DRAFT March 1994

UNOLS FLEET IMPROVEMENT PLAN UPDATE SPRING 1994

Prepared by the Fleet Improvement Committee
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Table of Contents
UNOLS Fleet Improvement Plan Update 1994

Appendices:

Executive Summary of the 1993 Update of the UNOLS Fleet Improvement Plan

The University National Oceanographic Laboratory System (UNOLS) plays an active role in assessing the quality and effectiveness of the academic research fleet. One aspect of this role is to try to look ahead to future facility needs of the academic research community and to compare these needs to the existing fleet and the projected fleet five to twenty years hence. This is basically a planning effort that is done in close coordination with NSF and ONR, the two principal agencies that fund ship construction, maintenance and operations. The plans and recommendations that evolve from this effort develop interactively between these agencies and the UNOLS community.

The UNOLS-Fleet Improvement Committee (FIC) is a standing committee of UNOLS and has the specific mandate to continually assess the number and mix of ships in the UNOLS fleet and develop plans for additions, replacements or retirements from the fleet. To this end the FIC published a document entitled the UNOLS Fleet Improvement Plan in May 1990 that gave, among other things, specific recommendations with respect to fleet size and composition for the decade of the nineties. The document is intended to be an evolving one that would updated periodically as new needs arise, financial circumstances change and as ocean science evolves. This report represents the first update of the May 1990 Fleet Improvement Plan.

At the time of publication of the first Fleet Improvement Plan significant changes in the UNOLS fleet were underway with respect to the large ships in the fleet. In 1990 the KNORR and MELVILLE were in a shipyard for refit, conversion of their propulsion systems, and a 30' stretch of their length. The Navy was building the first of a new class of large high-endurance research vessel (the 274 foot AGOR-23 class). The KNORR and

MELVILLE emerged from the shipyard in 1991. The AGOR 23, named the THOMAS THOMPSON was launched in 1992 and is operated by the University of Washington. Thus, many of the entries on schedules in 1990 Fleet Improvement Plan are now fact, and a short back log of experience with operating these new larger ships has accrued.

These changes are the first steps in a program to upgrade or replace the larger ships in the UNOLS fleet. In the early 1980's virtually all of the large ships were approaching the end of their expected hull life or had become mission obsolete. This upgrade and replacement program is supported primarily by ONR with major inputs from NSF.

Plans for the near future include construction of a second ship in the AGOR 23 class (AGOR 24) which will be operated by the Scripps Institution of Oceanography. ONR has announced intentions of building an AGOR 25 for the UNOLS fleet, which will be operated by Woods Hole Oceanographic Institution. Currently, NSF is supporting a preliminary design study for an Arctic Research Vessel (ARV), and anticipates proceeding with construction in 1995. If all of the construction that is underway or planned is realized there will be 6 ships in the UNOLS research fleet over 275' long in the year 2000, whereas in 1990 there were no UNOLS ships longer than 245'.

The issues and opportunities that arise as ocean science and the UNOLS Fleet evolve are explored in this update of the Fleet Improvement Plan, and lead to the following recommendations:

1. Funding the future UNOLS Fleet

In the Table below we compare the recommendations of the 1990 Fleet Improvement Plan with the composition of the Fleet as it will be in the year 2000, if all current plans go forward. If these projections are fulfilled then the UNOLS Fleet in the year 2000 will be significantly more expensive to maintain than at present.

Table: Comparison of FIP-90 recommendations for UNOLS Fleet size and composition with projected Fleets in 1996 and 2000.

(Reference Table 5 FIP-90, p. 33, Table I-1 of this report)

Class of vessel	FIP-90	Displ.	2000	Displ.
Large High Endurance (LHE)	3	9,200	4	12,450
Med. High Endurance	2	4,500	2	4,500
Intermediate 150<LOA<200'	6**	6,000	6	6,000
Small 100<LOA<150'	9	2,780	9	2,780
Submersible Support	1†	2,300	1	2,700
Polar Research Vessel	1††	1,000	1	12,000
Totals	22	25,780	23	40,430

* The three LHE ships will be MELVILLE, THOMPSON and REVELLE.

** The Harbor Branch Ships JOHNSON AND SEALINK are not included.

† KNORR was included in the FIP-90 plan as a LHE ship will be converted to submersible support ship and the AII retired.

†† FIP-90 recommended a small ice-capable ship to replace the ALPHA HELIX. The ice-capable ship projected for the year 2000 will be the largest ship in the UNOLS Fleet (340 feet LOA)

Data presented in Section I of the update shows that currently approximately 95% of the available large ship time is being used. This implies that funded ship time on UNOLS ships must increase by one ship operating year (275 days) or an increase of 25% by the year 2000. Another concern is the underutilization of intermediate sized vessels. Only 80% of the available shiptime is used. This low utilization has been chronic for nearly a decade.

Will there be a sufficient increase in funding for shipboard science by the year 2000 and beyond to warrant an increase in the number of large ships from three to four?

Will the demand for shiptime on intermediate-sized vessels increase to fill the current excess capacity?

These questions can only be answered in vague terms because neither UNOLS or funding agencies have no credible way of projecting ship demand for more than a year or two into the future. However, we believe that data exist to do a much better job of projecting ship needs.

Our first recommendation addresses this need.

- *FIC recommends that Federal Oceanographic Fleet Coordinating Committee (FOFCC) establish a mechanism for annually updating projections of future oceanographic facility needs looking 5 to 10 years ahead. Resources for developing this report are the facilities management centers at the agencies, the UNOLS Office and the principal investigators of large programs. This assessment should include needs of the oceanographic research components of NOAA, the Navy and other federal agencies..*

Arctic Research Facilities

The Arctic Ocean is the least explored of all the world oceans, and yet critical issues of climate change, climate prediction and pollution have underscored the need for a major increase in oceanographic research in the Arctic region. Currently, the United States has a very meager oceanographic capability for the Arctic Ocean. US scientists interested in working in the Arctic Ocean have been making observations from camps on the pack ice or ice islands or hitching rides on Coast Guard ice breakers, foreign research vessels as opportunities arise rather than according to the requirements of their research plans. These methods and vehicles will not suffice for future research in the Arctic.

To gain access to the central Arctic Ocean and carry out state-of-the-art, observational programs will be expensive; much more expensive than traditional ocean-going research. New types of platforms are required to adequately address the critical problems in the Arctic Ocean such as powerful ice breakers equipped with modern oceanographic capability. For certain types of observations the nuclear powered submarine with its long range and virtually unlimited access to deep, ice-covered regions of the Arctic offers a potent research platform. However, a major commitment of new federal funds to acquire and operate them is essential.

•*The Fleet Improvement Committee identifies the urgent need to develop a community-wide, interdisciplinary program of research in the Arctic of ten or more years duration [e.g. Decade of Arctic Oceanography (DAO)]. The program should involve all major disciplines; hydrology, ocean chemistry, ice dynamics, meteorology, climatology geology geophysics and biology. It should involve academic and agency scientists. The program plan should include an assessment of facility needs. Much of the background material for such a program has already been published in the form of workshop reports and articles.*

Efforts to obtain improved facilities for the Arctic are already underway. The Coast Guard is building a Class 4 or 5 ice breaker (Polar

Research Vessel, PRV), that will be equipped as an oceanographic research vessel. This ship, which will operate in Antarctic as well as Arctic regions, will be an important addition to the U.S. oceanographic capability in Polar seas.

NSF is pursuing the construction of an Arctic Research Vessel (ARV). The preliminary design of the ARV incorporates the very latest ice breaking technology, which has the potential to make a significant improvement in fuel efficiency and ice trafficability compared to conventional hull forms. The ARV will serve as the primary Arctic platform for U.S. scientists. Its operations will be enhanced by the Coast Guard's Polar Research Vessel (PRV) because the ARV and the PRV working together will make it possible to carry out expeditions deep into the permanent Arctic ice pack, which requires two or more ships. Additionally the Coast Guard's PRV will spend part of each year in the Antarctic; thus, is unlikely to be available for winter cruises in the Arctic region. However, the ARV will be able to work safely in marginal ice zones during the Arctic winter, and carry out critical cryological and hydrographic studies in winter conditions.

- *FIC recommends that the Arctic Research Vessel be the highest priority acquisition for Arctic oceanographic research. The FIC strongly supports the addition of the ARV to the UNOLS fleet and recommends that it be operated by a UNOLS institution. The FIC and UNOLS take the position that the Arctic Research Vessel should be built only if sufficient new funds are available for its construction and operation.*

Coastal Oceanography Needs

A February 1993 workshop on facility needs for coastal oceanography identified a specific need to investigate a new generation of large capacity, shallow-draft vessels for coastal ocean science.

•The FIC recommends that scientific mission requirements be established and a conceptual design study be carried out for a "shallow-water high capability research vessel".

The Coastal Workshop also recognized that because of the large number of ships of all sizes that are used for coastal research, it will be impossible to equip all ships with state-of-the-art technology. This situation can be ameliorated to a significant degree by sharing equipment and facilities.

•FIC recommends that funding agencies encourage regional or national arrangements to share certain expensive equipment and facilities used by coastal oceanographers. Coastal oceanographers should develop commonality between institutions for routine and widely used instrumentation, instrument calibrations, technician training, and computer applications.

Inter-Agency Cooperation

The recent increase in cooperation between oceanographers at government agencies and UNOLS institutions has greatly benefited both parties and is applauded by the FIC.

•FIC recommends that federal and academic scientists who depend on ships and other seagoing facilities for their research continue to examine ways to improve cooperation. The FIC recommends collaboration that preserves the distributed management of oceanographic facilities, and

recommends against central management of the U.S. research fleet by the federal government or private industry.

Modes of Operation

FIC recognizes that under certain circumstances leasing ships may be preferred because of logistical convenience, or a need for a capability that is not available on a UNOLS ship; however, for most funded research the direct feedback by scientists into operations, the research-centered management style and lower cost of operations are advantages that the UNOLS mode of operating research ships has over long-term leasing from a commercial operator.

•*FIC recommends that UNOLS vessels, operated by universities and academic research institutions, continue to be the primary source of seagoing facilities for the academic oceanographic community.*

Distribution of the Fleet:

Evolution of the UNOLS Fleet with time can lead to an unfavorable distribution of ships relative to regions of the ocean of greatest scientific interest or the demographics of the oceanography community. Such imbalances can adversely affect the efficiency of the Fleet, the accessibility of seagoing facilities to certain research centers, and the overall strength of oceanography in the United States. The possible retirement of the University of Hawaii's MOANA WAVE and the University of Alaska's ALPHA HELIX from the UNOLS Fleet in next 5 to 10 years would create such an imbalance and threaten the existence of one or both of these important operational bases for oceanographic ships. The consequences of such an eventuality deserve serious consideration and timely remediation.

•FIC recommends that the agencies that support the UNOLS research Fleet should evaluate the projected geographical distribution of the year 2000 UNOLS Fleet. They should reassign existing and/or assign new ships to maintain a geographical balance that best serves the U.S. oceanographic community as a whole. In particular we stress the need to maintain Hawaii and Alaska as operating bases for one or more ships of the UNOLS Fleet.

I. BACKGROUND

A. The Fleet Improvement Committee

A goal of UNOLS — and one of the objectives for which UNOLS was established — is to develop and update a long-range plan for university oceanographic facilities. The importance of such a plan cannot be overstated. Most oceanographic facilities, especially ships, are built with federal funds, all new acquisitions must compete in an increasingly rigorous contest for support. Unless requests for new ships and other facilities are accompanied by substantive, credible, and approved plans showing how such new facilities fit into the needs for future oceanographic research, those requests will have little likelihood of succeeding.

The UNOLS process of planning for an improved fleet was initiated with a Preliminary Report of a UNOLS Long Range Planning Meeting (May 1975), and a UNOLS Advisory Council report "On the Orderly Replacement of the Academic Research Fleet" (July 1978).

In 1984, based on recommendations of its Advisory Council, UNOLS established an ad hoc Fleet Replacement Committee (FRC) charged with planning for the orderly replacement of the UNOLS Fleet. The charges to the FRC were to:

> "1) Make an immediate start on planning for replacement of ships (large, long-range vessels [200 ft or greater LOA], some with special purposes). Some of these must be retired by the 1990's. Such ships are essential to our capability for modern oceanography. Planning for replacement must begin. The committee will prepare and propose mechanisms for drawing specific plans for new platforms.

2) A full schedule for replacement of intermediate and coastal vessels (150 to 199 ft LOA and 100 to 149 LOA), respectively must be prepared. Planning must begin for at least one replacement in the late 1980's.

3) Detailed consideration is required of new means to promote greater cost efficiency, particularly fuel efficiency.... ."

As of the writing of this update, the first charge has been fulfilled. With regard to the second charge planning to replace intermediate-sized vessels has not begun, however a program to greatly extend the life of the Oceanus Class vessels has begun. Replacement of the R. WARFIELD and CAPE HENLOPEN is being considered as an integral part of the planning for a new coastal research vessel (see Section II-A). The third charge has diminished in importance as oil prices have decreased.

The FRC formulated scientific mission requirements for six classes of oceanographic vessels: three large, one intermediate, and two small. It prepared plans for refitting the KNORR and MELVILLE and for construction of additional new large vessels with improved scientific capabilities. It commissioned and supervised six concept designs, worked with the U.S. Navy in the preparation of two other designs by Naval Sea Systems Command (NAVSEA), and in 1986 published summaries of ten concept designs for large oceanographic research vessels in three sub-classes; SWATH vessels, high-endurance monohull, and medium-endurance monohull. Finally, the FRC prepared "A Plan for Improved Capability of the University Oceanographic Research Fleet" dated June 1986. This plan included by reference a "Summary of Concept Designs", "Science Mission Requirements for New Oceanographic Ships", and six reports of individual new ship design studies.

So successful was the FRC, that in November 1986, UNOLS established a standing Fleet Improvement Committee. The purpose and organization of that committee, as adopted by UNOLS in October 1988 as an Annex to its Charter, follow.

