/Vs *Oceanus*, *Endeavor*, and *Wecoma* can be retired based on their age, progress of the renewal plan, and scientific demand generated from funded proposals.

If not already started, SMRs and concept designs should be initiated for additional Regional Class vessels and for an eventual Global Class, seismic-capable vessel. Preliminary designs and appropriations for construction of the next two Regional Class vessels should be initiated by the end of the period.

SMRs and concept designs for general-purpose Global Class vessels should also be reviewed and updated. Close evaluation of any new operating Oceans Class vessels will take place as part of the process of updating Global and Ocean Class vessel designs and for making decisions regarding replacement of retiring Global Class vessels.

2011-2015

Renewal: Construction of new vessels during this period are projected to include a Global Class seismic survey vessel, two Ocean Class vessels to support the Southwest Pacific and Southeast Atlantic, and two Regional Class vessels, one for the Atlantic and one for the Pacific.

Retirement: During this period two or three Intermediate Class ships, including the R/Vs *Johnson*, *Johnson II* (ex *Link*), and any not-yet-retired Oceanus Class vessels, will be retired. Two Global Class ships, R/Vs *Knorr* and *Melville,* and two Regional Class ships, R/Vs *Cape Hatteras* and *Point Sur,* will begin the retirement process during this period. The Intermediate Class vessel, R/V *New Horizon*, and the Global Class vessel, R/V *Ewing*, will also start the retirement process. If those two ships have not been retired during this period, retirement will be completed early in the next period.

Figure 19. A CTD (Conductivity, Temperature, Depth) instrument being deployed from the R/V *Oceanus* in the Irminger Sea (east of Greenland) to study the circulation and convection there. During the cruise, scientists did a basin-wide CTD survey of the sea, and deployed two "profiling CTD moorings." Photo by C. A. Linder, Woods Hole Oceanographic Institution.

