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EXECUTIVE SUMMARY

Oceans cover nearly three-quarters of the globe, and consist of nearly 1.4 billion cubic kilometers of saltwater, or about 97 percent of the free water on Earth. This volume of water strongly influences Earth's climate by transporting heat and energy around the globe, and exchanging gases with the atmosphere. The oceans host complex food webs that cycle energy and carbon, and provide the daily sustenance for millions. They are the highways of global commerce. Ocean processes operate at a variety of scales, ranging from global patterns of ocean circulation to localized processes occurring at scales of a few kilometers or less. The ocean floor also records 200 million years of climate history in its sediment blanket, in some places in great detail. The ocean floor's mountain chains—its mid-ocean ridges—provide laboratories for studies ranging from the origin of life to the chemical evolution of our planet. Long-term seafloor observatories are providing new information related to water and heat transport, and fault slippage that may result in large earthquakes. Oceanography, the science of the seas, explores these critical processes worldwide.

The U.S. Academic Research Fleet provides essential support to enable productive basic research in oceanography. Over the past four decades, the National Science Foundation (NSF) and other federal agencies have worked with universities and academic research institutions to provide the broadest possible access to the sea for the nation's oceanographic community. The current system for managing the Academic Research Fleet gets high marks from the scientific community and the federal agencies that participate in the system, which can be summarized as follows:

- **THE FLEET.** Ships of the Academic Research Fleet are both privately and federally owned. They are all operated by academic institutions. The fleet consists of large ships for ocean-wide investigations, intermediate size ships for regional investigations, small ships for coastal and estuarine work, and platforms with special capabilities such as the submersible *Alvin*. NSF provides a majority of the support for the operation, maintenance, and upgrade of the Academic Research Fleet. The U.S. Navy and the National Oceanic and Atmospheric Administration (NOAA) are the other major users of the Academic Research Fleet.

- **OVERSIGHT.** NSF, in partnership with the Office of Naval Research (ONR), supports and manages a ship inspection program to oversee safety practices, crew training, maintenance, operational procedures, and shipboard science laboratory facilities. The federal agencies maintain oversight on scheduling and operation of the Academic Research Fleet with respect to the federal programs they sponsor. As part of this oversight, goals for optimum annual vessel usage have been established, with recognition that geographic region, maintenance cycles, and other unique circumstances are a factor in usage.

- ***COORDINATION OF ACTIVITIES.*** Ship operations are coordinated through the University-National Oceanographic Laboratory System (UNOLS), a consortium of 57 institutions, 20 of which currently operate ships. UNOLS ensures community-wide ship access, cooperative ship scheduling, standards for operations and safety, and uniform funding and cost accounting procedures, among other activities.

- ***FLEET ACCESS BY OTHER FEDERAL AGENCIES.*** Other federal agencies using vessels of the U.S. Academic Research Fleet coordinate scheduling and operator oversight through NSF and UNOLS, while policy issues at the interagency level are managed through the Federal Oceanographic Fleet Coordinating Council (FOFCC).

- ***COMPETITION.*** For ships of the Academic Research Fleet constructed and owned by the government, selection of operating institution is made via competition and review of proposals responding to a formal solicitation or request-for-proposal process. Selection of the host institution for the UNOLS Office is also made through a competitive process. Selection of scientific programs to be carried out on Academic Research Fleet ships is handled independent of the facilities through normal merit review of research proposals within NSF (or other agencies through their own standard procedures).

- ***TECHNOLOGY AND SERVICES.*** Most research vessels carry a sophisticated array of instruments tailored to a vessel's operating profile. NSF is the lead agency responsible for shipboard equipment replacement and upgrades, technical services awards and managing the operational and maintenance awards to all institutions on behalf of most research sponsors.

This report is the culmination of a comprehensive external review of the U.S. Academic Research Fleet requested by NSF's National Science Board (NSB). A Fleet Review Committee (the "Committee") formed by the Assistant Director for Geosciences and which operated under the auspices of the Advisory Committee for Geosciences, was asked to report on two principal aspects of the Academic Research Fleet. The first was to evaluate the current and future vessel requirements that are necessary to effectively support NSF-sponsored oceanographic research, and research of other federal agencies, state and local governments and private sources. The second was to

evaluate the overall structure currently in place to manage the myriad aspects of the research fleet, and to recommend any changes to the structure that would further optimize operations.

The Committee met four times between June 1998 and March 1999. It received input from NSF and ONR managers; UNOLS managers, ship operators and members; and the scientific user community. Findings were augmented by cost analysis of UNOLS vessel operations and those of other operators provided by an independent contractor (Tecolote Research, Inc.). In addition, UNOLS provided post-cruise reports where both Chief Scientists and Vessel Masters provide independent evaluations of past research cruises.

There are eight principal findings and recommendations of the Committee:

Current and Projected Research Fleet Requirements

1. The potential for near-term decrease in utilization of ocean-going research facilities is real. It may represent a transient condition, as new planning for ocean programs identifies the next cycle of field efforts. This provides an opportunity to respond to some management issues in fleet operation and to continue to improve the capability, productivity, and quality of fleet operations as a means of achieving NSF research and educational objectives in ocean sciences.

2. NSF must accelerate and expand efforts within the oceanographic research community to articulate a broadly based vision for the future of ocean science and technology requirements. This will provide a much needed foundation on which to plan and procure major facilities for research.

Management Structure and Capabilities

3. The UNOLS system should be retained. The NSF-UNOLS current practices, using institutional operators funded by NSF and other federal agencies with centralized scheduling through UNOLS, seems to provide excellent access to the sea for US investigators. To the extent the committee can assess, costs appear comparable to or better than government operators, and not evidently different from costs of contracting commercial platforms.

4. The funding agencies and UNOLS need to support fleet improvements by enhancing quality control, expanding training of personnel in technical and safety procedures, and developing even higher standards for shared use facilities.

5. NSF should continue the practice of periodically competing the management of the UNOLS office, and should consider funding it by a cooperative agreement rather than a grant to ensure necessary management oversight.

6. We ask NSF to consider a trial which includes some commercial operators participating as UNOLS non-member operators to provide unique capabilities not otherwise available.

7. There is a need for a strong, continuing program of new technology introduction; steady improvement of existing facilities and technologies; greater, continuing attention to quality control and safety; and a more systematic, standard approach to maintenance, renovation, upgrading, and replacement.

8. 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.

1. Committee Charge and Procedures

Although annual administrative, management, and financial analyses and review of institutional ship operators are routinely conducted, the National Science Board (NSB) requested a comprehensive review of the overall system for providing access to the sea via oceanographic research vessels. A review of this kind had not been conducted since the formation of the current support system in the early 1970s. An additional impetus for a review of the fleet was the establishment of major principles and key issues for 'Competition, Recompetition and Renewal of NSF Awards' (NSB 97-224) by the National Science Board (NSB) in November, 1997. The supporting statement notes that even in cases where facility management has been explicitly and vigorously reviewed and found to be effective, NSF must evaluate periodically if there is a better management approach.

In response to this request by the NSB, the Assistant Director for Geosciences formed a Fleet Review Committee (the "Committee") which operated under the auspices of the Advisory Committee for Geosciences and reported to the Assistant Director for Geosciences (Appendix A). The Committee was asked to:

1. Review and evaluate the current and projected research vessel fleet required for research sponsored by the National Science Foundation within a national framework that includes research requirements of other federal agencies, state and local governments, and private sources.

2. Review and evaluate overall management structure of the Academic Research Fleet; review and evaluate existing capabilities and services provided by the operating organizations; and review and evaluate possible future changes in academic fleet operations to ensure optimal operations of the academic fleet to support research requirements.

3. Provide recommended actions by NSF to improve the organization, management, and cost effective operation of the Academic Research Fleet in support of scientific capabilities required to maintain world leadership in ocean and environmental science research.

The Committee met four times between June 1998 and March 1999 (Appendix B). During that time, NSF presented information on fleet management and support. UNOLS management, ship operators and members, together with other operators of oceanographic research vessels in the U.S. and abroad, addressed existing models for vessel support of oceanographic research. An independent contractor (Tecolote Research, Inc.) augmented the UNOLS presentation by providing an independent cost analysis of UNOLS and other vessel operators. NSF and ONR research program managers, and external community representatives, provided an assessment of trends and opportunities in ocean science research with a focus on sea-going requirements. A number of users of the Academic Research Fleet— from different subdisciplines, from both large and small oceanographic institutions, and from other programs which use the fleet but do not operate ships— presented their views on academic research vessel support. In addition, the oceanographic community provided written comments on the management, operation and future needs of the Academic Research Fleet. Finally, UNOLS provided post-cruise reports where both Chief Scientists and Vessel Masters provide independent evaluations of past research cruises.

WOCE: World Ocean Circulation Experiment

WOCE is a 30-nation research program whose goal is to better understand the role of ocean circulation in long-term climate change and to develop models for predicting such change.

- Work is conducted from large UNOLS vessels
- Used several satellites, dozens of ships, and thousands of instruments during its field program
- Acquired physical, chemical, and ocean current data along an extensive grid of transects in all the major ocean basins
- Used over 2200 days of ship time between 1990 and 1999
- Field programs concluded in 1999; program entering a five-year modeling and data synthesis phase

How does the ocean affect climate?

The upper layer of the ocean contains as much heat as the whole atmosphere. Interaction between the two results in changes in weather, sea level, and more. The ocean also absorbs trace gases implicated in global warming (e.g., carbon dioxide), mitigating their immediate effects. More importantly, however, the ocean mixes and moves water away from the surface and redistributes it to deeper layers around the globe as part of large-scale ocean circulation. Thus, the ocean acts as a buffer to reduce some of the potential climate shifts. Knowledge of the global ocean and its circulation is essential to understanding and predicting Earth’s climate variability, long-term change, and ultimately its impact on humankind.

2. Academic Research Fleet

The International Geophysical Year (IGY; 1957-58) brought to the international ocean science community a recognition that large-scale, multinational research initiatives could be conducted that offered a new way to observe and understand the Earth on a truly global scale. The experience of implementing the IGY led to a realization that global initiatives would require better national and international coordination of both the programmatic and logistical elements of ocean science research. The International Decade of Ocean Exploration (IDOE) in the 1970s stemmed from the success of IGY, and provided a substantial additional increase in requirements for research and oceanographic facilities. This initiated the development of the present academic fleet.

Several conditions must be met if the Academic Research Fleet is to be operated in an effective manner in support of NSF-sponsored science. First, the capabilities, operating modes, and geographic distribution of the fleet must meet research requirements. For NSF-sponsored research, this means that the fleet profile must include large ships with global range, intermediate ships for regional or ocean basin scale studies, and smaller ships for local, near-shore studies including the Great Lakes. Specialized capabilities to meet research priorities that cannot be met by general purpose ships must be maintained as needed. The submersible *Alvin* and associated support is an example of such a unique facility. Second, an effective science support infrastructure is required to ensure that shipboard equipment and technicians can support research needs. To achieve these goals, each operator within the fleet must maintain a shipboard technical support group and an inventory of shared-use instruments. Third, an effective and efficient management structure is required to ensure community-wide access to the ships and instrumentation, safe operating procedures, and uniform cost accounting.