"*Purpose*. The Fleet Improvement Committee works to assure the continuing excellence of the UNOLS fleet, to improve the capability and effectiveness of individual ships and to assure that the number, mix and overall capability of ships in the UNOLS fleet match the science requirements of academic oceanography in the U.S. To that purpose, the Committee maintains the currency of a dynamic *UNOLS Fleet Improvement Plan*. The plan, updated periodically, includes:

- •Assessment of the number and mix of ship capabilities needed in the UNOLS fleet,
- •Development of science mission requirements for all size- and capability-classes of ships,
- •Definition of roles and the need for innovative research platforms,
- •Consideration of means for acquiring the needed vessels, including new construction, modification to existing UNOLS ships, conversions, private acquisition and leasing.
- •Development of conceptual or preliminary plans for ships to fill the needs identified, and
- •Development of a schedule for improvement and replacement of vessels so as to assure continuing fleet excellence.

The Fleet Improvement Committee will serve as a *liaison and planning activity as well as an information source* for federal agency representatives concerning long range planning, and funding for design, construction, or renovation of vessels for the UNOLS fleet.

Organization.: The Chair and eight additional members of the Fleet Improvement Committee are appointed by the UNOLS Chair with approval of the UNOLS Council. Those appointed should be experienced in ship operations and from institutions which are either operators or users of UNOLS research vessels. The Chair and at least three other members will be from UNOLS operator institutions, at least two members will be from institutions other than operators, and two members may be from any UNOLS institution. The FIC Chair is, ex-officio, a member of the UNOLS Council. Terms for all members are three years, for no more than two consecutive terms.

In 1993 liaisons were established between the FIC and three other standing committees of UNOLS; the Deep Submergence Science Committee (DESSC), the Research Vessel Operators Committee (RVOC) and the Research Vessel Technical Enhancement Committee (RVTEC) to improve communications between the committees. A member of the FIC attends DESSC meetings in an ex-officio capacity and members of the RVOC and the RVTEC attend FIC ex-officio.

B. Purpose and objectives of the update

Beginning with the FRC plan, and incorporating its studies and new developments in ocean sciences, the Fleet Improvement Committee prepared a revised plan in 1990 for the continued improvement of the UNOLS fleet (UNOLS Fleet Improvement Plan, May 1990).

This 1994 update of the UNOLS Fleet Improvement Plan is based upon needs envisioned through the year 2010. Although overall numbers of ships probably will not differ significantly from current inventories, changes are anticipated in areas of special ships for submersible, ROV and AUV handling; coastal oceanography, polar research and new ships that can do kinds of science that our present ships cannot now do, and to do them in places, times, and sea states in which our present ships are prohibited.

Basic criteria brought forward from the 1990 fleet improvement plan still apply. The plan must be:

- •Responsive to the anticipated future trends and needs of oceanographic research and engineering,
- •Realistic in terms of the national economy,
- •Bear the general approval of the academic research community,
- •Sufficiently credible to compete in the federal funding infrastructure,
- •Provide a logical implementation scheme bridging the current and projected time frame, and
- •Provide for periodic updating.

C. The UNOLS Fleet

What is a UNOLS ship? According to the UNOLS charter, "UNOLS vessels are those so designated by the UNOLS Council. They are those United States research vessels generally operated in support of national oceanographic research programs, by academic (UNOLS member) institutions and are significantly funded by the federal government. They are operated in accordance with UNOLS safety standards, subject to regular, recognized ship inspection programs, scheduled by established UNOLS procedures and meet cruise reporting, cruise assessment, cost accounting and performance standards according to UNOLS uniform practices. UNOLS vessels... are regularly available to users outside of the operator institution provided that funding is available...."

Being designated a UNOLS vessel will mean that it is basically certified to safely and effectively carry out academic research and to be available to the oceanographic community for scheduling. UNOLS has become a certifier of academic research vessel operations by recommendations and responses to federally proposed actions to ensure that the research community has quality facilities from which to operate.

Most of the research projects of the federal oceanographic program are carried out by ships of the UNOLS fleet, although basic research also is carried out from vessels owned and operated by the National Oceanic and Atmospheric Administration, U. S. Navy, Environmental Protection Agency, U. S. Coast Guard, and U. S. Geological Survey. The chief sponsors for the use of UNOLS ships are the National Science Foundation and the Office of Naval Research.

The size of the operational fleet thus defined has varied with time. In recent years the number of ships longer than 100 feet has remained within 10% of twenty. In 1994, UNOLS ships comprise a 26-ship fleet operated by 19 institutions or consortia; see Table I-1. Although vessels constructed or converted with federal funds are owned by whoever holds title to them, they are designated as federally-procured. Nine of the UNOLS ships were built under grants from NSF. Five, including all of the large general-purpose UNOLS vessels, were built and are owned by the U.S. Navy and chartered by the Office of Naval Research.

Table I-2 shows the composition of the projected 2000 UNOLS fleet if all of the current plans for ship retirements, conversions and construction come to fruition. This table shows that if plans are followed the number of large ships in the fleet will increase by one (the Arctic Research Ship) compared to 1994.

In Figure I-1 we show a representative schedule of construction, mid-life-refits and retirements of the larger vessels in the UNOLS fleet based on a ship lifetime of 30 years and mid-life refits at 15 years. Figure I-1 also

Table I-1. The UNOLS Fleet – 1994

SHIP NAME	LOA (m)	LAUNCH/ CONVER.	DISPL. TONS	SCIENTIFIC BUNKS	OPERATOR
LARGE HIGH-ENDURANCE GENERAL-PURPOSE SHIPS					
≥ 250 Feet					
KNORR (AGOR-15)	84 (275')	1968/91	2,685	34	Woods Hole
MELVILLE (AGOR-14)	84 (275')	1968/91	2,685	35	Scripps
T.THOMPSON (AGOR-23)	84 (274')	1991	3,250	27	U. Washington
LARGE MEDIUM-ENDURANCE SHIPS					
200-250 Feet					
MAURICE EWING	73 (239')	1984	2,637	32	L-DEO
MOANA WAVE (AGOR-22)	64 (210')	1973/84	1,853	19	U. of Hawaii
INTERMEDIATE SHIPS					
150-199 Feet					
ENDEAVOR	54 (177')	1976/94	962	16	U. Rhode Island
GYRE (AGOR-21)	55 (182')	1973	980	23	Texas A&M
ISELIN	52 (170')	1971	830	24	U. of Miami
NEW HORIZON	52 (170')	1978	1080	19	Scripps
OCEANUS	54 (177')	1975/94	960	12	Woods Hole
WECOMA	54 (177')	1975/94	1059	20	Oregon State U.
SMALL SHIPS					
≤ 149 Feet					
ALPHA HELIX	40 (133')	1965/82	600	15	University of Alaska
BLUE FIN	22 (72')	1972	132	8	Skidaway
CALANUS	21 (69)	1971	88	6	Univ. Miami
CAPE HATTERAS	41 (135')	1981	539	12	Duke U.
CAPE HENLOPEN	37 (120')	1975	165	12	U. of Delaware
LAURENTIAN	24 (80')	1974	180	8	Univ. Michigan
LONGHORN	32 (105)	1971/86	210	10	Univ. Texas
PELICAN	32 (105)	1985	244	15	Louis. Univ. Consort.
POINT SUR	41 (135')	1981	539	12	Moss Landing
R. G. SPROUL	38 (125')	1981	524	12	Scripps
WEATHERBIRD II	35 (115')	1989	250	10	Bermuda BS
SPECIAL SHIPS					
Submersible-Support					
ATLANTIS II	64 (210')	1962/83	2300	28	Woods Hole
EDWIN LINK	51 (168')	1988	781	20	Harbor Branch
SEA DIVER	34 (113')	1959/93	189	18	Harbor Branch
SEWARD JOHNSON	54 (176')	1984	880	20	Harbor Branch

Table I-2. The PROJECTED UNOLS Fleet – 2000

SHIP NAME	LOA (m)	LAUNCH/ CONVER.	DISPL. TONS	SCIENTIFIC BUNKS	OWNER	OPERATOR
		LARGE HIGH-ENDURANCE SHIPS ≥ 250 Feet				
AGOR-25	84 (274')	1997	3,250	(35)	U.S. Navy	WHOI
MELVILLE (AGOR-14)	84 (275')	1968/91	2,300	35	U. S. Navy	Scripps
ROGER REVELLE (AGOR-24)	84 (274')	1995	3,250	(35)	U.S. Navy	Scripps
T.THOMPSON (AGOR-23)	84 (274')	1991	3,250	27	U.S. Navy	U. Washington
		LARGE SHIPS ≥ 200 Feet				
MAURICE EWING	73 (239')	1984	2250	32	NSF	L-DGO
MOANA WAVE (AGOR-22)	64 (210')	1973/84	1403	19	U. S. Navy	U. of Hawaii
		INTERMEDIATE SHIPS 150-199 Feet				
ENDEAVOR	54 (177')	1976/94	962	16	NSF	U. Rhode Island
ISELIN	52 (170')	1971	830	24	NSF	U. of Miami
NEW HORIZON	52 (170')	1978	1,080	17	Scripps	Scripps
OCEANUS	54 (177')	1975/94	960	12	NSF	Woods Hole
WECOMA	54 (177')	1975/94	1059	20	NSF	Oregon State U.
		SMALL SHIPS ≤ 150 Feet				
ALPHA HELIX	40 (133')	1965/82	600	15	University of Alaska	
BLUE FIN	22 (72')	1972	132	8	Skidaway	
CALANUS	21 (69')	1971	88	6	Univ. Miami	
CAPE HATTERAS	41 (135')	1981	539	12	Duke U.	
CAPE HENLOPEN	37 (120')	1975	165	12	U. of Delaware	
LAURENTIAN	24 (80')	1974	180	8	Univ. Michigan	
LONGHORN	32 (105')	1971/86	210	10	Univ. Texas	
PELICAN	32 (105')	1985	244	15	Louis. Univ. Consort.	
POINT SUR	41 (135')	1981	539	12	Moss Landing	
R. G. SPROUL	38 (125')	1981	524	12	Scripps	
WEATHERBIRD II	35 (115')	1989	250	10	Bermuda BS	
		SPECIAL SHIPS Diving and submersible support ships				
KNORR (AGOR-15)	84 (275')	1968/91	2,300	(34)	U. S. Navy	WHOI
EDWIN LINK	51 (168')	1988	781	20	Harbor Branch	Harbor Branch
SEA DIVER	34 (113')	1959/93	189	18	Harbor Branch	Harbor Branch
SEWARD JOHNSON	54 (176')	1984	880	20	Harbor Branch	Harbor Branch
		Ice Capable				
ARCTIC RESEARCH VESSEL[1]	104 (340')	1996	10,000	35	NSF*	TBD

[1] This Arctic Research Ship is currently in the preliminary design stage. The large size currently being considered is based on designing a ship with an ice capability that will allow it to operate in the Central Arctic Ocean with icebreaker escort.

PROJECTED SCHEDULE OF CONSTRUCTION, MID-LIFE REFIT AND RETIREMENT OF SHIPS IN THE UNOLS FLEET

	93	94	95	96	97	98	99	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
LARGE SHIPS																							
Thompson	—	—	—	—	—	—	—	—	—	—	—	—	—	—	MLR	—	—	—	—	—	—	—	Thompson
Melville	—	—	—	—	—	—	—	—	—	—	—	—	—	-R									Melville
Ewing	—	—	—	—	—	—	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	-R	Ewing
AGOR 24		C-	—	-L-	—	—	—	—	—	—	—	—	—	—	—	—	MLR	—	—	—	—	—	AGOR 24
AGOR 25			C-	—	-L-	—	—	—	—	—	—	—	—	—	—	—	—	MLR	—	—	—	—	AGOR 25
Atlantis II	—	—	-R																				Atlantis II
Moana Wave	—	—	—	—	—	—	-R																Moana Wave
INTERMEDIATE SHIPS (150-200')																							
Endeavor	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R							Endeavor
Wecoma	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R						Wecoma
Oceanus	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R						Oceanus
New Horizon	—	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R					New Horizon
Gyre	—	—	—	—	—	—	—	—	—	—	-R												Gyre
Iselin	—	—	—	—	—	—	—	—	-R														Iselin
Johnson																							Johnson
Link																							Link
SMALL SHIPS (100-150')																							
Point Sur	—	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R					Point Sur
Cape Hatteras	—	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R					Cape Hatterus
Alpha Helix	—	—	—	—	-R																		Alpha Helix
Cape Henlopen	—	—	—	—	—	—	—	—	—	—	—	-R											Cape Henlopen
Sproul	—	—	—	MLR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-R				Sproul
Weatherbird	—	—	—	—	—	—	—	—	—	—	—	-R											Weatherbird
SPECIAL PURPOSE SHIPS																							
Knorr	—	—	—	—	—	—	—	—	—	—	—	—	—	-R									Knorr
Arctic RV				C-	—	-L-	—	—	—	—	—	—	—	—	—	—	—	MLR	—	—	—	—	Arctic RV
C = Construction start																							
R = Retirement																							
L = Launch																							
MLR = Mid-life refit																							