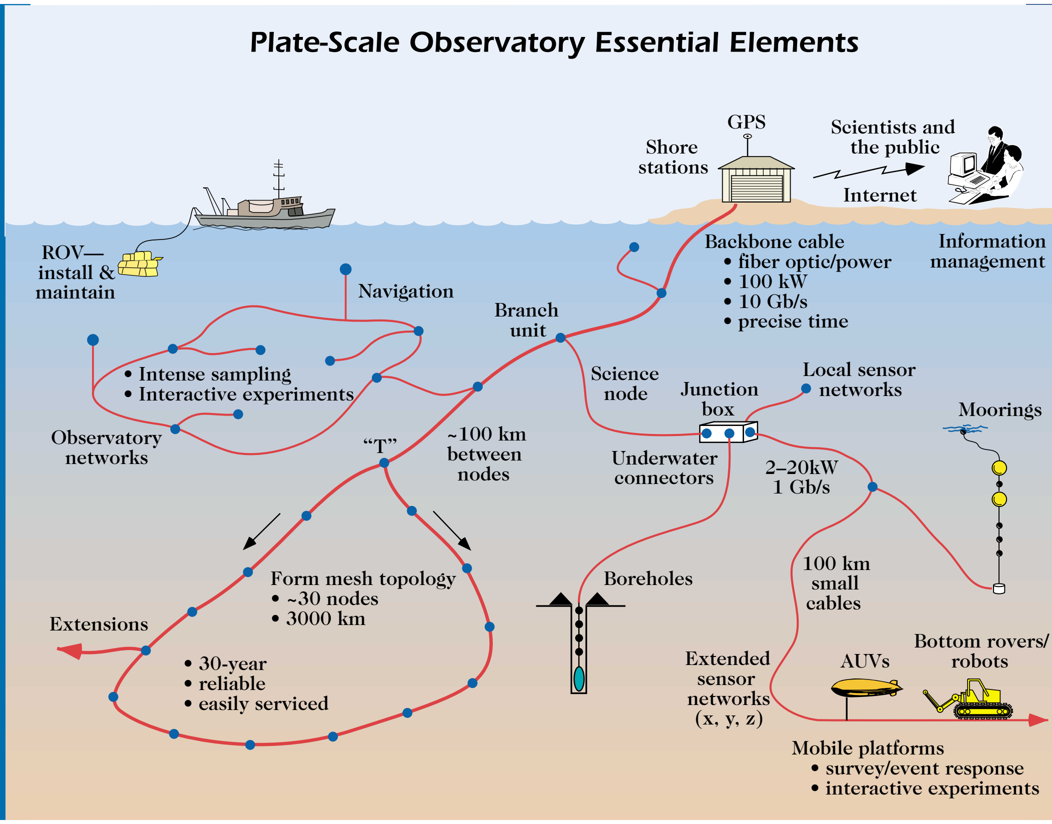


Figure 20. Essential elements of a seafloor observatory. Research vessels will be required to deploy and maintain instruments. Figure courtesy of the NEPTUNE project.

A determination will be made as early as possible during this period as to whether or not to proceed with detailed design and construction of any additional Global, Ocean, or Regional Class vessels. Retirements of existing vessels can be phased in and stretched out during this five-year period or early into the next period depending on funding levels, scientific demand and availability of replacement vessels.

2016-2020

From the present vantage point, if appropriations, planning efforts, and construction are completed aggressively according to this Plan, there will not be any retirements or new vessels needed during this period. Changing circumstances, however, incorporated into subsequent reviews and updates of the Plan may modify this view.

During this period, if not already started, preliminary design and appropriations planning for the next generation of Global Class vessels will be started for the eventual replacement of the AGOR-23 class vessels.

8. The Cost of Fleet Renewal

Large oceanographic research ships have been acquired with federal, state, and private funds in the past through three principal means—new construction, conversion or modification, and leasing. Most of the current vessels in the fleet over 40 m were built as a result of appropriated funds to federal agencies. The modification or conversion of naval non-oceanographic ships was important in the early development of the fleet. The R/V *Ewing* was converted from a relatively new oil-industry vessel in the 1980s. Commercial vessels have been leased on a long-term basis (see section regarding Antarctic and ocean drilling vessels). None of the UNOLS vessels are leased, although short-term leasing for federally funded academic research has been used where specialized facilities have been needed.

As a result of impending retirements, identifying funds for the construction of new ships is an issue that must be addressed now to meet fleet needs for the next two decades. This position was put forth strongly by the UNOLS Fleet Improvement Committee in an article in *EOS* (UNOLS Fleet Improvement Committee, 2000), the weekly American Geophysical Union newsletter. In addition to new ships, it will be important to identify incremental funds for the costly new shared-use instrumentation required to meet ocean sciences needs, as well as the training and support for personnel to maintain and operate these increasingly complex systems.