A. The Fleet

The overall U.S. oceanographic fleet includes research, survey, fisheries and other mission-related vessels of the federal agencies, of which the Academic Research Fleet (the "UNOLS Fleet") is the largest single component, and virtually all of the research component (Figure 1). In 1999, the Academic Research Fleet consists of 28 research vessels, broadly divided into four categories, with operating modes responsive to different components of national research requirements (Figure 2).

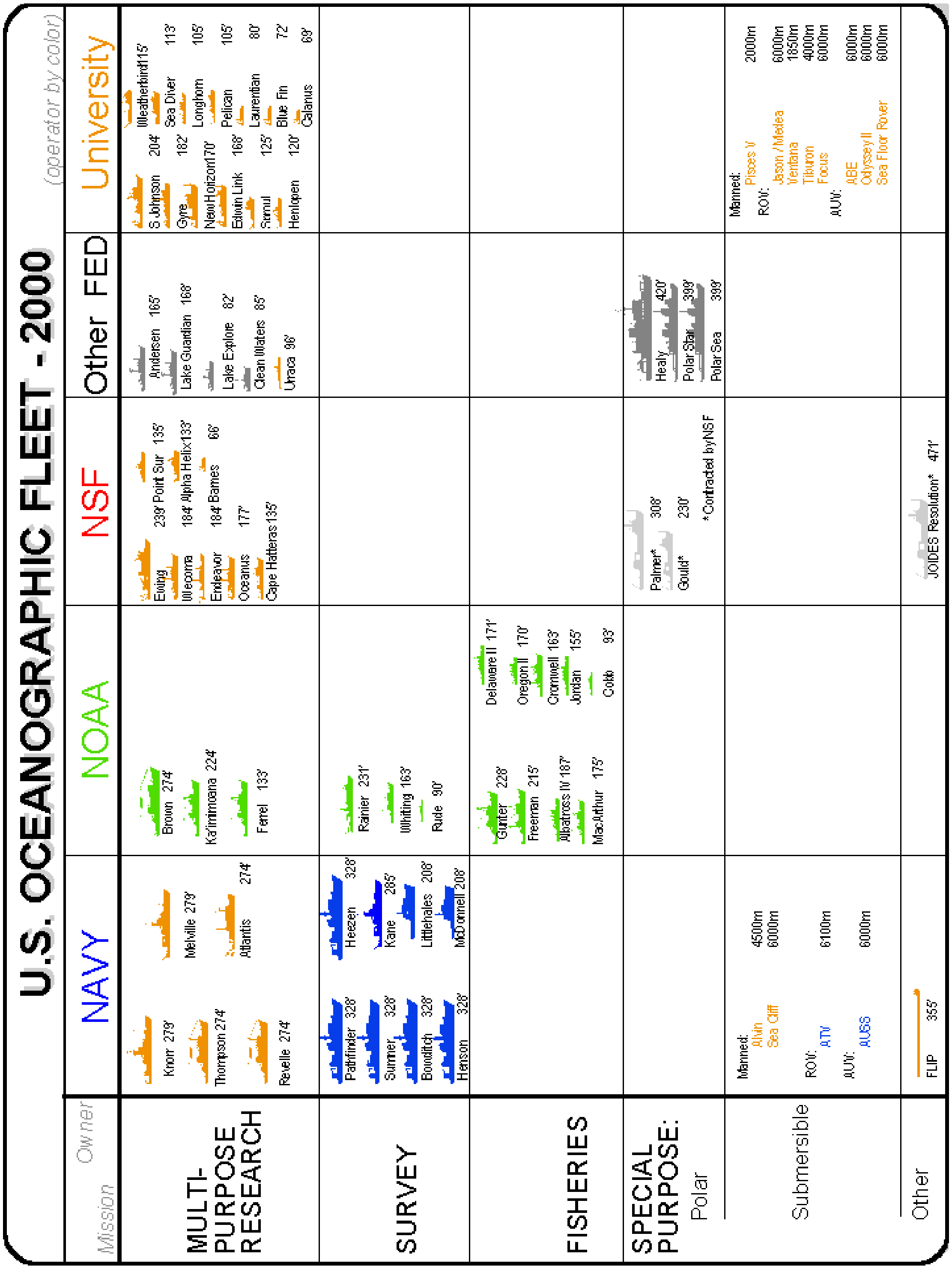


Fig. 1: U.S. National Oceanographic Fleet projected for 2000. NSF and Navy ships operated as UNOLS vessels are color-coded "University Ships."

	Name	Owner	Size
Large Expeditionary Ships			
Scripps Institution of Oceanography	MELVILLE	Navy	279 ft.
Woods Hole Oceanographic Institution	KNORR	Navy	279 ft.
Scripps Institution of Oceanography	ROGER REVELLE	Navy	274 ft.
Woods Hole Oceanographic Institution	ATLANTIS	Navy	274 ft.
University of Washington	THOMPSON	Navy	274 ft.
Lamont-Doherty Earth Observatory	MAURICE EWING	NSF	239 ft.
Intermediate Ships			
University of Hawaii	MOANA WAVE*	Navy	210 ft.
Harbor Branch Oceanographic Institution	SEWARD JOHNSON	HBOI	204 ft.
Oregon State University	WECOMA	NSF	185 ft.
University of Rhode Island	ENDEAVOR	NSF	184 ft.
Texas A&M University	GYRE	TAMU	182 ft.
Woods Hole Oceanographic Institution	OCEANUS	NSF	177 ft.
Scripps Institution of Oceanography	NEW HORIZON	SIO	170 ft.
Harbor Branch Oceanographic Institution	EDWIN LINK	HBOI	168 ft.
Regional Ships			
Moss Landing Marine Laboratories	POINT SUR	NSF	135 ft.
Duke University/University of North Carolina	CAPE HATTERAS	NSF	135 ft.
University of Alaska	ALPHA HELIX	NSF	133 ft.
Scripps Institution of Oceanography	ROBERT G. SPROUL	SIO	125 ft.
University of Delaware	CAPE HENLOPEN	UD	120 ft.
Bermuda Biological Station for Research	WEATHERBIRD II	BBSR	115 ft.
Harbor Branch Oceanographic Institution	SEA DIVER	HBOI	113 ft.
Louisiana Universities Marine Consortium	PELICAN	LUMCON	105 ft.
University of Texas	LONGHORN	UT	105 ft.
Local Near-Shore Ships			
Smithsonian Institution	URRACA	SI	96 ft.
University of Michigan	LAURENTIAN	UMICH	80 ft.
University System of Georgia	BLUE FIN	UG	72 ft.
University of Miami	CALANUS	UM	68 ft.
University of Washington	BARNES	NSF	66 ft.

***Moana Wave* is being retired in July 1999.

Fig. 2: U.S. Academic Research Fleet (1999).

- Six large ships with capabilities for extended, global research cruises to regions distant from home port. Five are Navy-owned, one NSF-owned.
- Eight intermediate and large coastal ships with capabilities for multidisciplinary and single investigator studies throughout U.S. waters and adjoining regions. One is Navy-owned, three are NSF-owned, and four are institution-owned.
- Nine regional, or "Cape Class" research ships with capabilities for smaller projects in coastal and near-shore regions. Six are institution-owned, three NSF-owned.
- Five local ships, with capabilities for small projects close to home port and in near-shore waters. Four are institution-owned, one NSF-owned. Operating Institution

In general, the large expeditionary ships are new and highly capable, and carry the most extensive and advanced scientific instrumentation in the fleet. In the 1990s, the Navy constructed three large ships, NSF acquired and converted an industry multichannel seismic ship, and the Navy extensively refitted two large, existing academic research ships. In contrast, many of the intermediate and regional ships built in the 1960s and early 1970s will require replacement in the next decade or so, and several of the local ships need to be replaced immediately (Figure 3). The University of Miami and the University System of Georgia, operators of two of the older local vessels, have indicated their intentions to replace their institution-owned vessels with internal funds in the next two years.

In addition to general oceanographic and environmental studies supported by the Academic Research Fleet, NSF sponsors specialized studies for Antarctic research and scientific ocean drilling through separate programs. The required facilities for both of these programs are provided by private companies through contracts with NSF for integrated scientist support, logistics and facilities operations.

B. Science Support Infrastructure

NSF maintains programs totaling about $5 million annually for upgrading and replacing scientific instrumentation and shipboard equipment throughout the fleet. Most vessels carry a sophisticated array of instruments tailored to a vessel's operating profile. This research instrumentation falls in four basic categories:

- Installed systems which sail permanently with the vessel. This includes items such as winches of varying capability, standard oceanographic cables, advanced navigation equipment, meteorological sensor suites, single-beam (all) and multibeam (6 ships) echosounder systems, acoustic doppler current profilers, and both voice and Internet communications systems.

- Widely-used shared-use instrumentation, which are common to most or all ships in the fleet. This includes CTD systems and related water samplers and sensors,