Total Cost Breakdown 1992

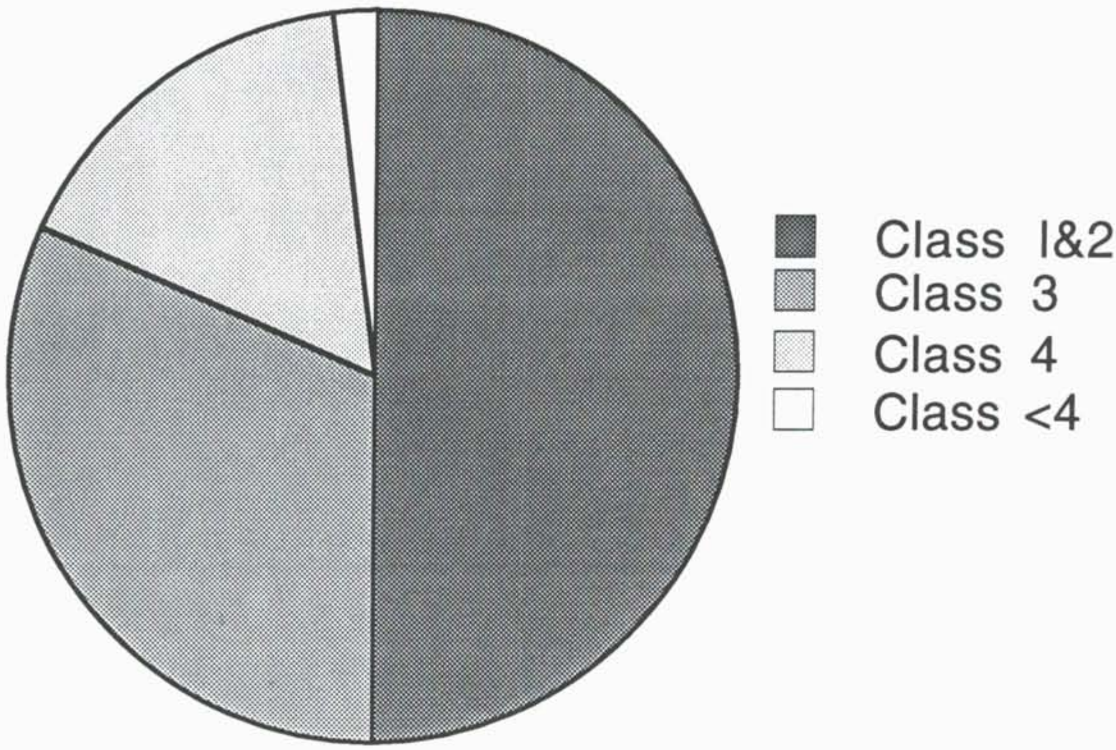


TABLE I-1A CLASS 1 & 2 (OPTIMUM SHIP YEAR 275 DAYS)

No. ships	Year	Days used	Days available	%use	Total cost thousands	Average daily rate	Adj. to 92 $ 4% inflater
7	1985	1916	1925	99.5	$19,277	$10,061	$13,240
7	1986	1612	1925	83.7	$18,832	$11,682	$14,782
7	1987	1771	1925	92.0	$19,285	$10,889	$13,249
7	1988	1964	1925	102.0	$21,401	$10,897	$12,748
5	1989	1093	1375	79.5	$13,294	$12,163	$13,682
4	1990	1052	1100	95.6	$15,865	$15,081	$16,311
5	1991	1279	1375	93.0	$17,436	$13,633	$14,178
5.8	1992	1595	1604	99.4	$23,161	$14,521	$14,521

TABLE I-1B Class 3 (OPTIMUM YEAR 250 DAYS)

No. ships	Year	Days used	Days available	%use	Total cost thousands	Average daily rate	Adj. to 92$ 4% inflater
7	1985	1177	1750	67.3	$8,660	$7,358	$9,682
6	1986	1191	1500	79.4	$8,112	$6,811	$8,618
7	1987	1499	1750	85.7	$11,320	$7,552	$9,188
7	1988	1272	1750	72.7	$10,842	$8,524	$9,971
6	1989	1281	1500	85.4	$10,136	$7,913	$8,901
8	1990	1628	2000	81.4	$11,291	$6,936	$7,501
8	1991	1700	2000	85.0	$14,897	$8,763	$9,113
8	1992	1675	2000	83.8	$14,681	$8,765	$8,765

TABLE 1-1C Class 4 (OPTIMUM YEAR 180 DAYS

NO. SHIPS	Year	Days used	Days available	%use	Total cost thousands	Average daily rate	Adj. to 92$ 4% inflater
7	1985	1110	1260	88.1	$6,019	$5,423	$7,136
7	1986	963	1260	76.4	$5,300	$5,504	$6,964
6	1987	888	1080	82.2	$5,268	$5,932	$7,218
6	1988	865	1080	80.1	$5,574	$6,444	$7,538
8	1989	1003	1440	69.7	$6,290	$6,271	$7,054
8	1990	1015	1440	70.5	$6,685	$6,586	$7,124
8	1991	1179	1440	81.9	$7,345	$6,230	$6,479
8	1992	1351	1620	83.4	$7,525	$5,570	$5,570

TABLE 1-1D Class 5 (OPTIMUM SHIP YEAR 110 DAYS)

No. Ships	Year	Days used	Days available	%use	Total cost thousands	Average daily rate	Adj. to 92$ 4% inflater
5	1985	566	550	102.9	$1,249	$2,207	$2,904
5	1986	493	550	89.6	$819	$1,661	$2,102
4	1987	491	440	111.6	$965	$1,965	$2,391
4	1988	348	440	79.1	$870	$2,500	$2,925
4	1989	383	440	87.0	$950	$2,480	$2,790
4	1990	371	440	84.3	$1,069	$2,881	$3,117
4	1991	416	440	94.5	$1,082	$2,601	$2,705
4	1992	408	440	92.7	$929	$2,277	$2,277

demonstrates the need for continued long-term planning for the refit and replacement of the academic fleet. As one example, four of the intermediate ships and two of the small ships are due for mid-life refits between 1993 and 1995, (the three OCEANUS class vessels are currently undergoing mid-life refits and a mid-life-refit for the New Horizon may closely follow). The same ships will reach retirement age in the interval 2008 and 2010. It is not realistic to anticipate 6 new ships during a 3-year span. Instead, new ship replacements must be planned to occur over a longer time period. Some ships will be expected to retire earlier and others operate past the nominal 30-year retirement age. If fleet capability is not to be jeopardized, replacement should begin as early as budget planning allows.

D. Utilization and cost trends

The total operating budget for the UNOLS Fleet in 92 was $48.7M. A breakdown of these costs by Class (Fig. I-2) shows that the Class 1 & 2 ships (ships longer than 200 feet) accounted for one half of all of the operating costs. Class 3 ships ("intermediates" 150 to 200 long) accounted for approximately one third, and about one sixth of the total funding for the UNOLS fleet goes to the ships less than 150 feet. All data cited in this section are taken from records kept by the UNOLS Office.

Tables I-3 (A-D) show utilization and cost data for eight years from 1985 to 1992 for each of the ship classes. The measure of utilization is the percentage of available ship days that were actually used for ocean-going research programs. For this analysis we use the RVOC definition of a "full operating year" as the number of days available as discussed in the next paragraph. The number of days in a "full operating year" varies with class of ship.

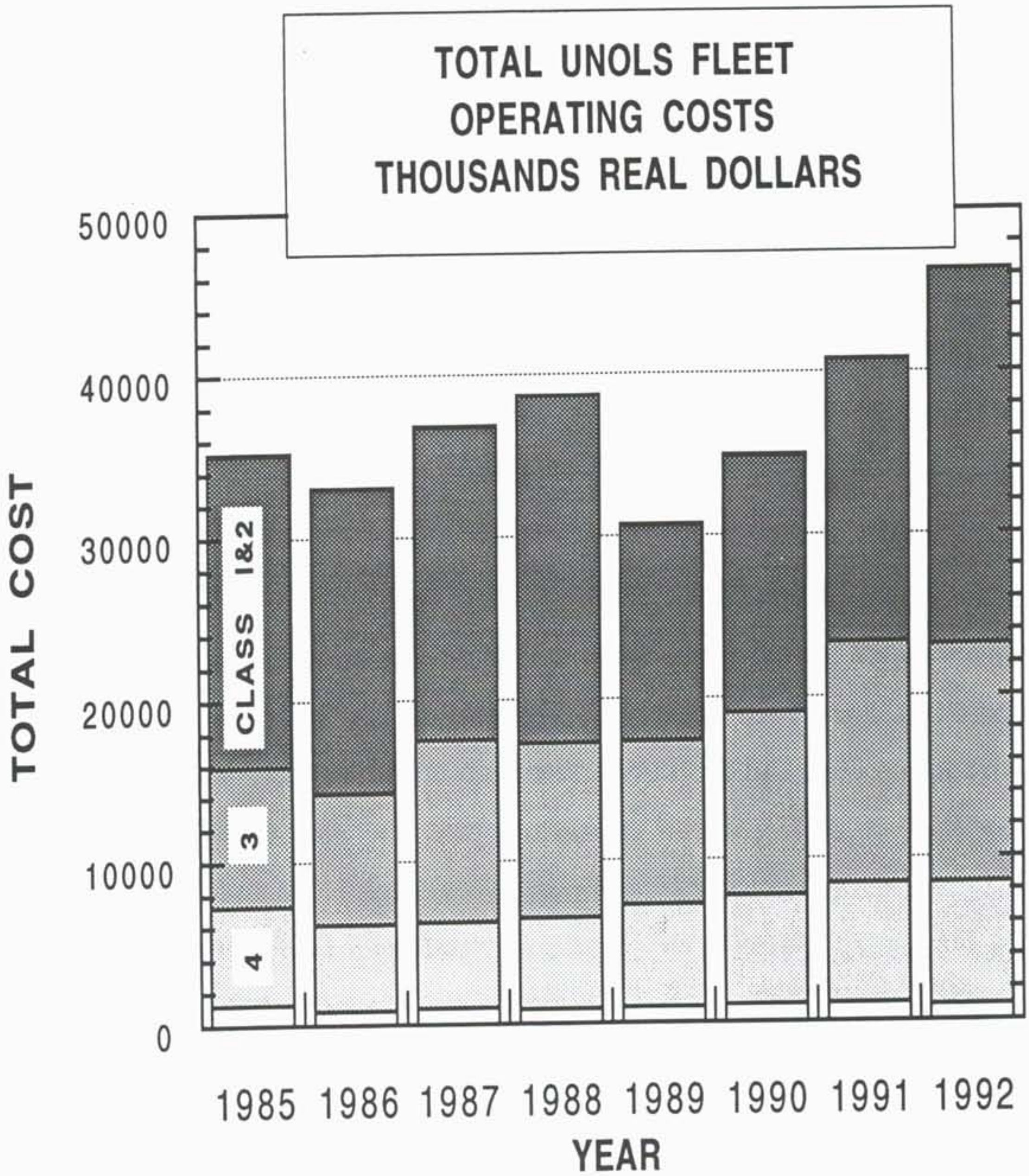
An analysis of the ship-use data is dependent on establishing realistic expected ship days per year of usage for each class of vessels. The UNOLS Research Vessel Operator's Committee (RVOC) has studied this issue and recommend the following definitions of a full operating year:

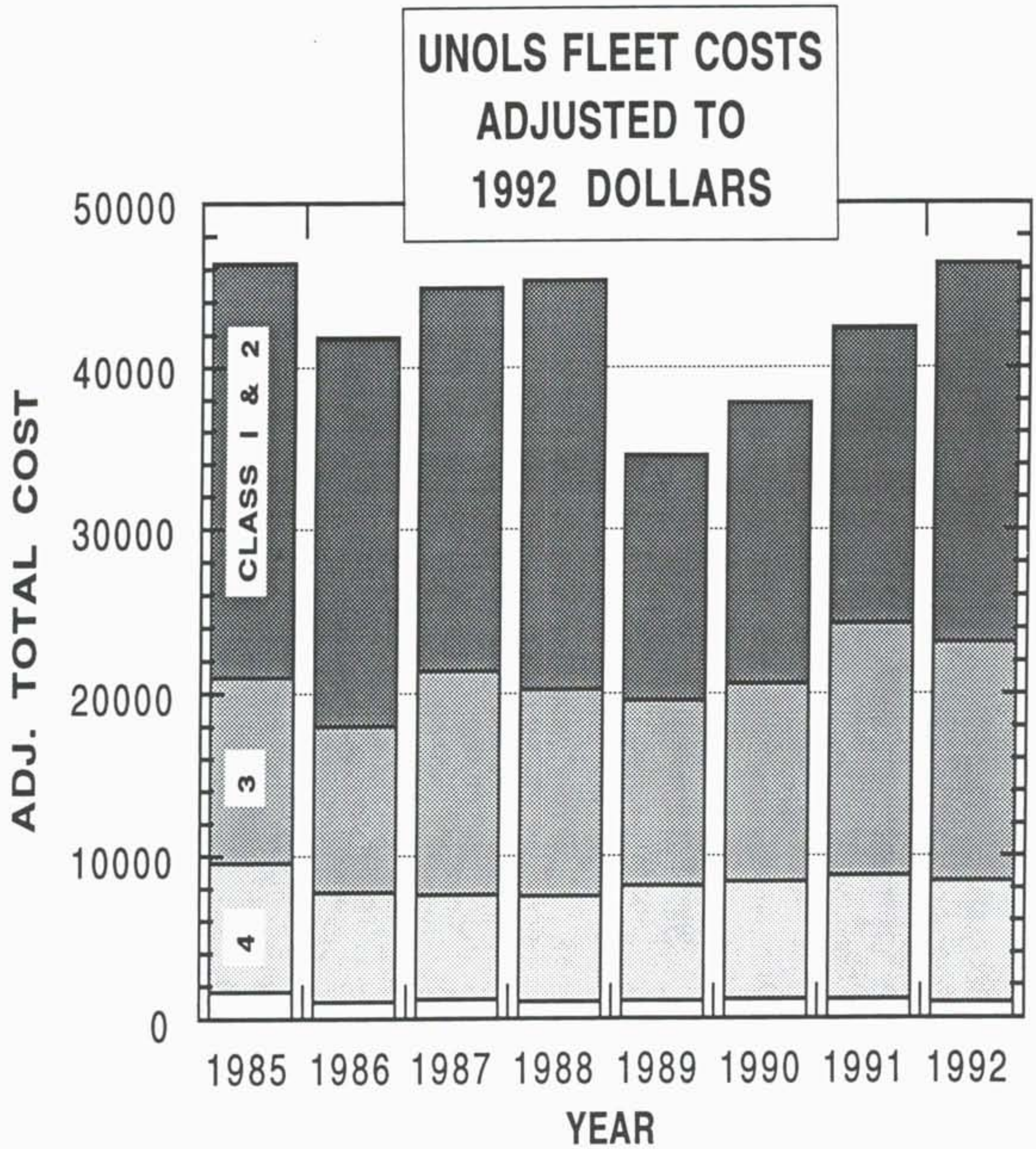
Class 1& 2	(200-275')	275
Class 3	(150-200)	250
Class 4	(100-150)	180
Class 5	(<100)	110

Judgments as to what constitutes a full ship year must be considered as flexible, because the actual number days that a ship spends at sea will depend on such variables as location home port, mode of operation, region of operation, age of the vessel etc. For example, if a ship usually operates near its home port and the home port is in an area where weather is often severe then an efficient full operating year may be somewhat less than average. On the other hand if a ship is operated globally and visits its home port infrequently, then it is practical to have a longer full operating year.