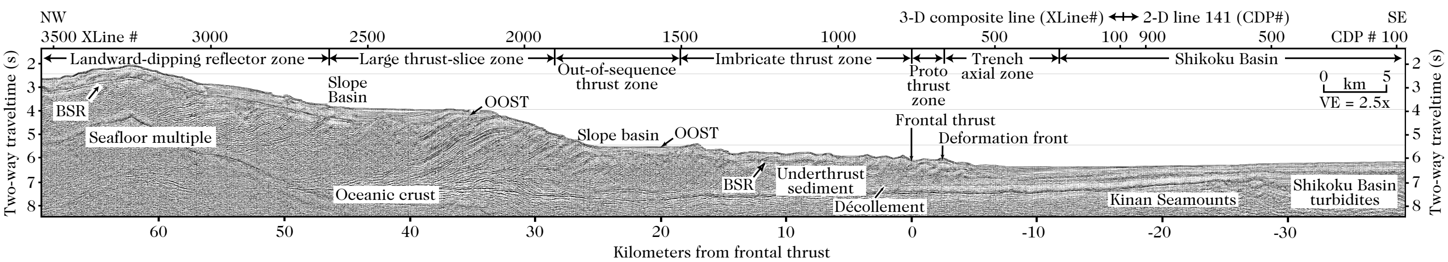


Figure 21. The Seismogenic Zone initiative of the MARGINS program is a multidisciplinary study of physical processes in the zone of earthquake generation. Acquisition of three-dimensional seismic profiles, such as this one collected off of Japan by the R/V *Maurice Ewing*, is one of the initial steps in characterizing an earthquake-generating region below the seafloor. These profiles were used to select sites for future drilling and long-term observatory emplacement by the Ocean Drilling Program's ship, *JOIDES Resolution*. (A long refraction transect from the trench to Shikoku Island was collected along this transect by scientists from JAMSTEC using 100 ocean bottom seismographs.) OOST is an out of sequence thrust fault, thought to possibly generate tsunamis. BSR is a bottom-simulating reflector; CDP is a common depth point. Figure courtesy of G. Moore, University of Hawaii, and N. Bangs and T. Shipley, University of Texas.

Table 3. Ship Distribution and Cost Estimates

Ship Class (Est. Cost/Vessel)	Number of Vessels	Cost Estimates
Global ($70M)	1	$70M
Ocean ($50M)	6	$300M
Regional ($25M)	3	$75M
Total Over Next 20 Years	**10**	**$445M**

Accurately estimating the construction costs of a new ship requires a series of steps, beginning with establishing its SMRs. Next, development of a preliminary or conceptual design permits the examination of trade-offs and a consensus on optimal physical characteristics of the ship. This leads to the detailed engineering design phase, complete with model testing, from which a contract bid can be drawn up. The actual cost of construction will be determined only at the point of acceptance of the successful bidder (assuming no design modifications during construction). The contract price will be heavily influenced by workload of the ship-building industry at the time, and whether there is any likelihood that more than one ship of the same basic design will be required.

The cost of an Ocean Class vessel today is indicated by the estimated $55M construction cost of R/V *Kilo Moana* (currently being built). On the basis of a concept design, The Glosten Associates (2001) estimated the cost of an Alaska Region Research Vessel at $57M. Both vessels, SWATH and ice-strengthened designs, are likely to be more expensive than a mono-hull ship built for general oceanography.

In an effort to estimate the total cost of fleet renewal, UNOLS assigned an approximate cost to a new Global, Ocean, and Regional ship as $70M, $50M, and $25M respectively, in today's dollars. Table 3 shows the approximate total cost of $445M for the 10 new ships (including the *Kilo Moana*) called for in the Plan. If the fleet were expanded under favorable budget conditions, it would increase to a total capital estimate of up to $610M, depending on the number and mix of additional ships. Over 20 years, it would be prudent to expect significantly increased expenditures beyond those quoted above, taking account of inflation, increased technological sophistication, and specialized missions.

9. Continuous Planning for Improvements and Technology Upgrades

This Plan provides guidelines for ship renewal and for improving the existing mechanisms used for upgrading and replacing the shared-use scientific instrumentation and shipboard equipment that is available on these platforms. The Plan recognizes that there is a constant need to plan for fleet improvement to maintain a state-of-the-art scientific research capability on UNOLS vessels.

Major upgrades to ship structure, outfitting, and machinery are important to keeping research vessels in operation for thirty or more years and may allow the extension of service life, adding flexibility to the process of orderly replacement. This process can and does take place on both a periodic basis and as major mid-life overhauls. Taking advantage of periods of low demand and careful scheduling of upgrade periods helps to ensure that fleet capacity is not adversely affected. These upgrade periods can be used for the introduction of new technologies in machinery and equipment. The same approach can and will be applied to the science equipment infrastructure.