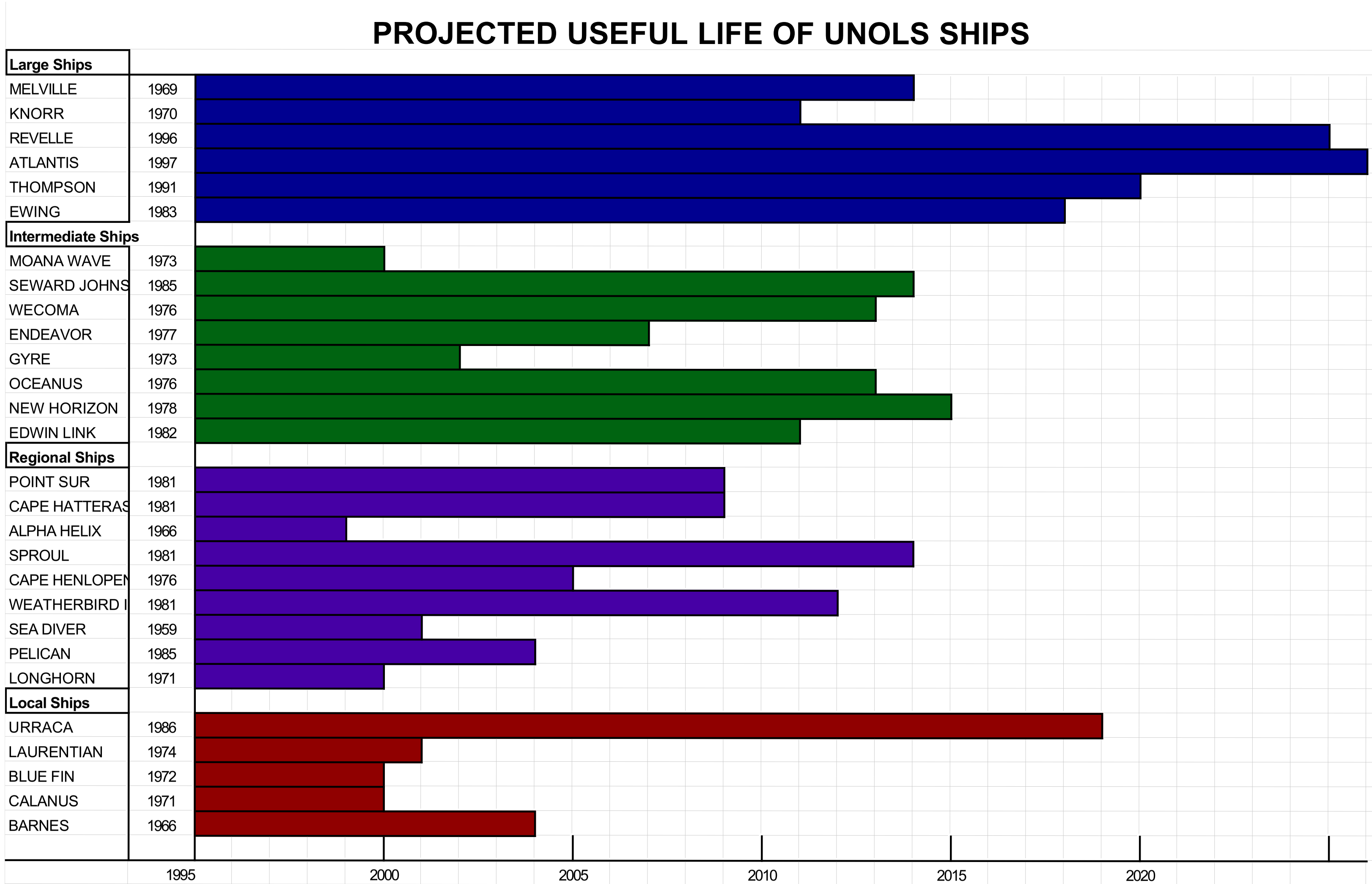


Fig. 3: Projected replacement/retirement dates for existing UNOLS ships. Based on 20 to 30-year service life modified to reflect mid-life refits and other service upgrades (UNOLS Fleet Improvement Committee data).

surface water underway analysis systems (most commonly for temperature, salinity and some nutrients), biological sampling nets of various types, corers, dredges and trawls, as well as a number of other tools.

- Specialized shared-use instrumentation, of which only one or a few systems are available to the fleet, which can be moved from one ship to another as needed. This includes such items as remotely-operated vehicles (ROVs), large piston coring systems, towed side-scan sonar systems, "clean" CTD systems, and undulating profiler systems, among others.

- Instruments provided by the scientific user.

In addition to these instruments, all ships in the UNOLS fleet carry computers for onboard research. Most ships have local-area networks on board, some of which are very sophisticated, allowing scientists access to computer resources required in their research, or to attach their own set of computers to the existing network.

Each operator maintains a group of shipboard technicians to support the shared-use instrumentation, and one or two of these technicians (depending on vessel size) always sail on research cruises to assist the scientific user. These technical support groups have responsibility for maintaining and calibrating their pool of shared-use scientific instruments as well as operating them at sea.

C. Management

UNOLS

The basic organizational structure for the operation of the Academic Research Fleet was established in 1972 with the formation of the 17-member University-National Oceanographic Laboratory System. Two key elements of the UNOLS structure are that UNOLS is not a ship operating organization, i.e., ship operations remain the responsibility of the individual research institutions; and federal agencies and other research sponsors continue to provide facilities support directly to the operating institutions.

Prior to establishing UNOLS, 33 research vessels were operated under rules and procedures of the individual institutions. Vessel access was primarily under the direction of institution scientists and managers. The federal and university administrators who established UNOLS saw the need to develop a system that made ships accessible to a broader community of investigators, established standards for operations and safety, and had uniform funding and cost accounting procedures.

Initial UNOLS efforts focused on ship scheduling and investigator placement procedures. This was followed by uniform cost accounting, cruise reporting, ship operations data and information services. Other UNOLS developments included stan-

Alabama Marine Environmental Sciences Consortium	Moss Landing Marine Laboratories
University of Alaska	Naval Postgraduate School
Bermuda Biological Station for Research	University of New Hampshire
Bigelow Laboratory for Ocean Sciences	State University of New York at Stony Brook
Brookhaven National Laboratory	University of North Carolina at Wilmington
University of California, San Diego, Scripps Institution of Oceanography	Nova University
University of California, Santa Barbara	Occidental College
Cape Fear Community College	Old Dominion University
Columbia University, Lamont-Doherty Earth Observatory	Oregon State University
University of Connecticut	University of Puerto Rico
University of Delaware	University of Rhode Island
Duke University / University of North Carolina	Rutgers University
Florida Institute of Technology	San Diego State University
Florida State University	Sea Education Association
Harbor Branch Oceanographic Institution	Smithsonian Tropical Research Institute
Harvard University	University of South Carolina
University of Hawaii	University of South Florida
Hobart & William Smith Colleges	University of Southern California
The Johns Hopkins University	University of Southern Mississippi
Lehigh University	University System of Georgia, Skidaway Institute of Oceanography
Louisiana Universities Marine Consortium	University of Texas
University of Maine	Texas A&M University
The Marine Science Consortium	Virginia Institute of Marine Science
University of Maryland	University of Washington
Massachusetts Institute of Technology	University of Wisconsin at Madison
University of Miami, Rosenstiel School of Marine and Atmospheric Sciences	University of Wisconsin at Milwaukee
University of Michigan, Center for Great Lakes and Aquatic Sciences	University of Wisconsin at Superior
Monterey Bay Aquarium Research Institute	Woods Hole Oceanographic Institution

Fig. 4: UNOLS member institutions. Ship operating institutions in blue.

dards for shipboard equipment and technical services, foreign research clearance procedures, science mission requirements for new ship planning, shipboard safety standards and community plans for ship replacements for aging and obsolete research vessels. UNOLS has a number of working committees which handle topics from ship scheduling and vessel operation to technical improvement and the use of specialized facilities (Appendix C).

All institutions with academic programs that use the research vessels may join UNOLS. Currently UNOLS has 57 member institutions, 20 of which operate UNOLS fleet vessels (Figure 4). Since the beginning of UNOLS, five institutions ceased being ship operators and eight new operators joined, bringing to UNOLS institution-owned ships.

CONTRACTUAL MECHANISMS FOR FLEET OPERATIONS SUPPORT BY NSF

NSF uses two fiscal instruments, grants and cooperative agreements, to support different aspects of the UNOLS fleet operations. Grants, the most commonly used instrument by NSF, are used to support the UNOLS office, technical services awards, acquisition of shared-use equipment and instrumentation, and research projects which are carried out on the ships. The cooperative agreement is used to support each operator's vessel operations costs. The cooperative agreements used by the Division of Ocean Sciences contain common provisions sharing responsibility for ship operation management between the operator and NSF, and have reporting requirements related to a number of operational factors, including accidents, maintenance, and safety. They require regular (every two years) vessel inspections, and they also require proposals in a common format which detail individual cost components for four years (two past, current and upcoming), to keep NSF informed of cost history and assist with "best practices" management procedures. Cost and data trends compiled for the last six years (1993-1998) show that the total funding ranged from $42.9 to $52.0 million annually from all research sponsors (Figure 5). The average cost per day (in constant 1998 dollars) to operate ships of the Academic Research Fleet ranges from about $16,000 for the large ships to about $4,000 for the local ships. Operating costs for all ship classes have remained nearly constant over this time and indicate costs are under control within the range of the ship utilization factors (Figure 6).

FACILITIES PLACEMENT

For the research vessels constructed by NSF and the Navy, agencies follow federal procurement regulations in making construction awards. To select ship operating institutions, calls for operating proposals are made via open competition. Selection of operator institutions is made based on terms outlined in the solicitation. Charter party agreements with the selected institutions are then negotiated. These agreements vary in length (usually five years) and are reviewed periodically. They may be extended by consent of both parties. During the period the charter party agreement is in force, the operating institution must agree to maintain the vessel to the U.S. Coast Guard (USCG) and the American Bureau of Shipping (ABS) standards and be subject to Navy or NSF inspections.

The ship-operating institution is responsible for the safety of all crew and scientific parties and is not guaranteed operational funds by virtue of selection as a vessel operator. The operator must meet all UNOLS access, operations and safety standards.

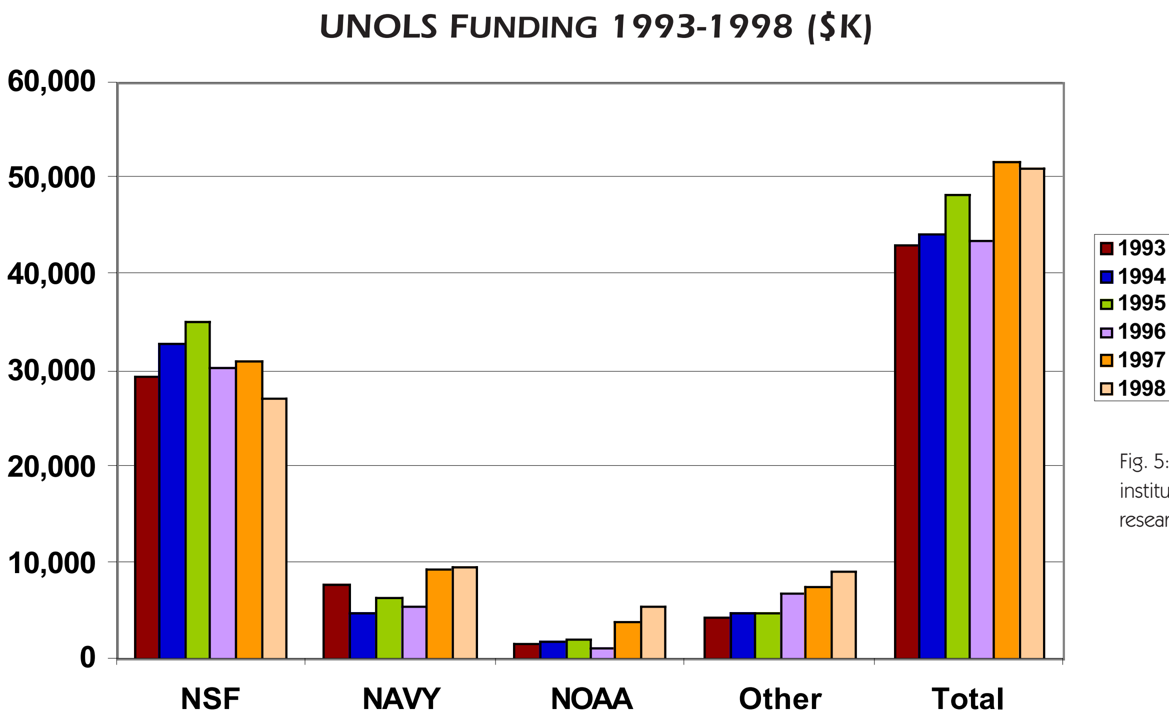


Fig. 5: Funding for UNOLS institutions ship operations by research sponsor.