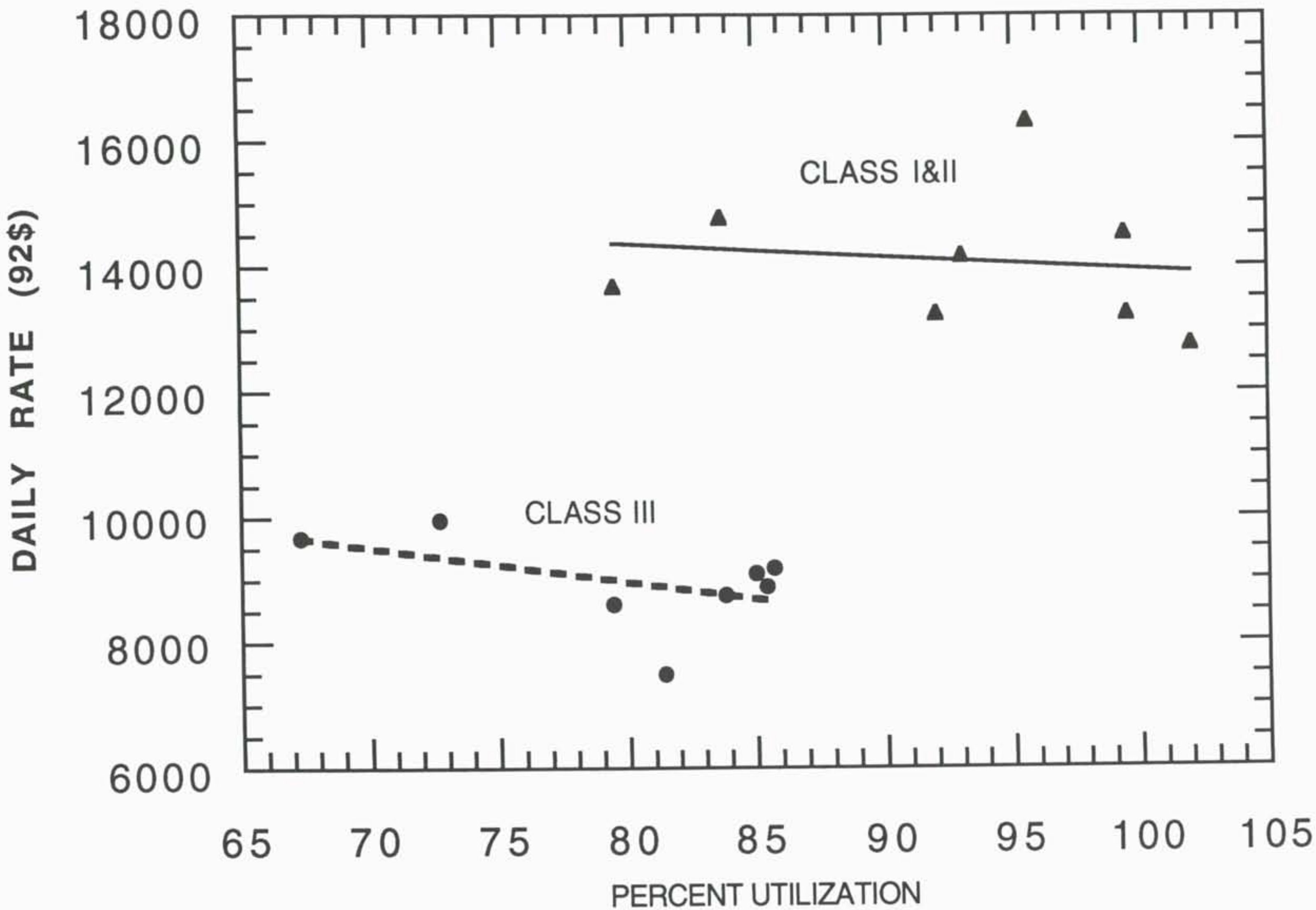
By these criteria the Class 1 & 2 vessels have been well utilized during the past eight years (average percent of usage is 93%) with no significant trend over the eight year period (Table I-3A). However, during the period from 1988 to 1992 one or two of the large ships were out of service, which may lead to unrepresentative utilization percentages.

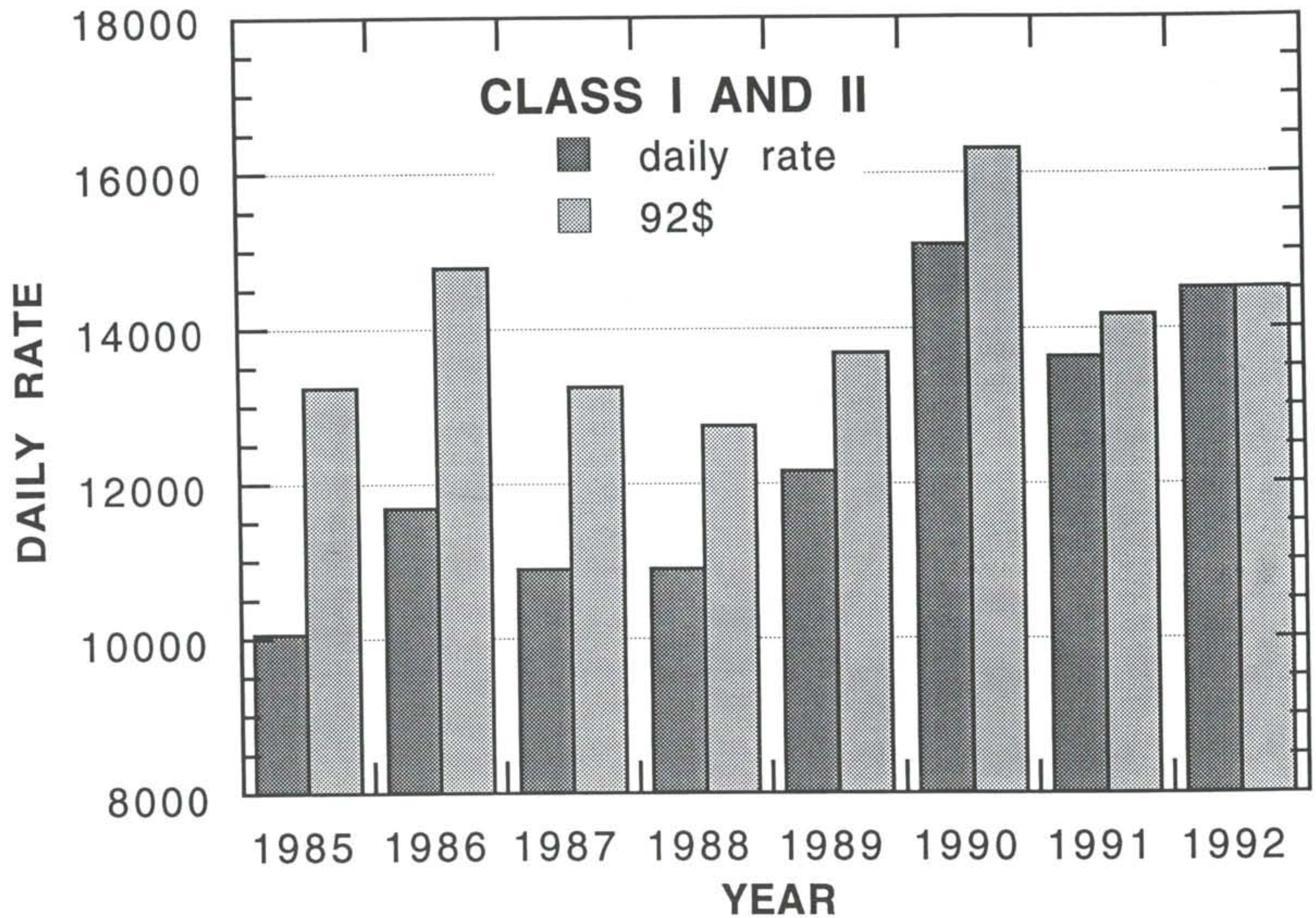
The average utilization of Class 3 vessels (Table I-3B) is somewhat lower, about 80%, based on a 250 day "full operating year", and no clear trend with time is evident. The difference between total available time and the total utilized time is about one "full operating year" for an intermediate-sized ship.

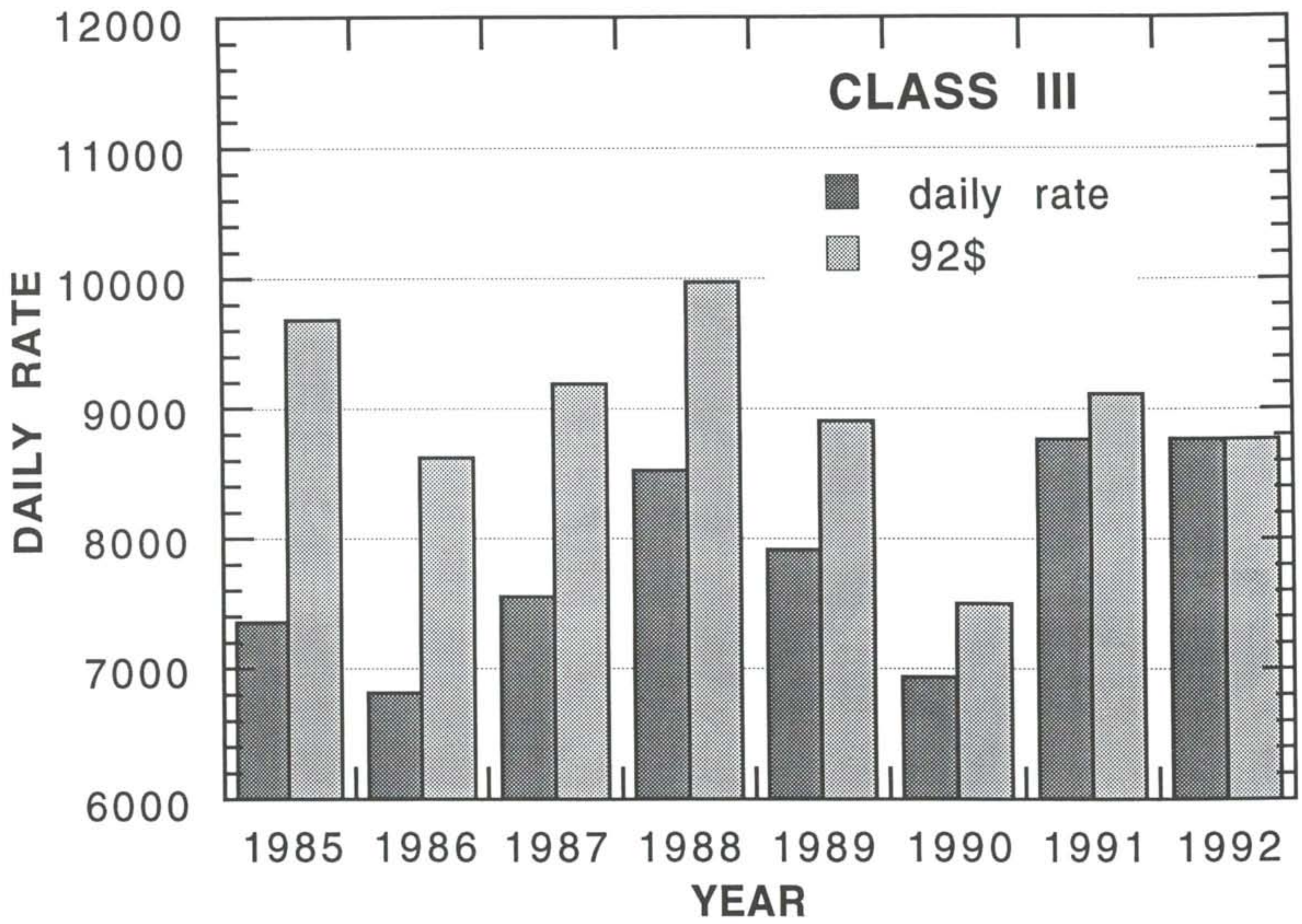

TOTAL UNOLS FLEET
OPERATING COSTS
THOUSANDS REAL DOLLARS
TOTAL COST
50000
40000
30000
20000
10000
0
CLASS 1&2
3
4
1985 1986 1987 1988 1989 1990 1991 1992
YEAR