Many science systems require replacement because they are technologically obsolete. The continually and rapidly evolving nature of technology is critically important in the areas of computing and communications technology, although by no means restricted to those fields. Other examples of areas that will be affected by the changing focus of research-vessel support for science include improved over-the-side handling systems, winch and wire technology, and continuous, underway sampling systems. The challenge to operators and federal agencies is to maintain first-class technology on the research ships in a time of rapid advances and constrained budgets.

As of FY 2001, the aggregate support for new instrumentation and equipment provided by NSF and ONR, exclusive of that provided with new construction, is roughly $5-8M annually. Much of this support, however, comes to UNOLS vessels via proposals to infrastructure programs that are not

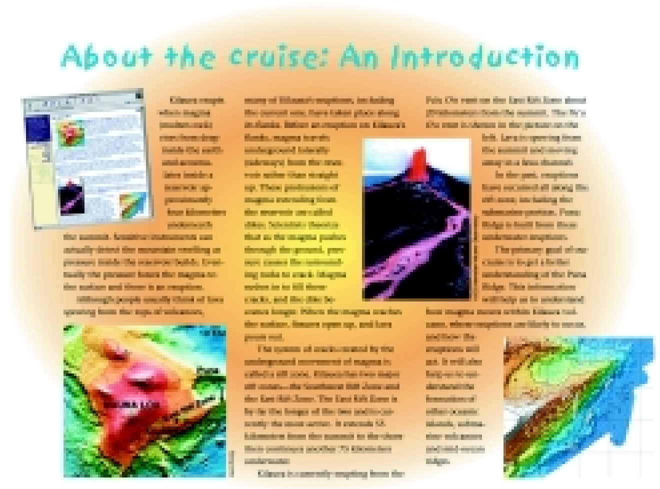
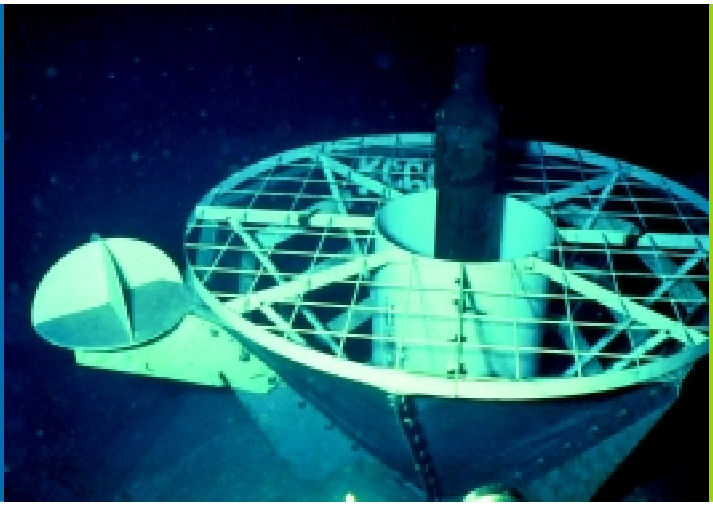


Figure 22. Research ships are now not only platforms for doing science. On many expeditions ships have been vehicles to teach science. Using satellite links, researchers on board ship update educational web pages daily and answer students' questions. Figure courtesy of Deborah Smith, Woods Hole Oceanographic Institution.

focused on ships, such as ONR's Defense University Research Instrumentation Program (DURIP) and NSF's Major Research Instrumentation (MRI) program. Although important to fleet evolution, the reliance on these broad-based programs for a substantial percentage of fleet equipment renewal significantly limits forward planning and common system availability across the fleet.

The Plan recommends the major agencies involved in supporting UNOLS ship use coordinate their consideration of infrastructure proposals. Annual evaluations of the quality of shipboard instrumentation and services, in consultation with the user community, should be used to help set priorities for shared-use instrumentation acquisition recommendations to the operators. Demands for increasing funding for shipboard technology will continue as the pace of technology evolution increases.