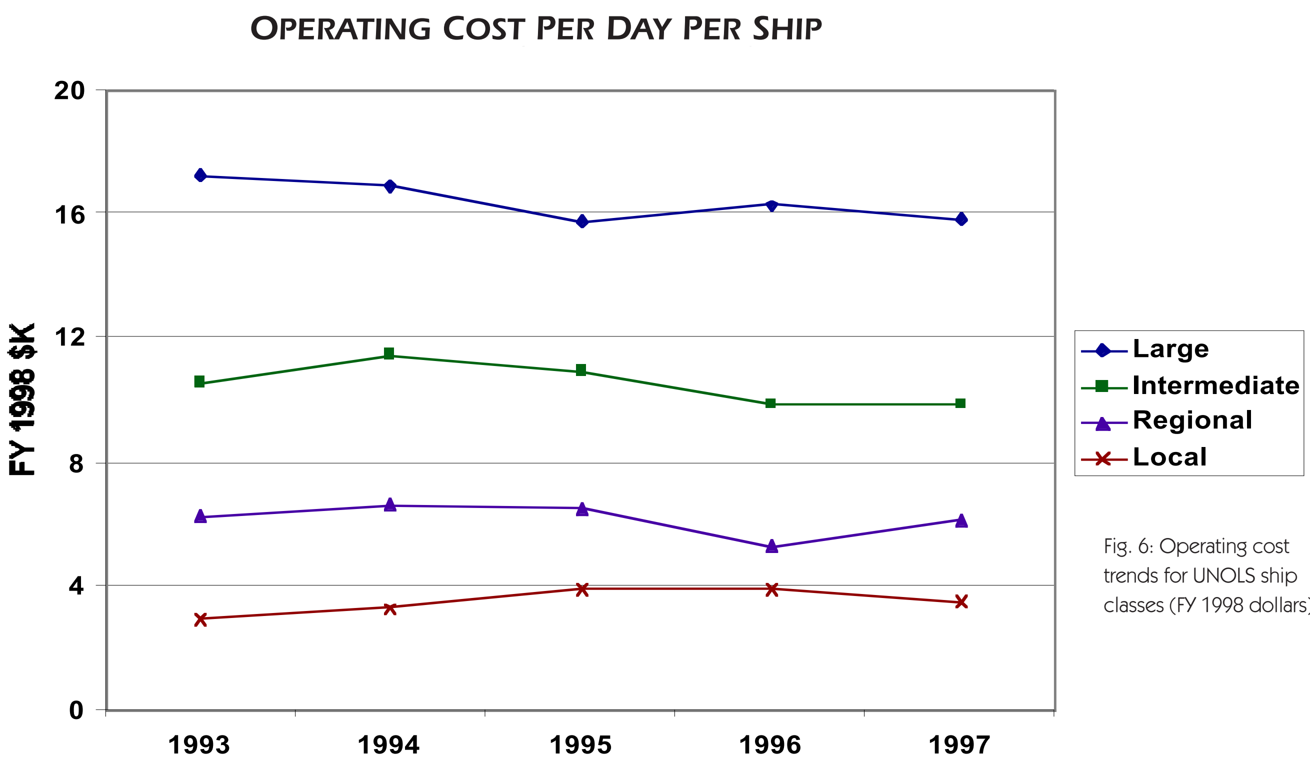
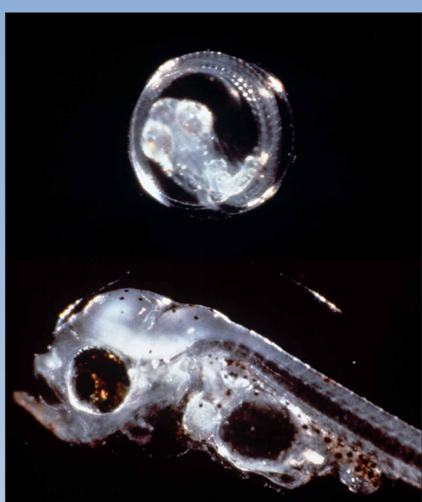


Fig. 6: Operating cost trends for UNOLS ship classes (FY 1998 dollars).

As an operator, the institution may propose to NSF, ONR or other agencies for support of scheduled scientific cruises using a negotiated day rate. It may also submit proposals for ship technician support, ship scientific support equipment and oceanographic instruments for shared use. The proposal regime, charter party agreements, UNOLS membership, and safety inspections provide strong fiscal and management oversight of the vessel operators. Five-year agreements with provision for extension provide the longevity needed for the operator to establish and maintain effective crews and technical personnel in support of science.

U.S. institutions with non-federally owned oceanographic research ships can apply to become UNOLS operating institutions. Once linked to UNOLS and abiding by UNOLS operational and scheduling constraints, these institutions can propose to



GLOBEC: U.S. GLOBAL ECOSYSTEM DYNAMICS

U.S. GLOBEC is a research program organized to investigate how global climate change may affect the abundance and production of animals in the sea.

- Majority of ship usage is intermediate and smaller vessels
- Used over 1000 days of ship time between 1992 and 1999
- Specialized biological sampling systems, chemical sensors and high precision navigation for 3-D volumetric studies of biology and environmental properties.

THE OCEAN FOOD WEB

The capacity of marine ecosystems to sustain fish and other animal populations depends on the growth of phytoplankton, tiny drifting plants that convert carbon dioxide into living organic matter. In ocean systems, nutrient availability often sets limits on this production. Therefore, changes in upwelling circulation, increasing or decreasing mixing of ocean waters, or changes in freshwater runoff patterns could reduce or shift nutrient inputs, in turn causing changes in phytoplankton productivity at both regional and larger scales. Fluctuations in this productivity would ultimately affect larger marine animals-such as fish, whales, and seabirds-throughout the ocean's food web, starting with the tiny zooplankton upon which they directly or indirectly feed. Changes in food availability may result in changes in species abundance and shifts in their distribution. Such changes may cascade throughout the food web, ultimately altering population stability in economically important fish species.

NSF annually for ship operations funding, as well as technician support and shared use equipment, in the same manner as a federally constructed research vessel. Often operational costs are partly supported by state or private foundation funding. Many of the smaller vessels in the UNOLS fleet are state owned, and a few intermediate vessels are partly supported by foundation resources.

Situations do arise when limits to available resources, the introduction of more modern vessels or geographic imbalance of assets cause ships in the Academic Research Fleet to be either laid up, retired, or relocated to new operators. These decisions have high local impact. This type of situation has often proved difficult for UNOLS to plan or mediate, and these decisions normally require coordination and agreement at the federal level, primarily through NSF and ONR. Such decisions can require direct coordination with congressional representatives.

OCEANOGRAPHIC RESEARCH SCHEDULING

Research proposals submitted from academic institutions around the U.S. and selected for support via merit review drive facilities' support. In 1998, over 150 individual NSF research projects required 2651 days of UNOLS ship time on 323 separate cruises ranging from 1 day to almost 50 days at sea, and involved all but one of the 28 UNOLS vessels. Ship operations support is based on merit review of research proposals having ship requirements, not on separate merit review of the operations proposals per se. Proposals for ship operations support are evaluated by the NSF Ship Operations Program Director in consultation with other agencies. Criteria are cost, operational capability and quality of operations, and support is provided to operators through cooperative agreements with strict reporting requirements.

While the basic approach and concept is straightforward, the actual assignment of funded research projects to fleet platforms involves a multi-stage process that considers ship and researcher schedules, maximizes ship utilization and incorporates the needs of researchers funded by all federal agencies. The NSF portion of this process is outlined in Appendix D. Scheduling of platforms and scientists is managed by UNOLS, with fiscal oversight by federal agency representatives. This process allows for the scheduling of researchers and platforms supported by all federal and state agencies into a coordinated national framework.

3. Current and Projected Fleet Requirements

The Committee reviewed recent use of the Academic Research Fleet in support of NSF-sponsored research projects. In addition, NSF and ONR research program managers and external community representatives provided an assessment of trends and opportunities in ocean science research with a focus on sea-going requirements.

A. Current Ship Use

NSF assembled detailed data on the use of the UNOLS vessels in support of sea-going science projects for 1988 through 1999. During this period, total Academic Research Fleet ship days used annually by all sponsors has fluctuated between about 4000 and 5400, and has remained between 5200 and 5400 for the past three years (Figure 7). NSF-sponsored ship-days, which are a subset of the total fleet days used, declined somewhat during this same period, from about 3500 days in 1988 to about 2600 for each of the past two years (Figure 8).

For the large vessels, use by all sponsors has gradually increased from about 900 days in 1989 to over 1500 days in 1999. NSF use of the large vessels has varied during that same period, increasing from about 500 days in 1989 to a peak of 1300 in 1995, before steadily declining to about 850 days in 1999. In part, this increase in total use by all sponsors corresponds to an increased number of available days as new vessel construction and midlife refits of these large ships have been completed. (The fleet had four large vessels available in 1990, increasing to six in 1999). When plotted as utilization rate (Figure 9), a measure of actual use versus recommended or target use levels, the large vessels have a >80% utilization rate for all but two of the twelve years (1989, 1990). A utilization rate of 90 to 100% for all ship classes is desired.

Overall use of intermediate vessels declined over the period illustrated from an average of about 1900 days prior to 1993 to an average of about 1500 days since then. Use of intermediate class vessels for NSF-sponsored research mirrors this decline, decreasing from an average of 1100 days prior to 1993 to 800 days more recently. In addition, the utilization rate for the intermediate class is the lowest of all groups, averaging only about 70%. Similar to the large vessels, midlife refits of this vessel class

Total Days by Class

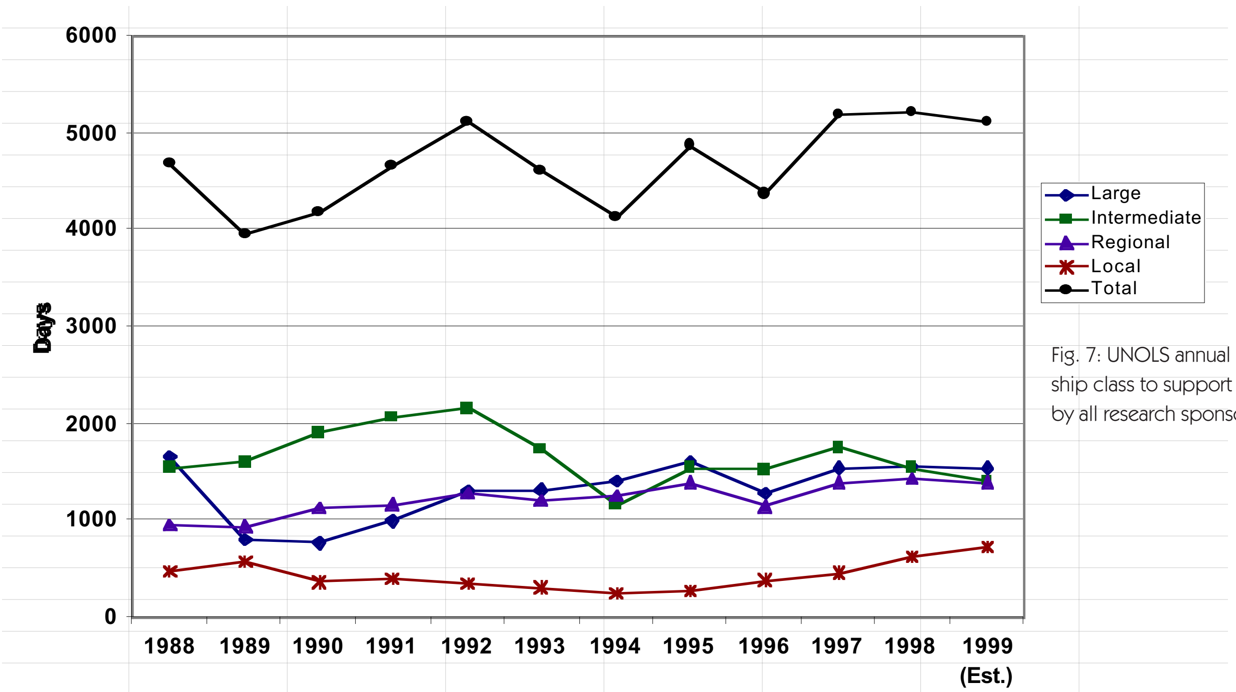


Fig. 7: UNOLS annual operating days by ship class to support sea-going projects by all research sponsors.