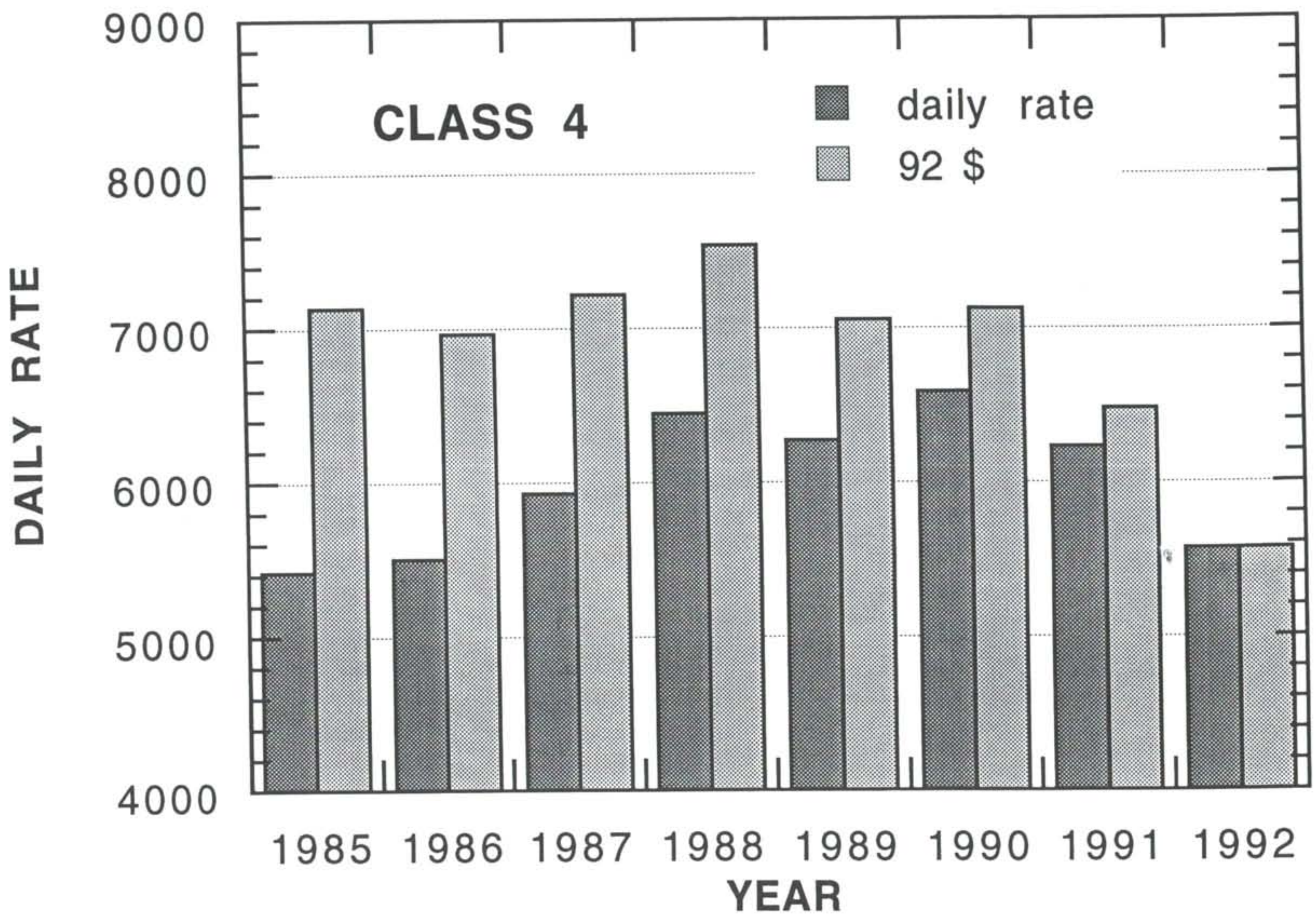

UNOLS FLEET COSTS
ADJUSTED TO
1992 DOLLARS
ADJ. TOTAL COST
50000
40000
30000
20000
10000
0
CLASS I & 2
3
4
1985
1986
1987
1988
1989
1990
1991
1992
YEAR

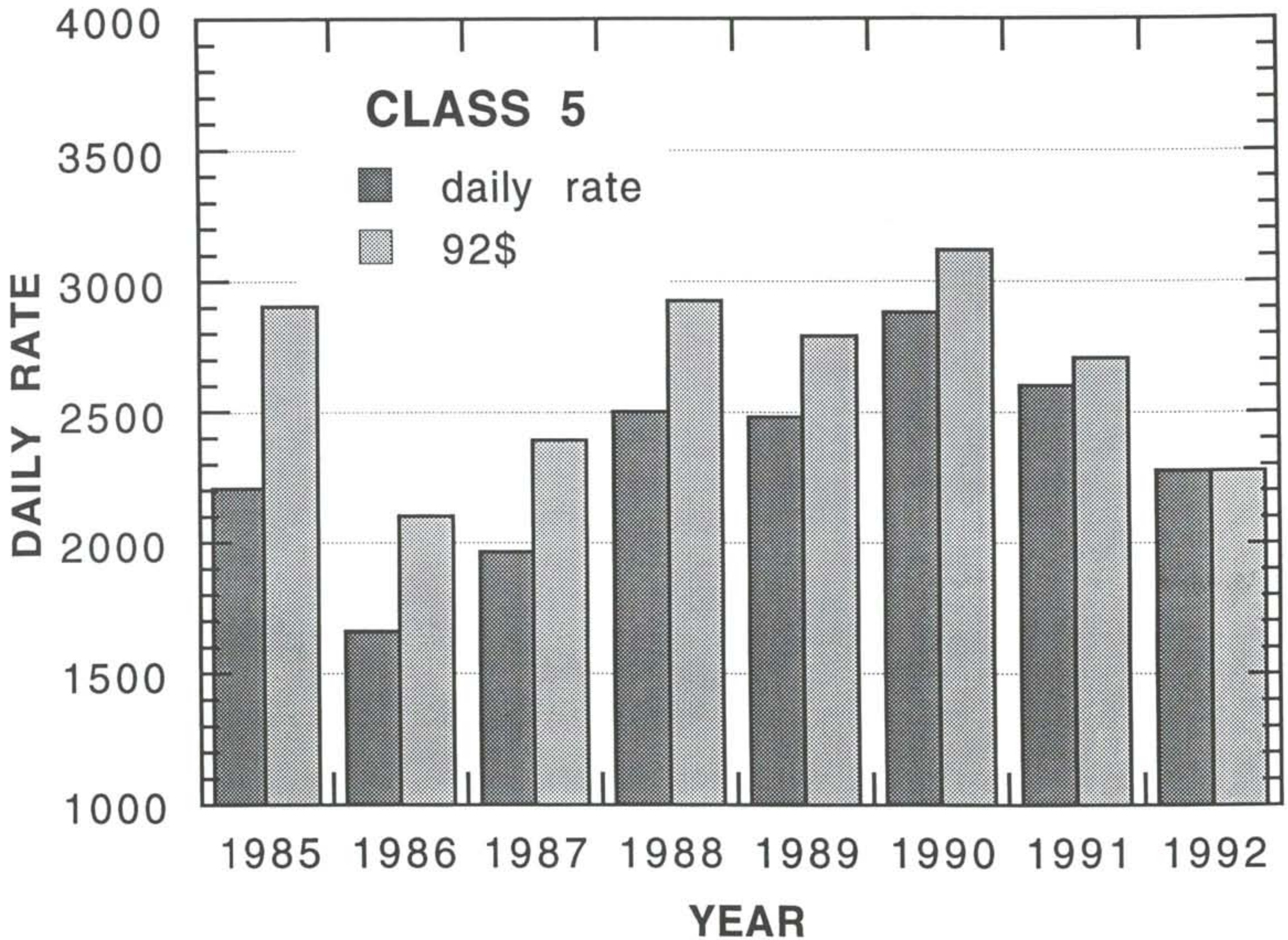
VS.
PERCENT UTILIZATION




CLASS I AND II
daily rate
92$
DAILY RATE
18000
16000
14000
12000
10000
8000
1985
1986
1987
1988
1989
1990
1991
1992
YEAR


CLASS III
daily rate
92$
DAILY RATE
12000
11000
10000
9000
8000
7000
6000
1985
1986
1987
1988
1989
1990
1991
1992
YEAR


CLASS 4
daily rate
92 $
9000
8000
7000
6000
5000
4000
DAILY RATE
1985
1986
1987
1988
1989
1990
1991
1992
YEAR


CLASS 5
daily rate
92$
DAILY RATE
4000
3500
3000
2500
2000
1500
1000
1985
1986
1987
1988
1989
1990
1991
1992
YEAR

Class 4 ships (Table I-3C) have about the same level of utilization as the Class 3 ships (79%). Again, there is no clear trend, but the utilization has increased recently after two lean years in 1989 and 1990. The anticipated increase in coastal ocean science may result in a greater utilization of this class of vessel in the near future.

The Class 5 ships (Table I-3D) are well utilized with an average percent of usage of 93% based on a full operating year of 110 days. This class of ship may also see increased usage as demand from coastal oceanographers increases.

Figure I-4A shows the total annual cost of operating the UNOLS Fleet in real dollars has been increasing in an irregular fashion over the past eight years. The variations are mainly the result of changes in the number of large ships operating in any given year. In Figure I-4B we show the total cost adjusted for an inflation rate of 4% per annum. The 4% per annum is applied to pre-1992 costs to make them comparable to 1992 dollars. When inflation is taken into account, the total cost of operating the UNOLS Fleet has not increased. In fact, the total cost of operating the Fleet is virtually the same in 1992 as it was in 1985.

Figures I-5 (A-D) shows graphically the variations in daily rates in real dollars and daily rates adjusted to 1992 dollars for the four classes of research vessel. The daily rates used in these figures are calculated by dividing the total cost of operating a class of vessel in a given year by the total days used during that year, thus represents an average daily rate over the size class. When inflation is taken into account the average daily rate over the eight years shows significant variation as the names and numbers of ships in operation change. The average daily rates, (in dollars adjusted for inflation) in all classes have not changed significantly during the eight years.

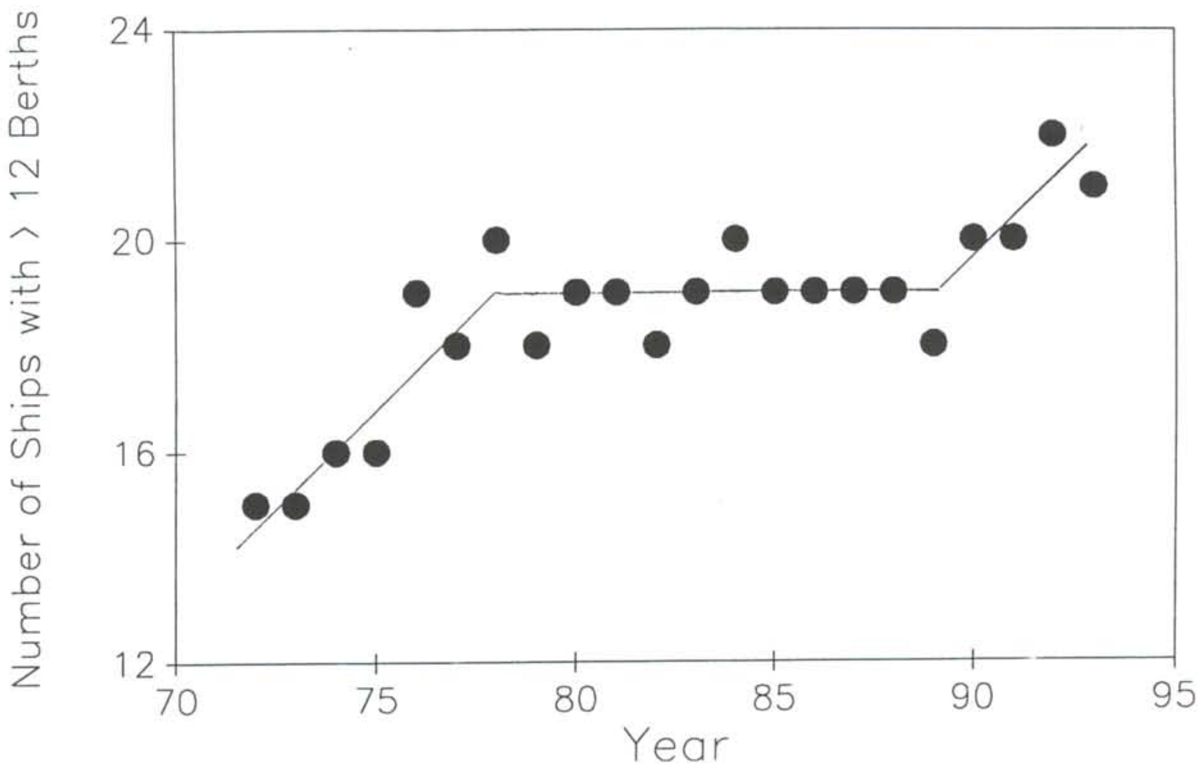
In fact, Classes 3, 4 and 5 have lower daily rates in 1992 than in 1985. Thus, concerns that the costs of operating the fleet have recently been increasing rapidly are not supported by the data if a realistic rate of inflation is taken into account.

In Figure I-6 we plot the inflation adjusted daily rates vs. percent utilization of the Class 1 & 2 and Class 3 ships. The lines fitted to the points are linear regressions that show the expected decrease in daily rate with increased utilization, however the slopes of these lines are not very great and may not be significant. These graphs suggests that a certain amount of equalization of daily rates despite changes in utilization occurs by interactions between the operators and the funding agencies. The total funds available for UNOLS ship operations is the primary controlling factor..