Figure 23. Photo of a "CORK," a type of long-term seafloor observatory. The CORK keeps ocean water from flowing into the hole, and its data loggers record *in situ* borehole conditions such as temperature and pressure. While CORKs are initially installed by the Ocean Drilling Program drillship, *JOIDES Resolution*, information from the data loggers is retrieved, and the observatory maintained, using ROVs or submersibles deployed from research vessels.



10. Concept Designs

and Science Mission Requirements

Science missions will evolve and ship and facility designs must evolve to accommodate them. Towards that end, developing complete SMRs and a range of well-thought-out concept designs will improve the ability to plan future research vessels and their science infrastructure. The process must begin as early as possible, seeking community input through UNOLS, ship operations committees, ship design committees, and other forums.

The concept design allows the naval architects, users, and operators to better define the scientific missions, ship features, and capabilities. It also provides an initial estimate on ship construction and operations costs. An acquisition approach that relies on concept designs for the various classes of research vessels with consideration for regional and mission variability will enhance the ability of the federal agencies to plan capital fund needs and make decisions regarding future fleet plan revisions.

The Plan also represents an opportunity to investigate new technologies for improving ship capabilities and life-cycle management. Consideration of novel technologies for prototype demonstrations could be beneficial both to the ship and the federal agency sponsoring the design. Technologies such as novel electric motors, power electronic controls, fuel cells, conditioned-based maintenance, and advanced coatings are examples of areas that should be considered in future designs. If a technology is considered to be feasible for an oceanographic research vessel, then a selected new ship would be equipped with the specific technology, undergo a test period of up to one year, and be restored, if necessary, for oceanographic research before entering the UNOLS schedule. Technology demonstration support would be provided separately from construction and restoration costs.

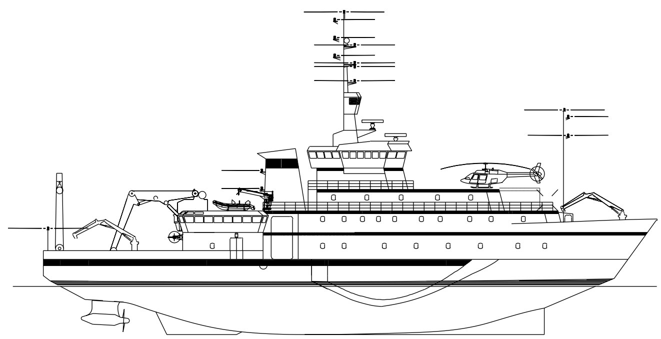


Figure 24. In 2001, NSF funded a preliminary design study for an Alaska Region Research Vessel (ARRV). Shown above is the preliminary concept design illustrating the ARRV's 226-foot outboard profile. Figure courtesy of The Glosten Associates.

11. Conclusion and Continuation

Developing a realistic long-range plan for the facilities required to support future ocean sciences research is difficult, but necessary. The Plan provides a framework for goals and milestones to be met, permitting the national academic research fleet to keep up with changing demands. The Plan is a living document that will serve as the frame of reference for future decisions. Recommendations in the Plan require decisions that involve substantial sums of money and long lead times. Planning, evaluating, and developing concept designs are all relatively inexpensive in comparison to actual construction of new facilities. These actions must be initiated as early as possible to ensure the success of the renewal of the national academic research fleet. For these reasons, and because it is vitally important to our nation's ability to maintain a viable research, exploration, and education program in the ocean sciences, progress on the Plan will be formally updated by FOFC at least every five years and reported to the NORLC annually.

Surface ships represent the core "facility" for oceanographers, and are historically the longest serving facility. Increasingly, other facilities are added to the oceanographer's toolbox for use in conjunction with the national academic research fleet. Incorporating these other facilities into the planning process is an important next task to expand our knowledge and understanding of the ocean and seafloor environments of our home, the Blue Planet.