NSF Total Ship Days by Class

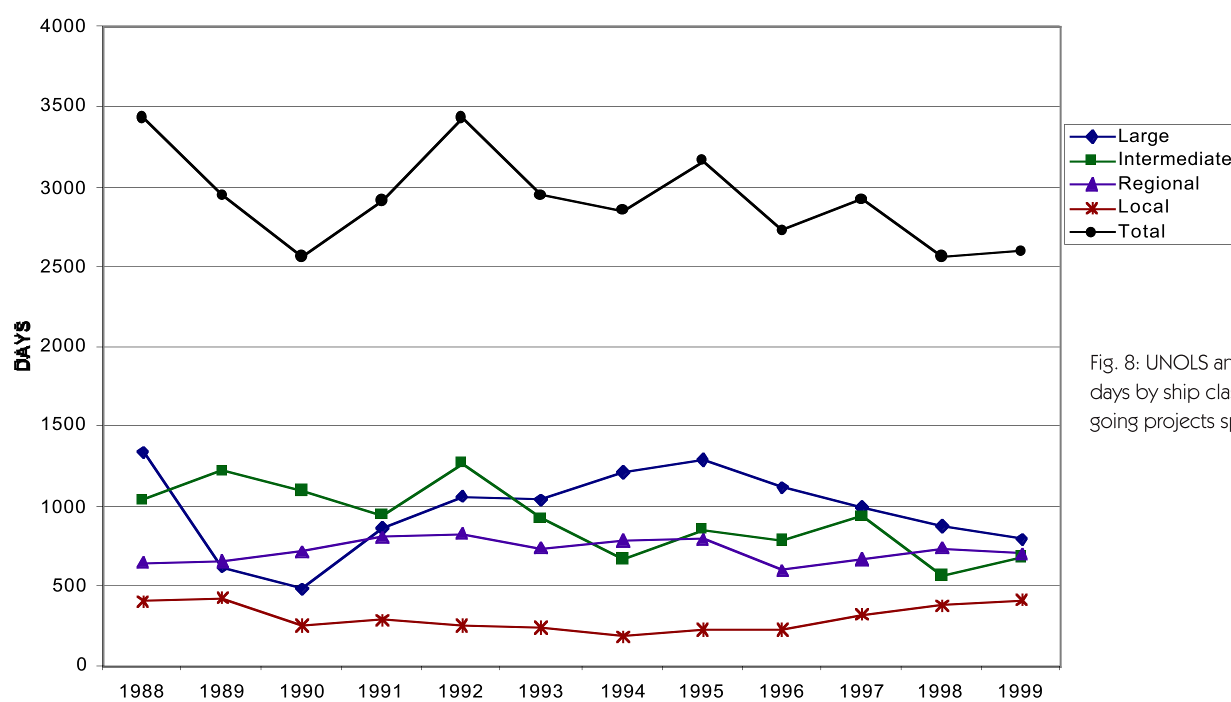


Fig. 8: UNOLS annual operating days by ship class to support sea-going projects sponsored by NSF.

and changes in fleet composition, including both ship retirements and fleet additions has had an impact on the number of available ship days. The R/V *Moana Wave* will be retired in 1999 and her replacement will not be completed for about two years, further reducing the number of available ship days in this vessel class.

Use of the regional ships by all sponsors over the 12 years evaluated has, like that of the large vessels, gradually increased, although utilization rates for the period are only slightly higher than for the intermediate vessels (about 75%). Use of regional vessels in support of NSF-sponsored research has been very steady, averaging about 700 days during this period.

Use of the local class of ships has fluctuated between 300 and 800 days during the 12-year period evaluated, with NSF-sponsored program use ranging between about 200 and 400 days. With only five available vessels, all of which are very limited in operating area, the impact of a single multi-year program can be pronounced. The rise in local ship use in 1998-1999, clearly seen as the spike in utilization rate of local vessels, is a result of Great Lakes research, which requires as much time as can be provided by the one UNOLS vessel available.

B. Projected Ship Use for NSF-Sponsored Research

There are two principal user components to NSF-sponsored ocean-going field programs: individual-investigator projects and major ocean science initiatives. Ship use for both components is driven by merit review of individual proposals by the various research programs at NSF, thus projections of ship use can have substantial uncertainty. However, when viewed historically, field programs using the Academic Research Fleet have made up about 30% of the awards in the Division of Ocean Sciences in the past decade. The ship use for individual-investigator science is projected to continue at current levels or increase slightly in response to a modest, 7.8% increase in the research program budgets in 1999. Additional support for multidisciplinary research is also requested for 2000.

The development of several major ocean science initiatives in the 1990s has greatly influenced NSF-sponsored use of the Academic Research Fleet, particularly the large ships. The major ocean science initiatives accounted for about 20% of the NSF-sponsored ship use during the decade, but was as high as 40% in 1995 (Figure 10). At that time, the World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), Ridge Interdisciplinary Global Experiments (RIDGE) and other initiatives were in the midst of their data acquisition phases (see science boxes throughout report for more information on individual programs).

Currently, WOCE and JGOFS have completed data acquisition and are focusing resources on data analysis and synthesis. RIDGE is still executing field programs, as are other initiatives such as Global Ocean Ecosystem Dynamics (GLOBEC) and

Ship Utilization Rates

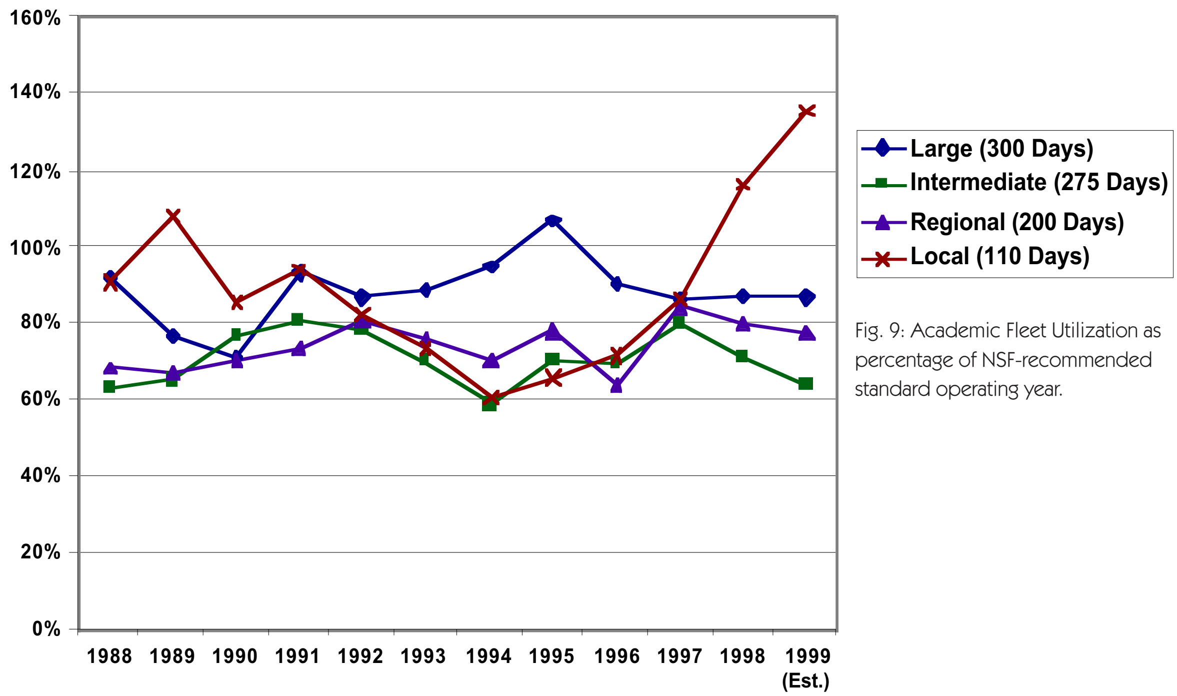


Fig. 9: Academic Fleet Utilization as percentage of NSF-recommended standard operating year.

UNOLS Ship Use by Major Oceanographic Program

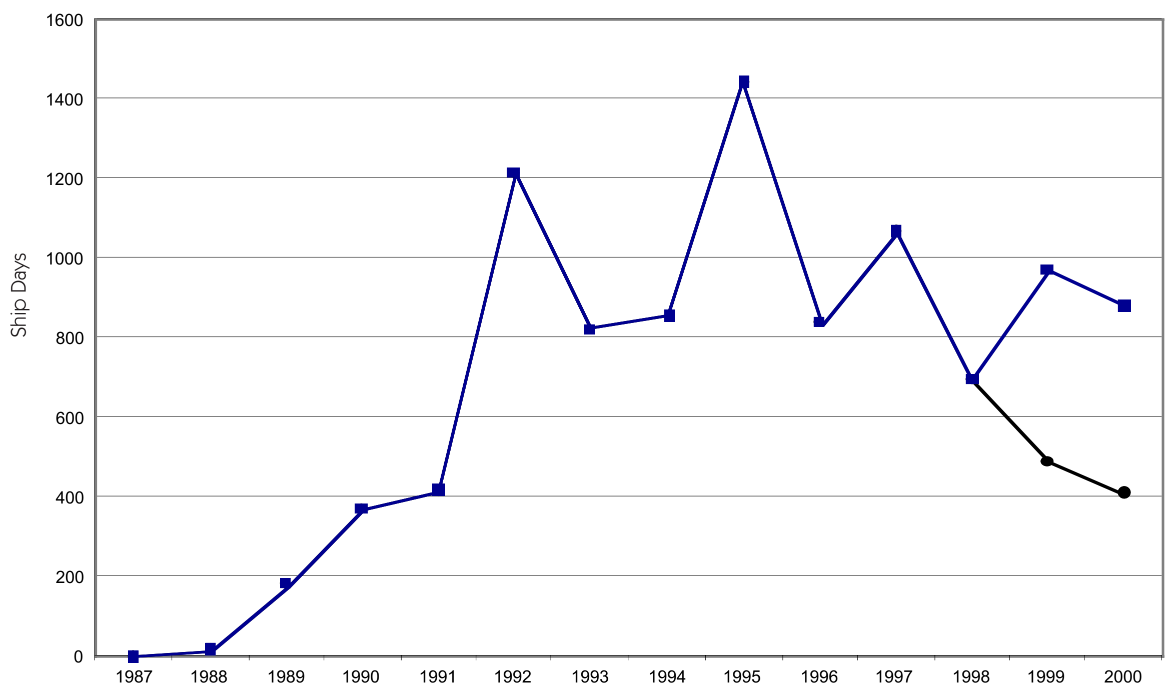


Fig. 10: Total UNOLS ship use by major oceanographic programs (from Global Ocean Science, NAS/NRC, 1999). Lower data points for 1999 and 2000 as shown in that report; upper points for those two years updated by NSF.