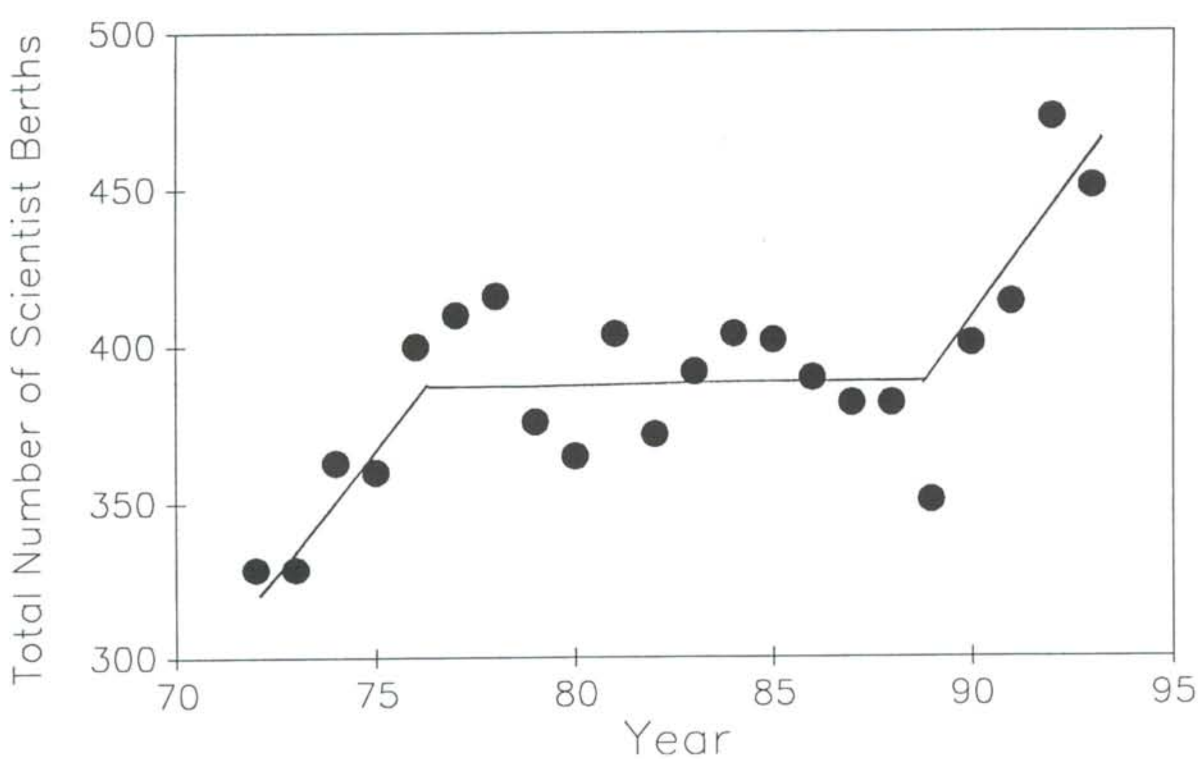
Trends in Berthing on UNOLS Vessels

The present configuration of the intermediate and small-sized ships in the UNOLS fleet was essentially established by 1982, during which the RV CAPE HATTERAS was completed. That was the end of a building program for intermediate and coastal ships that provided CAPE HENLOPEN, OCEANUS, WECOMA, ENDEAVOR, NEW HORIZON, CAPE FLORIDA (now POINT SUR) and CAPE HATTERAS. Several ships have been removed and added to the stock of small ships (e.g., VELERO IV and E.B. SCRIPPS retired, and SPROUL and WEATHERBIRD II added), but the stock has been roughly steady. Larger UNOLS vessels have been retired and replaced, with some short-term ups and downs, but the stock has been roughly steady. The main trend has been that the new and the refitted large vessels are larger and carry more scientists than did those of 10 years ago. In 1978 only MELVILLE and ATLANTIS-II had the then maximum bunk number of 29. This year MELVILLE, KNORR, EWING, and ATLANTIS-II all carry 29 or more berths. MELVILLE and KNORR carry 35 and 34 respectively. The THOMPSON (AGOR-23) carries 26 plus 8 additional berths in vans and conversion of space for more berths is also being considered. An additional recent trend is for intermediate ships to add berths. The RV ISELIN increased from 16 to 24 in 1989, WECOMA from 16 to 20 in 1990, GYRE from 20 to 23 in 1990. Thus a fleet with a roughly constant number of ships has grown substantially in capacity to carry scientists; berths are up an eighth since 1982. This summary is based on records from the office of the UNOLS Executive Secretary. A graphical representation of the growth is shown in Figure I-7.

The motivation for this trend is clearly the increasing complexity of oceanographic programs. This was recognized by the original UNOLS Fleet Replacement Committee, which guided planning for the new large ships of the early 90's (THOMPSON and refitted MELVILLE and KNORR). Oceanographers are trying to pack more and more observations; and coupled, coincident observations into every major expedition. Each class of sample or type of measurement usually requires its own scientist or technician to gather the materials or data and provide the necessary on board handling. When the need to keep observations running round-the-clock is added, the demand for berths rises spectacularly. This is particularly true of the major programs such as WOCE, JGOFS, and GLOBEC, which are now being implemented. Expeditions mounted by these programs challenge the capacity of the largest vessels in every respect, particularly capacity to carry scientists. Both WOCE and JGOFS have been immediate users of the new THOMPSON (AGOR 23) and the converted MELVILLE and KNORR. As stated, the new larger vessels were designed with this need in mind, and the realization of the anticipated demand is generating work for them.



Number of Ships with > 12 Berths
24
20
16
12
70
75
80
85
90
95
Year



Total Number of Scientist Berths
500
450
400
350
300
70
75
80
85
90
95
Year

II TRENDS IN OCEANOGRAPHY AND FACILITY NEEDS

A. Coastal Oceanography:

Research activities in the coastal ocean, defined here as embracing estuaries and the entire continental margin, have increased measurably in recent years and are expected to increase dramatically over the coming decade. The National Science Foundation has recently initiated interdisciplinary research programs in coastal oceanography such as: Land-Margin Ecosystem Research (LMER), Global Ocean Ecosystems Dynamics (GLOBEC), and, with joint support from ONR and NOAA, Coastal Ocean Processes (CoOP). In addition to the NSF programs, recent NOAA initiatives include a major Coastal Ocean Program (COP), while the Ecological Research Division of the Department of Energy is supporting interdisciplinary studies of the Dynamics of Continental Margins. Significant shifts in emphasis within the Office of Naval Research toward coastal marine science have recently been announced (7). Additional coastal research activities are in progress or planned by EPA, USGS, MMS, NASA, and the U.S. Army Corps of Engineers. A science plan outlining some broad coastal marine science objectives has been prepared by the CoOP steering committee (2). A similar science plan entitled Land-Ocean Interactions in the Coastal Zone (LOICZ) has been prepared by European scientists under the auspices of IGBP (4).

Recent workshops and related reports have focused, appropriately, on science questions and interdisciplinary program planning. Implicit in these discussions and documents is the assumption that sophisticated research platforms and other facilities will exist to enable the research objectives to be met. Included are research platforms of various sorts: ships, small boats, aircraft, semi-permanent moorings, and specialized facilities such as research piers, offshore platforms and jack-up rigs.

Ongoing and foreshadowed activities of coastal ocean field research can be broadly grouped into four basic categories: (1) synoptic observations; (2) time series measurements; (3) interdisciplinary studies; and (4) information management and communication.

Synoptic Observations

Synoptic observations are critical to understanding spatial (as opposed to temporal) variability. In the coastal ocean where spatial gradients are steep, synoptic data approximating nearly instantaneous "snapshots" of an entire region are particularly important and are essential to deciphering time series data. Although remotely-sensed aircraft and satellite data provide the bulk of synoptic data, important roles are also played by rapid sampling from ships and by moored arrays of instruments.

Capabilities for the transmission of data from satellites and moorings to vessels in real time needs improvement as do techniques for rapid, high resolution data collection. Limitations also exist at present with respect to our ability to operate inshore in heavy weather and to carry out simultaneous sampling in support of interdisciplinary studies. Synoptic observations, like other research needs, require more medium sized vessels with shallow draught (<3m), but capable of carrying large scientific parties (16-20).

Time Series Measurements

Coastal ocean processes vary on time scales ranging from seconds to millennia. Time series studies are required to enable us to understand the forcing functions for many phenomena including changes in productivity and climate. Continuous measurements at specific points are needed to capture short lived events, and multiple samples in a burst mode are needed to deal with both spatial and long-term temporal variability. Longer time series observations are needed to verify a host of predictive models. To date, most time series studies have relied on various kinds of moorings, and, further, this is likely to continue. Large ships are needed to support the deployment of numerous in the coastal ocean. These moorings are commonly large and contain numerous sensor packages. In addition to the above there is an ongoing need for smaller, quick response vessels that can service moorings and conduct rapid spatial sampling. Improved ability to telemeter data from moorings to shore or to vessels is required.

Interdisciplinary Studies

Coastal ocean studies in recent years have become increasingly interdisciplinary in the sense that they involve paradigms, ideas, and field efforts that embrace more than one oceanographic discipline. Interdisciplinary studies are needed to address some of the most compelling coastal research questions including those pertaining to: sources of materials entering the coastal ocean; the processes responsible for biogeochemical cycling and transformation; the health of the coastal ocean with respect to nutrient enrichment; the role of the coastal ocean in global change; and societal uses of the coastal ocean.

By necessity, interdisciplinary field teams are normally larger than those involved in single-discipline investigations. Interdisciplinary research also necessitates the observation, often at the same time, of multiple parameters using a diversity of instrumentation. Accordingly, some coastal research vessels must: 1) accommodate large scientific parties (>20 scientists), 2) permit simultaneous use of several winches and wires, and 3) operate in shallow water. The large scientific parties and diversity of instrumentation require large laboratory spaces to accommodate equipment and sample analysis, and place greater demands on electrical and air-conditioning systems.

Information Management and Communication

The expected explosion of data on coastal ocean processes will benefit scientists only insofar as the data are effectively analyzed, managed and communicated. New technology is now making it easier to acquire, store, analyze, manipulate, and exchange coastal data. However, the community still needs to develop an infrastructure to support information management needs of coastal marine scientists.

Among the specific requirements for information management for coastal oceanography are: 1) distributed centers for data synthesis and storage; 2) standardized shipboard protocols for all UNOLS vessels for certain types of data; 3) standard suites of certain sensors on all UNOLS vessels; 4) improved communication links among vessels, buoys, platforms, satellites, and shore facilities. One approach to data transfer has been proposed by JOI. Their proposed system (SeaNet) would provide 24-hour INTERNET communications between ships at sea and research centers throughout the world.

The Role of Ships

There are important regional differences that influence the use of research vessels in the coastal zone. For example, the west coast of the United States, including Hawaii, has deep water almost directly adjacent to the coast which means that large and intermediate research vessels cover essentially everything up to, and in some cases into the estuaries. In the Arctic region ice represents a substantial operational problem that dictates use of an ice capable vessel. At the present time an Arctic research vessel is being designed and will probably be constructed in the next several years (see section II B). It will be capable of studying U.S., Canadian, Russian, and Scandinavian shelves. Both the Gulf and East Coasts have broad shallow continental shelves that present special challenges for sea going platform designs. The Great Lakes operating conditions are similar to those of the New England coast. If we use 7 m as a cut off depth for inshore work by large and intermediate research vessels in the UNOLS Fleet, there is a substantial amount of shelf area that will have to be studied using shallow draft vessels and/or other facilities.

Large and Intermediate ships

The class 1 and 2 vessels in the UNOLS fleet are capable of carrying out interdisciplinary studies of the coastal zone to water depths as shallow as 7 m under appropriate weather conditions. The special characteristics that make the large ships suitable platforms for coastal research include: (1) an ability to accommodate large scientific parties (25 or more); (2) large deck and storage space; (3) considerable laboratory space; (4) capability of handling large arrays; (5) ability to carry specialized vans (isotope/trace metal/organic); and (6) good seakeeping during foul weather.

The six class 3 vessels are also capable of working as far shoreward as the 7 m isobath under appropriate weather conditions. Although these ships cannot carry as many scientists and have more limited laboratory and deck space and storage capacity, they can serve the need of interdisciplinary field programs of moderate size.

There is a recognized need to conduct complex, interdisciplinary research at shallower water depths. This need is especially important for studies of the large shallow-water regions on the East and Gulf coasts as well as some distant areas like the delta areas of major river systems (Amazon, Orinoco and Yellow Sea). The FIC recommends that the

Scientific Mission Requirements be developed for a "shallow-water research vessel" and that the study be followed by conceptual design studies of such a vessel. The characteristics of a shallow draught coastal research vessel are presented in Appendix I.

The role of small research vessels

The inability of large ships to operate close inshore, particularly over shallow shelves, dictates that coastal oceanographers will continue to need smaller vessels. Smaller vessels have the advantage of being shallower draught, having greater maneuverability, generally being able to respond more quickly to event-dependent opportunities, and being less expensive. However, they are also limited to smaller scientific parties and crew size. Because small vessels have limited range and endurance, it is important to maintain a fleet of regionally-dedicated vessels. The mission requirements vary from region to region as will vessel designs.

Included in the "small vessels" category are day boats for short trips in protected waters (typically less than 80 ft in length) and "small expedition vessels" ranging from 80 to 150 feet in length. Future generations of such vessels should be designed with the following aims: 1) keep the daily cost as low as possible; 2) accommodations for parties of 12 to 20 scientists; 3) endurance of up to three weeks and a range of approximately 1200 miles; 4) draft under 4 meters; and 5) underway sea-keeping at sea state 5 to 6.

General scientific capabilities expected of future vessels in the "small expeditionary" class include: 1) multiple wire deployment capability; 2) three point moorings and dynamic positioning; 3) mooring deployments of up to 5,000 lbs.; 4) support for high resolution bathymetry and side scan; 5) underway flow-through sampling capability; 6) ADCP, sea-soar, and coring capabilities; 7) best available communication systems; and 8) high quality data acquisition.

Role of non-ship observing platforms

Given the rigorous requirements for synoptic observations with high spatial resolution and for prolonged time series measurements at many locations, ships alone cannot serve the full spectrum of needs of coastal oceanographers. Complementary and essential are other types of research platforms including aircraft, satellites, moorings, and fixed platforms. Without such platforms it would be impossible to obtain truly synoptic data of very long-term time series. These platforms also facilitate the acquisition of data during extreme storm events when most vessels are ineffective.

Jack-up rigs for coastal oceanography:

One proposal that has major scientific advantages with modest budgetary implications involves deploying a number of jack-up platforms in selected coastal areas to serve as long-term observatories and sampling facilities. The rigs can be deployed in water depths up to 100 ft. The cost of maintaining jack-up rigs is relatively small, about $1,000/day. Deployment of several such platforms could become a valuable research facility for coastal studies.

Aircraft:

Airborne platforms including airplanes, blimps, and remotely piloted vehicles (RPVs) are likely to play much more important roles in coastal oceanography than is the case for deep sea oceanography. Blimps provide the special advantage of being able to sample with extremely high spatial resolution owing to their slow speed. Remotely-piloted vehicles will, in future, offer increased utility for coastal applications; they can fly at elevations as low as 5 meters above the surface carrying payloads of 200 kg.

Moorings and other facilities:

Currently-available surface platforms include moored and drifting buoys, piers, and hover craft type vehicles. Moored and drifting buoys have been used extensively by the oceanographic community. Noteworthy is the "spar" buoy. Its open and stable structure with enormous power capacity allows the design of integrated aerosol, gas, and heat flux profile data bases in the atmosphere, and subsurface biology and chemistry sampling. FLIP is a specialized platform that continues to be needed and is being refitted to enhance its capability. Piers support long term monitoring of temperature, salinity, and tides, for long term seasonal and climatological monitoring.