Figure 25. Here, Oregon State University's multicore system, deployed from the R/V *Melville*, is recovered full of mud. This device lands gently on the seafloor, then penetrates about 50 cm before closing trap doors to safely recover multiple pristine samples of the sediment-water interface. Recovery often reveals living tube worms or shrimp—somewhat startled but essentially undisturbed. Such sampling devices offer an unique glimpse of life at the seafloor and the chemical transformations that occur as newly fallen biogenic debris is converted into the sedimentary record. Photo courtesy of A. Mix, Oregon State University and M. Lyle, Boise State University.

Appendix A

Current Vessels in the National Academic Research Fleet

	Year Built/ Refit	LOA m/f	Projected Retirement*
Vessels > 40 m			
Alpha Helix	1966	41/133	2005
Gyre	1973	55/182	2006
Endeavor	1976	56/184	2008
Oceanus	1976	54/177	2009
Wecoma	1976	56/185	2010
Point Sur	1981	41/135	2011
Cape Hatteras	1981	41/135	2011
Seward Johnson II (ex *Edwin Link*)	1982	51/161	2012
Melville	1969/1991	85/279	2014
Knorr	1970/1989	85/279	2015
Seward Johnson	1985	63/204	2015
New Horizon	1978	52/170	2016
Maurice Ewing	1983/1990	73/239	2018
Thomas G. Thompson	1991	84/274	2021
Roger Revelle	1996	84/274	2026
Atlantis	1997	84/274	2027
Kilo Moana	2002	57/186	2032
Vessels < 40 m			
Edwin Link (ex *Sea Diver*)	1959	34/113	2002
Clifford Barnes	1966	20/66	2005
Cape Henlopen	1976	37/120	2005
Longhorn	1971	32/105	2011
Weatherbird II	1981	35/115	2013
Pelican	1985	32/105	2013
Robert Gordon Sproul	1981	38/125	2015
Blue Heron	1985	26/86	2015
Urraca	1986	30/96	2016
Walton Smith	2000	30/96	2031
Savannah	2001	28/91	2032

Acronyms

ABS .... American Bureau of Shipping

AGOR .... Auxiliary General Oceanographic Research

AGU .... American Geophysical Union

AUV .... Autonomous Underwater Vehicle

ARRV .... Alaska Region Research Vessel

DURIP .... Defense University Research Instrumentation Program

D/V .... Drilling Vessel

EEZ .... Exclusive Economic Zone

EOS .... American Geophysical Union's weekly newspaper

FIC .... Fleet Improvement Committee (UNOLS)

FOFC .... Federal Oceanographic Facilities Committee

FOFCC .... Federal Oceanographic Fleet Coordination Council

FOY .... Full Operating Year

FRVs .... Fisheries Research Vessels

ICES .... International Council for the Exploration of the Seas

IODP .... Integrated Ocean Drilling Program

JAMSTEC ... Japanese Marine Science and Technology Center

JGOFS .... Joint Global Ocean Flux Study

JOI .... Joint Oceanographic Institution, Inc.

LEO-15 .... Long-Term Ecological Observatory at 15 meters

MRI .... Major Research Instrumentation

NAS .... National Academy of Sciences

NOPP .... National Oceanographic Partnership Program

NOAA .... National Oceanic and Atmospheric Administration

NORLC .... National Ocean Research Leadership Council

NSF .... National Science Foundation

ODP .... Ocean Drilling Program

ONR .... Office of Naval Research

OPP .... Office of Polar Programs

RIDGE .... Ridge Inter Disciplinary Global Experiment

ROV............ Remotely Operated Vehicle

R/V .... Research Vessel

SMRs .... Scientific Mission Requirements

SOLAS........ Safety of Life At Sea

SWATH .... Small Waterplane Area Twin Hull

TENOC .... Ten Years in Oceanography

UNOLS .... University-National Oceanographic Laboratory System

USCG .... United States Coast Guard

USCGC .... United States Coast Guard Cutter

WOCE .... World Ocean Circulation Experiment

www .... World Wide Web

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