JGOFS: Joint Global Ocean Flux Study

JGOFS is a research program whose goal is to understand on a global scale the processes controlling the time-varying fluxes of carbon and associated biogenic elements in the oceans, and to evaluate the related exchanges with the atmosphere, sea floor and the continental boundaries. Another goal is to develop a capability to predict on a global scale the response of oceanic biogeochemical processes to anthropogenic perturbations, in particular those related to climate change.

- From 1987 through 1999, 222 principal investigators from 66 institutions have been funded to carry out JGOFS research
- Used over 2200 days of ship time between 1988 and 1997
- Used large UNOLS ships
- “Clean” sampling systems, sediment traps, buoyed air-sea interaction instrumentation.
- Over 30 nations participate in the program

The marine carbon cycle:

The oceans contain about 50 times as much carbon dioxide as the atmosphere, and small changes in the marine carbon cycle can therefore have large atmospheric consequences. Such changes are believed to have had important feedback effects on climate during the transitions to and from ice ages; they may also have important consequences during the climate changes that are predicted to occur in the next 50-100 years, as a result of rapidly rising levels of atmospheric carbon dioxide and other greenhouse gases. Models indicate that the oceans are currently taking up at least a third of the anthropogenic carbon dioxide, by dissolving it in water that then loses contact with the atmosphere because of sinking or vertical mixing. Biological processes complicate the oceanic carbon cycle, although they probably do not affect the current uptake of anthropogenic carbon dioxide.

Coastal Ocean Processes (CoOP). MARGINS, a new program to study the geological structure of continental margins, begins field programs in 1999. In addition, increased survey efforts related to ocean drilling are expected during this period in anticipation of a new, international program in ocean drilling beginning after 2003. As a result, the projections for NSF-funded ship time for the major ocean programs remain flat for the next 2-3 years at about 800-1000 days/year.

Beyond about 2001, specific plans for major ocean initiative field programs are still being developed. However, there are planning efforts in the community and at NSF in two thematic areas – climate variability and carbon systems science – which are likely to develop into initiatives requiring substantial ship use beginning after 2001. In addition, the Division recently sponsored discipline-based workshops to identify future trends in ocean science. Workshops were held in Biological Oceanography, Chemical Oceanography, Marine Geosciences, and Physical Oceanography. Each community identified major research areas for the future (Appendix E). A fifth activity on future directions, which is an interdisciplinary synthesis, is currently underway, with report expected in late 1999. Past experience indicates that multidisciplinary or regional efforts will emerge as drivers for future requirements of the Academic Research Fleet. There is a suite of environmentally and socially relevant ocean science topics for the future.

It is worth noting that "intermediate-scale" programs, involving coordinated groups of investigators but smaller than major initiatives, are an active area of growth at NSF. This scale of project was specifically identified in the National Research Council's 1999 report, "Global Ocean Science: Toward an Integrated Approach," which emphasizes meeting evolving research requirements. Community response to the report's recommendation is already evident in proposals to NSF, particularly in the area of physical oceanography, and least one or two such projects involving 100-200 days of ship use are expected beginning in 2000.

Even under the most optimistic projections, however, there appears to be a near-term period of two or three years during which use of the academic oceanographic fleet will remain below existing capacity before the impact of new ocean sciences initiatives is felt.

C. Technology and Facilities Support Requirements

As merit-reviewed science programs progress, they introduce new instrumentation and facility support requirements to the Academic Research Fleet. New physical, chemical, geophysical, optical, and biological sensors all collect data at rates and densities which challenge the capacity of existing shipboard computer systems. Along with this increase in data rate is an increased need to communicate broadband data at high-speeds from ship to ship, ship to fixed or mobile platforms and to shorebased labs. Rapid two-way data transmission between platforms at sea and shore can optimize data acquisition during cruises that sample ocean structures and ecosystems. AUVs and ROVs extend the reach and efficiency of shipboard systems. Already emerging is the technology to tap into deep-ocean telephone cables and place long-term sensor systems on the seafloor at great depth with constant communication ashore. These new technologies require special handling systems, hull mounted navigation systems, and platforms with reduced self-noise.

Tomorrow's research platform may function both as delivery systems for special vehicles and moorings and as nodes on a complex web of sensors communicating with laboratories and computer centers ashore. Near-shore ocean observatories which mesh AUV and satellite technologies are being developed. Preparing the present Academic Research Fleet to be a part of these emerging technologies and to use them effectively is an important task which merits continued NSF investment with federal and institutional partners. Clearly, the need for technical support will change (and has, substantially, over the past decade), with much greater reliance on computer technology and communication. The impact on oceanography of new technology is clearly demonstrated by the advent of satellite remote sensing. Global views of sea surface temperature, ocean color, wind speed, rainfall and sea ice have been instrumental in the formulation of new research efforts. Radar altimetry has provided new insights on patterns of global circulation and earth structure. Modern oceanographers plan and modify sampling designs based on remotely sensed imagery even as cruises progress. These new data sets are having a broad impact on science and modify patterns of the use of research vessels. As with the advent of remotely sensed oceanographic data, the role and need for ocean research vessels will evolve, and certainly will not disappear.

NSF is currently addressing new technology issues on several fronts. It has an active Oceanographic Technology program in Division of Ocean Sciences that has been addressing issues of computation, communication, and emerging ocean technology. This program is very interactive with ONR, and numerous emerging technology efforts have been jointly funded. NSF is also part of the National Ocean Partnership Program (NOPP), a multi-agency effort with congressional support, which is supporting a significant effort in new technologies and measurement systems.

4. USER INPUT

The Committee used several methods to sample opinions of operators and users of research ships. Formal presentations were made by vessel operating institutions, and scientists from several institutions and disciplines gave briefings. NSF requested input from the scientific community via the Division of Ocean Sciences newsletter and by web sites and e-mail announcements, and UNOLS provided a sample of cruise reports written by masters and chief scientists. A summary of user comments in response to NSF is in Appendix F and a tabular summary of cruise reports to UNOLS is provided in Appendix G.

A. GENERAL USER SATISFACTION

The Committee assessed the satisfaction of the user community with the Academic Research Fleet by obtaining comments from users at major operating institutions, non-operating institutions, and non-academic agencies and organizations. It is clear from the responses that user satisfaction with the current system is very high. Praise for the UNOLS system focused on the high quality and flexibility of the ships' crews and support staff, which was attributed to the distributed nature of the UNOLS management structure and the operational responsibility that this system invests in the user community. To quote from one of the respondents:

> *"Routinely, the crew and officers go beyond their duties to assist the science operations and I feel that the UNOLS fleet has directly contributed to many of the achievements in marine research. I feel that the success of the fleet operations is generally promoted by the present organizational structure. Individual, distributed operators encourage crew stability and pride of ship operations; scheduling coordination by the UNOLS office optimizes the efficient utilization of fleet assets. As a frequent long-time user, I am very satisfied with the operations of the UNOLS fleet."*

Perhaps even more compelling were the responses from those who have had experience using both UNOLS and non-UNOLS vessels.

Comments from scientists working for the Naval Oceanographic Office (who typically work with Military Sealift Command-operated vessels) and the U.S. Geological Survey were very complimentary of the UNOLS fleet operations, particularly with respect to the competence and flexibility of the UNOLS crews and the condition of the ships. Scientists who have worked on commercial vessels also commented on the general lack of enthusiasm and flexibility of commercial crews (when compared to UNOLS crews) though there are notable exceptions where commercial arrangements have provided excellent service and value (e.g., the German system, in which government-sponsored research is conducted from vessels on long-term charter from commercial operators).

Individual Investigator Science

Testing the Link Between Environmental Conditions and Harmful Algal Blooms

Quay Dortch (Louisiana Universities Marine Consortium)

This research project, which is to test whether there is a link between Harmful Algal Blooms and eutrophication, was carried out as "individual investigator science" and not as part of a larger scientific research initiative.

- Work was conducted mainly from small UNOLS ship (R/V Pelican)
- Collected data over three years at both estuarine and shelf sites, ca. one day per month
- Collaboration between academic and government researchers and private industry

Understanding the relationship between environmental conditions and Harmful Algal Blooms (HABs) in coastal areas is essential for predicting blooms, protecting human health, and preventing economic losses. Recently, considerable interest has focused on Pseudo-nitzschia, a diatom genus in which some species produce domoic acid, a potent neurotoxin, causing, among other things, death or short-term memory loss (Amnesic Shellfish Poisoning; ASP). Preliminary data from the Louisiana coastal zone show that Pseudo-nitzschia spp. (including potentially toxic species) reach very high abundances every spring in the plumes of the Mississippi and Atchafalya Rivers, and high abundances occur frequently, but less predictably in a Louisiana estuary. The hypothesized link between HABs and eutrophication was tested by 1) comparing the highly eutrophic shelf environment with the less eutrophic estuary and 2) examining changes in Pseudo-nitzschia preserved in cores taken from the shelf where increasing eutrophication over time is well documented.

Another theme that emerged from the user satisfaction survey was the complexity of the scheduling procedure and in particular the desire to see schedules finalized earlier. Over the past decade, ship scheduling has become increasingly challenging as more research projects have become interdisciplinary. Scheduling must take into account groups from different disciplines, often from different universities, who use equipment that must be shipped from different places. Investigators note that frequent or last minute changes in schedules present problems such as additional shipping costs and disruptions in teaching schedules. Equally disruptive to investigators are schedule shifts that make arrangements to use critical equipment or technicians no longer viable. The shift of families to the two wage-earning model, with carefully orchestrated schedules to cover child rearing, is becoming a norm in scientific research. Unplanned shifts in cruise schedules are highly disruptive and can threaten career and family stability.

B. Distributed Operations

A frequent comment made by those responding to the NSF informal survey was that they strongly support the current system of distributing ship operations to oceanographic institutions. The clear message from users was that this system leads to better service. The distributed nature of the ship support provides a degree of direct access for scientists planning cruises or analyzing their data afterwards; when not at sea both the ship's crew and the technical personnel are often working on shore at one of the oceanographic institutions. This gives scientists access even when not on board the vessel, and it keeps the scientists abreast of new developments which might affect a future project, particularly for those who use their own institutions' vessels (and they are still a large plurality of users, if not the majority). Other important factors cited by users for the high-quality service provided by this system is the interest of the institutions in vessel operations and their ability to attract crew and technical personnel to work and remain in the academic environment, which is highly unusual for most seafaring employees. These individuals also tend to be interested at some level in the science of oceanography.