Field and shipboard instrumentation:

All oceanographic vessels should continually monitor a suite of navigational, meteorological, and hydrographic parameters while at sea. These observations should be user accessible in real time, available at the end of the cruise, and archived. Parameters include: position, depth, ship speed and heading, wind speed and direction, air temperature, humidity, barometric pressure, photosynthetic active radiation (PAR), seawater temperature and conductivity correlated with time.

A large variety of important scientific equipment (too expensive for an individual user) should be available on a shared-use basis from regional equipment pools. Examples include: ROV's, AUV's, SeaSoar, OSCR, CODAR, MET-SPAR Buoy, and Sidescan Sonar. This equipment requires maintenance and technical assistance for its operation. Regional or national shore-based facilities are recommended to support an increasingly complex fleet of ships and oceanographic equipment.

B. Facility Needs of Arctic Oceanography

In preparing its report, "Priorities in Arctic Marine Science" (1988), the Committee on Arctic Marine Science of the Polar Research Board (PRB), National Research Council, conducted a poll among users of research vessels in the Arctic. The responses showed three primary areas of interest: the Bering/Chukchi Seas, the Arctic Ocean Basin, the Greenland Sea/Fram Strait/Norwegian Sea/Barents Sea areas. Scientific plans included, among others, such activities as box coring in the Norwegian Sea, marine geology/geophysics in Baffin Bay, radiotracer studies in the Barents and Beaufort Seas and Fram Strait, and winter work in the Greenland Sea, all requiring significant ice breaking capability. Many respondents planned to work in multiple regions, such as the Barents, Greenland and Chukchi or Beaufort Seas – spanning both eastern and western Arctic regions; others needed access to the Central Arctic Ocean Basin. In compiling this information, it became evident that research proposals were not being generated and much work was simply not getting done due to the lack of a suitable US research vessel.

The timeliness and importance of the work identified in the PRB survey has increased, with high priority issues driving the development of national research initiatives; for example, global change and Arctic pollution. The National Science Foundation has initiated the ten-year Arctic System Science program with a multidisciplinary study of the Northeast Water polynya in the Greenland Sea among the first marine projects funded under this umbrella. This region is exhibits strong fluxes of heat between the ocean and atmosphere, and extremely important from the global point of view, since it is an area of exchange and mixing of water between the Atlantic and the Arctic Ocean. It is also the site of formation of subsurface water layers that affect large areas of the world oceans. Access is difficult because the area is surrounded by heavy ice that moves southward from the Arctic Ocean via the East Greenland Current. The lack of a US dedicated research vessel strongly impacts our ability to understand the influences of these oceanographic processes in the eastern Arctic. In the western Arctic there is a need for research that spans the national boundaries between Russia, the US, and Canada. The most important processes probably occur during the ice-covered season.

Geological and geophysical studies:

Geological and geophysical data from the Arctic Ocean Basins are still sparse and are urgently needed if we are to fully understand the geological evolution of these basins and particularly their role in climatic change. For example, nothing is known about the state of the polar oceans in Cretaceous times, a time of extraordinarily equable climate. We have only a few sediment cores from the Arctic Ocean that penetrate the Cretaceous, but their geological context and correlation potential are unknown, as their sites are only crudely surveyed. Future Arctic Ocean drilling programs will require a geological and geophysical data base of the Arctic Ocean, which can only be obtained with site surveys. Other important geological and geophysical studies include work on sedimentary processes in the Arctic Basin and at the continental margins, tectonics of the Arctic, and the interaction of the North American and Eurasian Plates. Finally, the opening of the Amerasian Basin in the western Arctic Ocean is a matter that remains unsettled.

Physical Oceanography:

Physical oceanographic studies in ice-covered waters are essential, since the permanent, dynamic ice cover significantly impacts the Arctic

Ocean on a number of time and space scales. Studies of large scale processes in the Arctic Ocean, including mixing and generation of cold saline water, require access to regions of heavy ice, as does work on shelf/basin dynamics and structure. These studies must take place during times of active ice formation. Operations in these environments require an ice capable research vessel.

Studies of sea ice properties and ice dynamics require ground truth measurements in conjunction with satellite remote sensing using Synthetic Aperture Radar (SAR) and other sensors, including the upcoming SeaWiFS, require access to ice covered regions.

Marine Chemistry:

There is a great deal of concern about the increasing pollution of the Arctic, specifically with respect to radionuclides which may have been introduced into Arctic shelf waters by the former Soviet Union. There is also evidence of heavy metals, hydrocarbons, PCBs and pesticides entering the Arctic Ocean from Russian rivers. An ONR research program aimed at addressing Arctic pollution was funded in FY 93 and 94 at a level of $10 million per year. The primary focus being marine pollution from the former Soviet Union. Programs to address monitor and address these problems include physical and chemical oceanographic studies, sediment sampling as well as ecological work.

Marine ecology:

Marine ecological work requires access to high latitude ice-covered regions where ice-related biological production and food chains dominate. We currently lack information on the basis for the relatively high productivity of Arctic waters, and therefore cannot estimate the impact of climate change and pollution on these systems. The long ice-covered season in polar seas does not necessarily result in biological dormancy, and critical biological activity may take place in brief time periods early in the spring. Lack of access beyond the marginal ice zone has precluded efforts to address this problem. Knowledge of the biological role of sea ice is needed to predict the effects of variability in ice extent on marine species, including those fish and marine mammal species that are commercially exploited or subject to subsistence utilization. Sampling must be expanded to earlier and later dates in the season than currently possible with non-ice capable ships. Antarctic studies suggest radical changes in the ecology during winter, and similar changes are anticipated in the Arctic.

Current Research Planning:

Fundamental to any scientific discussion of the Arctic Ocean, its marginal and adjacent seas, and its atmosphere and seabed is the suggestion in presently available global climate models that the Arctic contains many powerful processes and feed-back mechanisms that distribute its climatic influence world-wide and that the Arctic will be dramatically affected by the predicted climate change. Since our knowledge of past climate change in the Arctic is practically nil (Thiede *et al.*, 1992), and our understanding of critical state variables of the system is similarly deficient (Moritz *et al.*, 1990), it is clear that a wide variety of observational information is needed.

The workshop on Arctic System Science (Moritz *et al.*, 1990) identified urgent scientific needs in two broad categories: climate change/models and first order features. The topics of highest priority in the first category were deep water formation, ice retreat, warming, atmospheric radiation, clouds, surface energy budgets, and albedo. In the second category, research on circulation, seasonal biological cycles, stratification, riverine influences, seasonal chemical cycles, and brine formation were viewed as urgently needed. Most topics in both categories require not just a single investigation but rather a detailed climatology that allows accurate assessment of variability.

The conclusion of both these community-wide statements of scientific needs and scientific issues in the Arctic is that there is a vast amount of knowledge required in the near future, but this knowledge will not be obtained without a new, substantial, ice-breaking research vessel in the UNOLS fleet.

Development of the Arctic Research Vessel Design:

The lack of a dedicated Arctic research ship has long been identified as a major deficiency in the US ability to conduct research in northern seas. US Arctic oceanographers have had to use non-US platforms to conduct their research. In using these platforms, they have been able to access regions far beyond the limitations of the ice-strengthened R/V *Alpha Helix*. Science cruises to the North Pole on the German research vessel *F.S. Polarstern* and the Swedish icebreaker *Oden* in 1991 have given scientists renewed hope and interest in Arctic Ocean work. An Arctic ice capable research vessel was established among the highest acquisition priorities for the academic fleet, and as a result the Fleet Improvement Committee established an Arctic Research Vessel Subcommittee to develop scientific mission requirements (SMR) and conceptual designs for an Arctic Research Vessel (ARV). See Appendix II. Several iterations of the conceptual design have been produced in response to input from the Arctic research community and others.

The preliminary design study was carried out by Glosten Associates, Inc. of Seattle, Washington. Glosten subcontracted with the German marine research organization, Hamburgische Schiffbau Versuchanstalt (HVSA), to evaluate various hull forms on behalf of the FIC ARV subcommittee. HVSA is one of the most experienced in the world with regard to ice breakers, having designed and conducted model and full scale tests on many ice breakers now in service. The preliminary design, included ice breaking and seakeeping model tests at HSVA to validate and the design concept. These tests showed that the proposed design provides superior ice breaking performance.

The designed vessel has an ABS A3 ice classification, roughly equivalent to breaking 3.5–4' of continuous ice cover at 3 knots, and is able to carry 36 scientists for up to 90 days, Fig. II-1. It will require a ship of approximately 340' and 18,000 hp. This capability reflects the scientific support needs identified by the US Arctic marine scientists to meet today's science requirements.

Sea ice determines the environmental and navigational characteristics of polar seas, and yet it is one of the more variable of the physical features of the earth's surface. Within the Arctic Ocean, sea ice is primarily of multi-year origin. It averages 2–3 meters in thickness, and is often rafted into pressure ridges and hummocks. Navigation in winter is not feasible, but summer access is possible as demonstrated by the 1991 Oden and the Polarstern. Extensive sea ice forms seasonally around the boundaries of the Arctic Basin and extends into the Chukchi and Bering Seas, the Canadian Archipelago, Hudson Bay, and the Barents and Greenland Seas. Maximum ice extent is reached in March or early April. The characteristics of this peripheral ice vary with geographic region. Bering Sea ice is seasonal and seldom exceeds 1 meter in thickness, although it is often rafted and ridged to greater thickness. Greenland Sea ice, in contrast, originates in the Arctic Ocean and is 2–4 meters thick. At its minimum extent, the ice is confined to the central Arctic Ocean and portions of the Greenland Sea, Kara Sea and Canadian Archipelago. The Bering Sea, Hudson Bay, Sea of Okhotsk and Baffin Bay/Davis Strait are free of ice during the summer months.

The A2 capability used in an earlier design of the ARV was not acceptable to many in the Arctic community, however, an A4 capability would begin to conflict with the ice capability of the US Coast Guard vessel now under construction. A ship with A3 capability can spend twice the amount of time in the Arctic offshore ice compared to A2 capability. An A3 ice capability will also allow this vessel to work in the central Arctic Ocean if it is accompanied by a more ice capable vessel such as an A4 or A5. Thus, cooperation between the Coast Guard and UNOLS will be very important to the success of the US Arctic marine research program.

Coast Guard's Polar Research Vessel:

The U.S. Coast Guard is constructing Polar Research Vessel (PRV), which will be significantly larger than the planned ARV. The PRV will have greater ice capability and higher operating costs than the ARV. The Coast Guard plans to equip the PRV with scientific capability comparable to an AGOR-23 class ship. It is designed to operate in both the Arctic and Antarctic. The Antarctic mission of the PRV will occupy half of its yearly schedule probably during the northern winter months. At the same time the PRV is designed and will be prepared to carry out other Coast Guard missions such as search and rescue, critical escort service and national defense should the need arise.

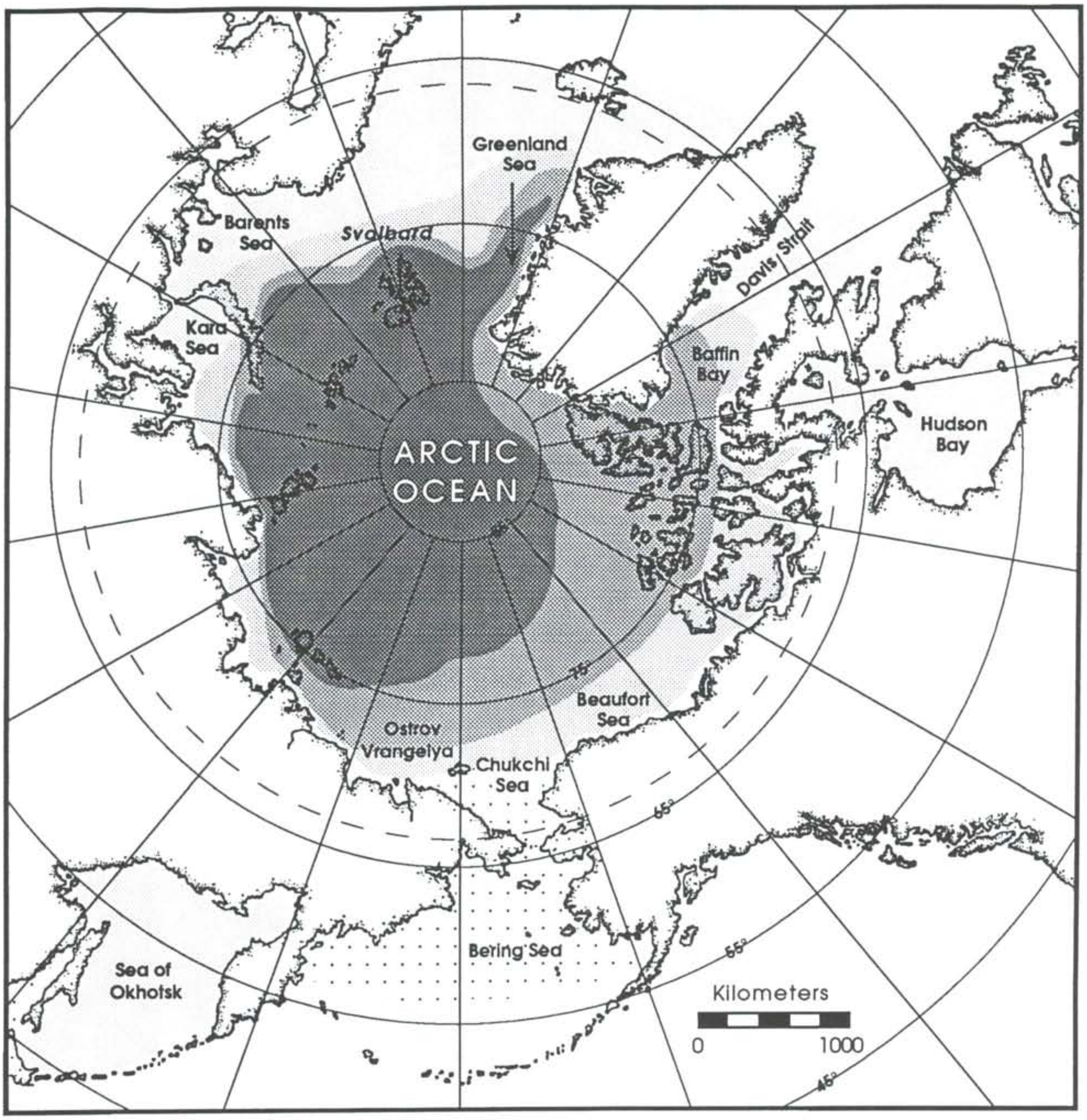
Regions of Arctic Research Vessel Operation:

Operating areas for an research vessel with A3 classification working alone and escorted are shown in Figure II-2. The A3 classification would allow the Arctic research vessel to operate independently in the Central Arctic Basin for short term, short distances from July through September and along the Arctic shelf from July through December (see the map for operation areas). The operating areas are approximate and subject to local conditions that are quite variable.