The very positive sentiments expressed above were by far the most common thread throughout the user responses and are supported by both the analysis of the post-cruise assessment forms and the reports made to the committee during its meetings. Nonetheless, a number of issues were raised, particularly from those users further removed from the operating institutions, and these need to be addressed. First, is the question of accountability. What recourse does a scientist have when a ship, its equipment, or its technical staff fails to deliver the level of service necessary to meet the scientific objectives of the cruise? While major incidents of this sort are apparently rare, there was clear indication of minor situations that have led to frustration on the part of users. Second, some users were dismayed at the lack of consistency of the shared-use equipment and technical capabilities available across the fleet. There was a clear desire by many respondents for ships to have uniform shared equipment on almost every UNOLS vessel with equal standards of technical support and common charges, if any, to the investigator. Third, there was some frustration that certain types of equipment that can have a wide variety of applications, such as specialized navigation systems, must be provided by the users. This creates duplication within the community and puts users from small institutions at a disadvantage. Fourth, there were concerns about the universal accessibility and cost of some of the major geophysical systems (or the data they collect) aboard some of the larger vessels, specifically multibeam soundings and multichannel seismic data.

C. Quality Control, Shipboard Equipment, and Technical Support

The reliability of shared-use shipboard systems emerged as a major concern through the review of user responses, discussions with UNOLS operators, and NSF management. This seems to be the result of the increasing technological complexity and quantity of shipboard systems, which has increased the potential for problems, as well as limits to both funding and berths for the number of technical personnel who can sail on a cruise. The continued trend toward increased complexity of systems has a clear impact on the need for shore-side and onboard technical help with increasing skills. The community relies heavily upon this pool of expertise and shared-use equipment, and major cruise goals can be lost when crucial systems fail without adequate backup.

The Committee feels that NSF and UNOLS should examine equipment issues to see if a list of shared-use equipment for each vessel and class can be identified and a quality-based system adopted fleet-wide to ensure that this equipment gets proper logistical and technical support at each operating institution. While adequate funding to optimize repairs and technician performance and availability are part of this problem, the Committee discussed the possible fleet-wide adoption of modern quality control efforts, including increased education and training of personnel and rigorous evaluations. The Committee feels that the NSF budget should support this program and evaluate operator performance on a regular basis as part of the quality program. UNOLS appears to be a well-suited vehicle to institute and evaluate such an effort in conjunction with the federal agencies. It is clear, however, that accommodation will need to be made to address employment contracts, state and federal workplace regulations, and similar unique employee factors at the various private and public institutions involved in vessel operation.

5. Consideration of Options

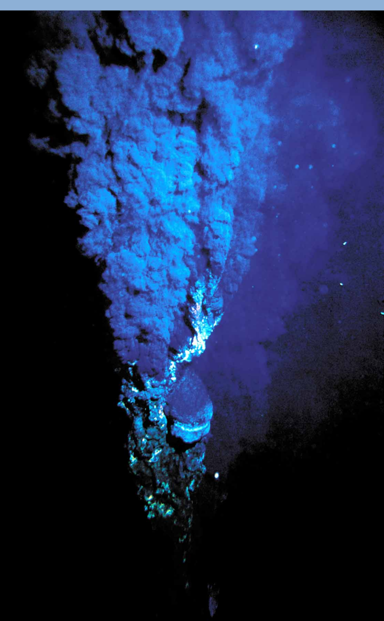
A research vessel is a major capital investment and expensive to operate. Most ships have a 20- to 30-year service life when modernized by mid-life refits and other service upgrades. The need for estimates of long-term requirements for ship resources is clear. Presentations and data that the Committee reviewed indicate that the Academic Research Fleet has more capacity than is projected to be used in the near term by the community of scientists being funded by U.S. agencies and scheduled by UNOLS (See Chapter 3). However, emerging needs and opportunities for sea-going ocean research are large for future years. Programs for for new construction or modernization of ships and facilities can easily span a decade or more and require considerable financial resources. The committee examined several options to meet short-term operational issues and provide cost effective and optimal scientific capabilities for longer-term research requirements.

A. Strategies for Dealing with Excess Ship Capacity

An effective way to promote full use of the UNOLS fleet when excess capacity is relatively small and short-term is to make agreements for ship use with non-academic users such as those in Navy applied oceanography programs and industry. UNOLS has done this in recent years, and plans to continue this practice in the future. Use of the fleet by outside groups preserves the full capacity of the fleet for future increases in academic use while providing needed services for other users. Navy scientists who have participated in this program view it as a success. However, continuation of support by such sponsors is difficult to predict.

When the level of funded programs requiring ship time or the dollars available to support facilities falls below that needed to support the operation of the research fleet, one or more other options must be implemented. Consideration must be given to the age and engineering history of the vessels, the geographic distribution of assets and the placement of special purpose technologies (like DSV *Alvin*).

One way to manage excess ship capacity, suitable to relatively new vessels of good engineering condition, is to reduce the schedule of several ships. Some crew and technicians can be cycled into other tasks at the operating institutions or participate in training. Ships are retained in good working order and there is only a minimal im-



RIDGE: RIDGE INTER-DISCIPLINARY GLOBAL EXPERIMENTS

The goal of the RIDGE Program is to promote an improved understanding of the geophysical, geochemical, and geobiological causes and consequences of energy and material transfer within and through the global mid-ocean ridge system.

- Work is conducted from large UNOLS ships
- Work is heavily concentrated on using specialized facilities (e.g., ROV's, submersibles, multibeam echosounding)
- Multidisciplinary and international collaborations
- Used over 1000 days of ship time between 1993 and 1997

THE MID-OCEAN RIDGE SYSTEM

The mid-ocean ridge system extends more than 30,000 miles around the globe. It is a dynamic expression of internal convection processes, which strongly influences the shapes of the oceans and continents. The mid-ocean ridge system dominates Earth's volcanic activity, driving much of our planet's physical and chemical evolution. Five cubic miles of new oceanic crust are created every year, resurfacing more than 70 percent of the Earth's surface during the last 100 million years (a time span that is less than five percent of the planet's age).

Massive amounts of energy and material move from Earth's mantle into the mid-ocean ridge system to form new crust. "Hydrothermal" circulation of heated seawater through fractures in this young ocean crust promotes chemical exchange and acts as a long-term regulator of ocean water chemistry, strongly influencing the long-term chemical evolution of the planet. At high-temperature hydrothermal vents, unique biological systems, that derive both energy and nutrients from these fluids, in the complete absence of sunlight, may hold the key to understanding the origin of life, both here and on other planets.

pact on crews and technicians. Some maintenance can be performed during these periods if plans exist and funds are available. The impact on ship operations is low, but cost savings are minimal.

If the excess ship capacity is large and is projected to remain for a protracted period, the vessel, if modern and in good shape, may be a candidate for long-term lay-up with expected return to the fleet at some future date. There are several consequences of this management option. One can anticipate a costly yard period to return the ship to operational status, plus recruitment and training of lost personnel. Savings accrue if the lay-up lasts one or more years. Contracting ships to industry is also a possibility, depending on economic conditions and industry needs.

UNOLS has recognized the necessity for occasional or rotating lay-ups, but there has been little formal advance planning to implement them. Ships have been considered for lay-up only if they present a weak schedule, and generally the decision is not finalized until after the fall scheduling meeting immediately preceding the operating (calendar) year. A schedule is considered weak if it falls substantially below the guidelines for the number of operating days appropriate for each class of vessel. An established program of regular maintenance and upgrade periods, properly planned and funded, would benefit the fleet. Major projects, which require naval architects and shipyard bid packages, take well over a year to prepare and thus are not done during lay-up periods. If a defined rotation schedule for taking ships out of service is established for each class of ship or region, then operators and crews can make productive use of the lay-up time. This could increase short-term costs as projects are completed during lay-ups, but in the long term the need and cost of major midlife overhauls could be reduced or eliminated.

Another strategy is to remove older and less capable platforms from the academic fleet and reallocate one or more of the remaining vessels to new operators. This can achieve better geographic distributions of resources and if refit with new instrument systems, better quality vessels for operations in an area. Such reallocations of assets between operators are expectedly controversial at the local level where crewing and technical support staff are impacted. This type of fleet realignment is usually coordinated at the interagency level in the Federal Oceanographic Fleet Coordinating Committee (FOFCC). Changes in vessels operators can also be a subject of Congressional interest.

B. Review of other Research Vessel Operating Systems

The committee reviewed several other research ship operating systems to place NSF/UNOLS procedures in context. These included the National Oceanic and Atmospheric Administration (NOAA) and Naval Oceanographic Office (NAVOCEANO) systems from the U.S., and comparable systems in the United Kingdom and Canada. They cover a range of both management and operational models, including centralized and decentralized systems. The various operational and management models were compared keeping in mind the research tasks to be performed. A detailed look at each system is provided in Appendix H.

Comparative cost data for academic research ship operations and analogous operations of research vessels by NOAA, NAVOCEANO, and the Canadian Coast Guard were compiled by Tecolote Research, Inc (Appendix I). A complication in analyzing comparative costs is that differences exist among the rate structures and accounting systems of the various ship operating systems. The NSF/UNOLS operating system uses a standardized accounting system for all operating costs of the research ships, with technical support, new instrumentation and equipment, and research costs of the scientific projects provided separately. NOAA and NAVOCEANO operating systems include as part of ship operations some instrument systems, deployment costs and general management functions not included within UNOLS. The Canadian Coast Guard operating system uses a different crewing system than most U.S. operations.

In general, the data show that UNOLS, NOAA and Canadian Coast Guard operations costs for comparable research ships are similar, with differences reflecting utilization, specific operating conditions, and ship age and condition. NAVOCEANO costs are significantly greater, reflecting both larger ships than the largest academic research ships and expenses for "forward-based" or remote operations support that is not provided for UNOLS operations.

C. Use of Commercial Ships

The Committee reviewed the effectiveness of contracting vessels from industry, giving consideration to costs, services, and safety. NSF and ONR managers provided information about how costs for the various aspects of UNOLS fleet operations are supported, the contractor's report provided a basic comparison of operational costs of UNOLS vessels and commercial charters.

As a result of partnerships with private and public institutions and with the U.S. Navy, the bulk of vessel capitalization and a large portion of major equipment purchased for oceanographic research vessels has been borne outside of NSF. Since 1990, the Navy has spent about $190 million to build R/Vs *Thompson*, *Atlantis* and *Revelle* and extensively refit *Knorr* and *Melville,* all of which are large ships. The Navy has committed $45 million to replace one intermediate research vessel, R/V *Moana Wave*. The Navy has also funded expensive multibeam sonar systems, winches and fiber optic oceanographic cables for the large ships, and has provided the bulk of the support for the development of remotely operated vehicles and autonomous underwater vehicles. In the past decade, private institutions have capitalized five new vessels for the Academic Research Fleet without cost to the government. Such institutional support continues. This new construction is providing state-of-the-art platforms that are specifically designed to support oceanographic research. In addition, because of the distributed nature of vessel operations, state and institutional funds offset operational costs in some cases. These partnerships continue to be highly cost effective for all.

As the ability of the UNOLS fleet to support more sophisticated and demanding oceanographic research has increased significantly in recent years, so has the gap between what UNOLS ships and industry vessels can provide. A key drawback of contracting industry vessels is that there are few platforms available which are configured and equipped to support the diversity of oceanographic research without significant additional outfitting costs. Commercial ships suitable for general purpose oceanographic research often have spartan lab facilities, if any at all. The independent contractor even noted that "clean" power, a staple on UNOLS ships, and a basic requirement for operating computers and other equipment, may be unavailable, even unknown on commercial vessels.

However, where industry does present significant capabilities not available within the UNOLS fleet (e.g., special 3-D geophysical systems), NSF has in the past provided funds to make such capabilities available to individual research projects. In these few cases, the arrangements have fallen to the principal investigator of the project. The Committee is concerned that such arrangements put a heavy burden on the investigator's ability to provide due diligence and ensure high standards of safety. After considerable discussion, the Committee decided to encourage NSF to consider an experiment where an industry contractor could participate as a non-member operator of UNOLS for the purpose of arranging for unique capabilities when needed. This would ensure the use of UNOLS standards for operation, safety, and reporting and obtain a benchmark for the cost of such operations.

There was a special discussion of the use of "bare boat" (no food, fuel, equipment and limited daily hours of operation) charters. There are cases where the research being supported requires no additional installed equipment other than that which can be brought aboard by the investigator. The independent contractor's report provided bare boat estimates for four operators and ten vessels. When the average daily costs of food and fuel were added to these estimates, the costs were comparable to or slightly higher than equivalent UNOLS operating costs (Appendix I). These estimates were provided in a market with the lowest costs seen in several years. The Committee was concerned that a proliferation of this type of charter arrangement through individual investigators could lack in due diligence and compromise safety standards.

For ocean research platforms other than the general purpose platforms discussed above, NSF has made effective use of commercial arrangements. The special element of these arrangements is either a unique operational mission (e.g., deep ocean drilling) or unique long-term deployment to a specific unique environment (e.g., Antarctic ocean research). In both instances very specific modifications to the vessel under contract were required to make the vessels suitable for scientific research.

In addition to the obviously beneficial capital investment and operational support from Navy and other operating institutions, the Committee concluded that the true strength of the NSF/ UNOLS system, beyond the scheduling process and high safety and operating standards, lies in operator interest in science and provision of the well trained and motivated crews which support research at sea. Given the diversity of science supported by the general oceanographic ships, this appears to be the most difficult challenge for the commercial operator to duplicate except when the capabilities provided are unique and the contractual relationship is long-term.

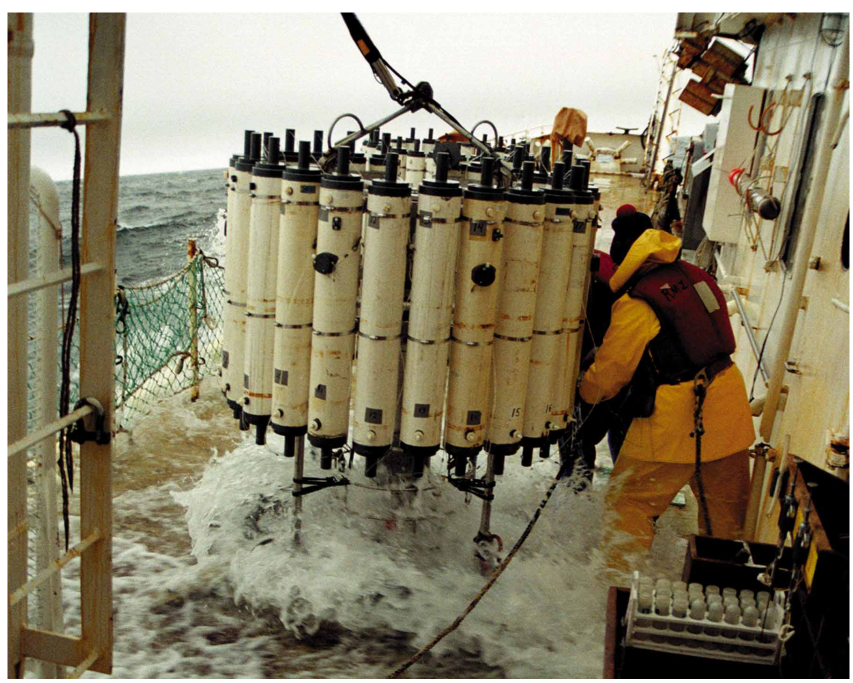
6. Findings and Recommendations

Current and Projected Research Fleet Requirements

The Academic Fleet is emerging from an era of intense utilization. During the last decade, several major programs of oceanographic research have completed their field efforts. Currently these data are being processed, analyzed and used to better understand the oceans. Projections for fleet use for the next few years may decline, falling to less than the current capacity. Federal agencies with responsibilities for funding of the oceanographic fleet have been evaluating courses of action ranging from lay-up of some platforms to expanded use of UNOLS assets by more applied oceanographic programs.

Emerging needs and opportunities for fleet-based ocean research are large. Current issues centered on global climate change and marine ecosystems cannot be resolved without a significant increase in our understanding of the oceans, their exchanges with the atmosphere and the impact of anthropogenic stresses. Such understanding requires collection of large amounts of high quality data, and will require substantial use of research vessels, moored sensors and satellites. Further, more and more human demands are being placed on the resources of the sea (especially in the coastal regions of the world and by fisheries) without fully understanding their long-term impact. Thus many global and international issues of high importance depend on knowing more about the oceans. The ocean research community, at many levels, needs to accelerate planning for this future need.

The potential for near-term decrease in utilization of ocean-going research facilities is real. It may represent a transient condition, as new planning for ocean programs identifies the next cycle of field efforts. This provides an opportunity to respond to some management issues in fleet operation and to continue to improve the capability, productivity, and quality of fleet operations as a means of achieving NSF research and educational objectives in ocean sciences.



The community of ocean scientists must assess the future needs and opportunities of the field to establish priorities for future work, and to clarify the balance between coordinated programs and individual investigator efforts. Several recent workshops have addressed the goals of individual disciplines, and a National Research Council report, "Global Ocean Science," has examined the major oceanographic programs. There now needs to be an integration of these various efforts into a broad, coherent vision that can guide future directions, of small, intermediate, and major programs. Ocean science, like astronomy, space science, and high energy physics, all requiring major, shared facilities, cannot address every important need and opportunity by relying solely on proposals of independently working investigators. A broad vision is essential to anticipate future fleet requirements.

Additionally, a separate, but closely related, effort should be made to identify emerging and future technologies that can have a great impact on future research efforts. Many opportunities exist for significant advances in instrumentation, equipment and techniques that do not emerge automatically from presently identified research needs. As new capabilities arise, new research ideas can emerge and vice versa. Neither, alone, should be relied upon to identify all of the promising avenues of future research.

> ***NSF must accelerate and expand efforts within the oceanographic research community to articulate a broadly based vision for the future of ocean science and technology requirements. This will provide a much needed foundation on which to plan and procure major facilities for research.***

MANAGEMENT STRUCTURE AND CAPABILITIES

Overall, the UNOLS system of planning and allocating the resources of the Academic Research Fleet gets high marks from the scientific community and from other agencies that participate or cooperate with it. Several recurrent issues such as improvement in the scheduling process (especially abrupt changes), equal support of non-operator researchers, quality of shore support, and maintenance/support of installed and pool equipment need to be worked on and improved. The orientation towards a continuous improvement program and a formal quality control program (looking toward the best industry training and practices) needs to be infused into the entire UNOLS and operator system.

NSF, on the behalf of the committee, engaged an independent contractor to conduct a review and cost analysis for support of oceanographic research. Findings indicated that the NSF-UNOLS system, with institutional vessel operators and centralized scheduling of scientific parties, is on par with costs for operation of like vessels by other federal agencies and international organizations. UNOLS operating costs are comparable to estimates provided by several commercial contractors when adjusted from their "bare-boat" estimates. Even with this analysis, however, the committee finds that it is very difficult to get fully comparable estimates of cost between UNOLS and commercial operations.

The goal of any research facility should be to find the optimum path to satisfy the needs of the research enterprise. In this context, for support of oceanography, this may require going outside the present UNOLS fleet for specific capabilities. We believe a case can be made to include some commercial charter operations that meet UNOLS standards as part of UNOLS operations, to provide capabilities unavailable within the UNOLS fleet. We note that in special circumstances, the federal funding agencies already go outside the UNOLS system for specialized capabilities; we recommend here that this might be better done inside the UNOLS system. We do not recommend "bare-boat" chartering due to complex issues of safety, mobilization and technical support. We expect the use of commercial vessels to be only a small fraction of total usage, but expanding UNOLS' scope in this manner would have at least two important advantages: greater ability and flexibility to meet science needs, and outside benchmarks.

> ***The UNOLS system should be retained. The NSF-UNOLS current practices, using institutional operators funded by NSF and other federal agencies with centralized scheduling through UNOLS, seems to provide excellent access to the sea for US investigators. To the extent the committee can assess, costs appear comparable to or better than government operators, and not evidently different from costs of contracting commercial platforms.***
>
> ***The funding agencies and UNOLS need to support fleet improvements by enhancing quality control, expanding training of personnel in technical and safety procedures, and developing even higher standards for shared use facilities.***
>
> ***NSF should continue the practice of periodically competing the management of the UNOLS office, and should consider funding it by a cooperative agreement rather than a grant to ensure necessary management oversight.***
>
> ***We ask NSF to consider a trial which includes some commercial operators participating as UNOLS non-member operators to provide unique capabilities not otherwise available.***

The current system of ownership and operation of ships works well. While there is general satisfaction with ship operations in the UNOLS fleet, there are opportunities for improvement. This is the right time to launch a significant campaign to upgrade and strengthen the fleet, not only to prepare it for increasing technological sophistication, but also to improve the future productivity and quality of fleet operations. For the owners, operators and crew there should be programs implemented for continuous improvement and high standards of safety and quality control. To this end, appropriate programs of education and training for all participants should be a regular and ongoing activity.

Improvements are needed in the strategies and practices of planning and managing "common" shipboard equipment. Owners and operators, working through UNOLS and in conjunction with NSF and other federal agencies, should develop policies and practices for managing shared-use, technical support in the Academic Research Fleet.

> ***There is a need for a strong, continuing program of new technology introduction; steady improvement of existing facilities and technologies; greater, continuing attention to quality control and safety; and a more systematic, standard approach to maintenance, renovation, upgrading, and replacement.***

It is clear from the projections of the service life of all ships supporting oceanographic research that continuous planning is needed to prevent obsolescent facilities. In past years, individual agencies initiated construction efforts as need and budget opportunity presented. In addition, new ships have been brought into the UNOLS fleet without the guidance of a comprehensive long-range plan. With such a plan, research requirements can be directly addressed even in circumstances where external political processes modulate vessel allocation.

Nationally, the federal agencies can and should do a better job of coordinating long range planning for facilities with twenty to thirty year life spans. More commonality of design will provide cost savings. Joint planning can keep average fleet age relatively low in each major class and provide the latest in technology to support research. Any such plan should be robust enough to accommodate both adding and removing vessels from the fleet. This is clearly beyond the scope of NSF and UNOLS acting independently. However, by virtue of its dominant funding role for the Academic Research Fleet, NSF should lead the effort with strong support from the Navy and NOAA.

> ***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.***