Table II-1 Ice Operating Capability of A3 with and without Escort

Region	Independent A3 Operation	With A4 Escort	With A5 Escort
Central Arctic Basin	July to September	July to October	Year around
Sea of Okhotsk	Year around	Year around	Year around
Bering Sea	Year around	Year around	Year around
Hudson Bay	Year around	Year around	Year around
Baffin Bay/Davis St.	Year around	Year around	Year around

Greenland Sea	Offshore shelf, July to December	Offshore shelf, Year around Central Arctic, July to November	Year around Year around
Kara and Barents Seas	July to October	Year around	Year around
Canadian Archipelago	July to December	Year around	Year around

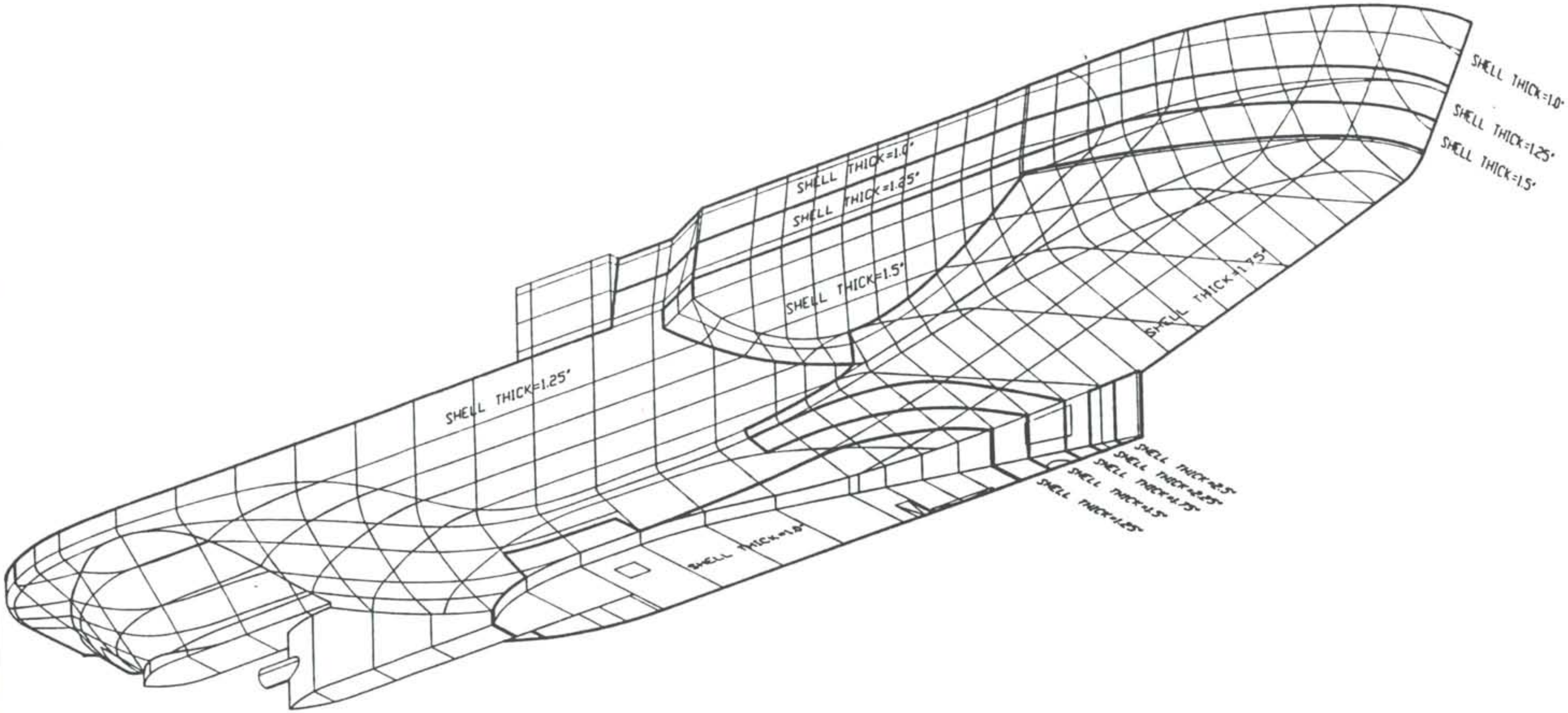


Multi-year ice. Winter operation not possible. Summer operation possible with icebreaker escort (A5 or better).

Operation possible July—December.

Extended operation possible June—December. Some winter accessibility.

Seasonal sea ice. Year-round operation possible.



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C Trends in Chemical Oceanographic Research

Chemical oceanographic research has evolved rapidly from a primarily descriptive science, oriented towards identifying the composition of seawater, to a science that focuses on the molecular and biological processes that control seawater composition. Modern studies are increasingly conducted as parts of large, interdisciplinary programs involving chemical, physical, biological and geological oceanographers. Interdisciplinary programs require large ships with extensive laboratory facilities that can support many scientists performing a range of scientific experiments. These needs have been reflected in the recent planned changes of the UNOLS Fleet.

There is also increasing attention being focused on the chemistry of the coastal zone. Much of the coastal zone will be accessible to the largest vessels of the UNOLS fleet. However, there is a need for a new generation of Class 5 coastal vessels to replace the current stock of aging coastal vessels in the UNOLS fleet. These coastal vessels must be capable of supporting many of the more complex operations described below. (Also see Section II-A on Coastal Oceanography).

Some of the most significant recent advances in chemical oceanography have been a result of the implementation of specialized facilities for chemical research at sea. These specialized facilities have made it possible to perform measurements that were previously impossible. For example, the development of clean sampling gear, including Class 100 clean vans and non-metallic sampling gear with Kevlar wires, has led to a remarkable change in our understanding of trace metal chemistry in seawater. Before 1975, we did not have an accurate picture of the total concentrations of many metals in seawater.

We are now able to perform detailed studies of photochemical, biological and surface chemical reactions that control the distributions of metals in the sea.

The evolution of chemical oceanographic research will result in the conduct of more detailed process oriented studies at sea that will require even more specialized facilities. These studies often involve conflicting requirements between research groups, which can only be resolved by the development of specialized facilities. The use of radioisotope spikes in seawater samples to trace the flow of chemicals during incubation experiments has now become routine. However, this work often produces conflicts with tracer geochemists, who want to study the distributions of natural levels of the same isotopes in the sea. For example, the presence of artificial amounts of isotopes such as ^{14}C on board ship may cause sufficient contamination of seawater samples that tracer work cannot be carried out on a ship. Development of very sensitive detection methods, such as accelerator mass spectrometry for natural isotopes, will increase the contamination hazard. These problems can only be resolved by the development of special facilities on board ship for work with artificial isotopes.

Chemical analyses performed on board ship are becoming increasingly complex. Many chemical species, such as hydrogen peroxide or the structure and composition of marine particles, are too labile to be preserved for later analyses. Other interdisciplinary studies require real-time analyses in order to monitor shipboard experiments. High resolution studies of the spatial distribution of chemicals must often be performed at sea to study the interaction of physical, chemical and biological processes. Long cruises require that the activity of short-lived isotopes be determined at sea. Gas chromatography, liquid chromatography, continuous flow analysis and a suite of other analytical methods are now routinely performed on ships. Instruments such as mass spectrometers, low level radiation counters and atomic absorption spectrophotometers, which require specialized laboratory facilities, are more frequently seen at sea. These instruments often require environments with low accelerations and vibration, specialized ventilation facilities, or ultraclean areas.

Much effort has been oriented to the development of chemical sensors and sampling gear that can operate unattended on oceanographic moorings or which can be deployed as vertical profilers. These instruments are often prototype designs that do not interface easily with each other. Multiple winches that have a variety of wire types (multiple conductors, fiber optics, kevlar sheaths) are, therefore, needed to accommodate the variety of instruments used on modern research vessels. Moorings will have a broader suite of instrumentation as chemical sensors are placed on them. This will require larger open decks and laboratories to accommodate these complex moorings. Free vehicles and benthic landers have become common tools over the past decade to study chemical interactions at the sediment-water interface. These instruments are complex and often require a large team to support them and to process the samples that they collect.

Specialized facilities, such as deep submergence vehicles and remotely operated vehicles, have played a significant role in chemical oceanographic research. For example, the discovery of deep-sea hydrothermal systems on mid-ocean ridges, using the submersible

ALVIN, has had a profound impact on our understanding of ocean chemical cycling. Large, interdisciplinary programs such as RIDGE have proposed the established of a deep-sea observatory at a ridge crest site to continue studies of the processes. In the past, interdisciplinary programs have used multiple ships, which require routine transfers of scientists and samples between ships. This is only practical in regions with relatively mild weather.

Remotely operated vehicles will play an important role in chemical oceanographic research. Programs that use submersibles and ROV's simultaneously will require larger vessels, as well. Plans to convert the R.V. KNORR into a submersible and ROV support ship will, to large extent, meet this requirement since she has ample laboratory space, and can accommodate large scientific staffs required for interdisciplinary programs.

Chemical interactions actions between the ocean and atmosphere have been recognized to play an extremely important role in controlling global climate, marine aerosols and ocean productivity. Production of dimethyl sulfide in the surface ocean controls cloud condensation nuclei over the ocean, for example. Studies of these processes will require specialized shipboard facilities for atmospheric sampling and in situ chemical measurements. Atmospheric sampling, for example requires large sampling towers mounted on the bow to allow the collection of uncontaminated samples. Laser based instruments can be used to profile chemical composition in the atmosphere. Global programs such as the International Global Atmosphere Chemistry (IGAC) program have already begun using UNOLS vessels for detailed studies of atmospheric chemistry. Modern research vessels must be designed to accommodate more easily the needs of these programs.

An additional feature that needs to be incorporated into UNOLS vessels, in general, are facilities for dealing with hazardous wastes at sea. Large interdisciplinary programs can generate significant amounts of chemical wastes on long cruises. This material cannot easily be disposed of in foreign ports. It must be held on board ship for disposal in the United States. Few ships currently have sufficient capability in this regard.

D Trends in Biological Oceanographic Field Work

There are identifiable trends in biological aspects of oceanographic field work. Research continues to depart from systematics-based approaches to ocean biota, moving toward production studies for broad categories like "primary producers", "grazers", "the nekton", and so forth. Each biologist has a personal view of the rightness of this shift. New research directions are coming both from new techniques applied to old problems and from new questions that can be asked because of new techniques. In most cases the central logistic problem remains getting the observers and their equipment to sea, keeping them rested and fed, giving them time to gather samples and data. However, in some instances the focus has become launch and recovery of drifters or moorings, both short term (recovery on same cruise as launch) and long term (launch and recovery on separate cruises). There is and will be increasing emphasis on guiding observations with very recent satellite information received on board sampling vessels. This makes for emphasis on communications capability and navigational precision.

General - There is increasing emphasis on applications of modern biological techniques to oceanographic problems. On the whole this means applications of molecular biology, such as gene sequencing, gene probe studies and enzymatic activity determinations. Requirements are two: 1) capacious, flexible laboratories to accommodate the extensive instrumentation for this work (spectrophotometers, cold baths, PCR machines, electrophoresis apparatus, etc.) and 2) classical collection techniques to capture organisms for attention in the shipboard laboratory. The most recently constructed UNOLS vessels have enormous laboratories that absorb large arrays of instrumentation. Some of the smaller, older ones are more limited; however, laboratories of amazing complexity are often stuffed into very modest quarters by creative packaging. Most molecular biology techniques are already ultraminiaturized, so that many operations requiring separate instruments still take up a small total space. In some cases the protracted laboratory protocols of molecular biology push biological oceanographers to extensive use of liquid nitrogen preservation. Mostly this is done very simply using large Dewar flasks that are filled with nitrogen before sailing, loaded with samples at sea, then topped up on return. No particular problems are encountered doing this. Freighting of loaded Dewars to distant laboratories is the most difficult part of such operations. No special requirements for UNOLS operators are involved. Eventually molecular techniques will probably require specially equipped vans so that laboratories need not be created aboard for each cruise, then torn down. To a degree such vans are already in use.

There is current and expanding interest in the interaction of biological and physical processes in the sea. This is an explicit focus, for example, of the GLOBEC Program which is finally reaching the stage of field research. There is biological concern now with every aspect of water movement including horizontal advection, upwelling, internal waves, tidal mixing, and turbulence at all scales. The practical effect of this is that biologists now have a contributing interest in all the operational requirements typical of physical oceanography. We are part of microstructure profiling, SeaSoar towing, current metering, basic hydrography, the entire gamut of physical measurement in the sea. Thus, whatever the physicists want in the way of facilities is going to be seconded by biological oceanographers.

There will be increasing interest in the biological impact of storms at sea, including studies of nutrient input from enhanced mixing and the immediate response of phytoplankton. There is also interest in studies of phenomena like the Arabian Sea monsoon, which is a storm of several months continuous duration. For both purposes, it is increasingly important to improve our ability to carry out ordinary observations at substantially higher sea states, the higher the better. Safety to personnel and equipment is the prime consideration in this. The main requisite will be engineering of mechanized gear handling apparatus. For example, gear recovery systems should be designed so there is no need for people to step to the deck edge and attach tag lines to swinging apparatus coming aboard. Actual acquisition and use of constant tension winches will be necessary so that much larger ship surges can be compensated.

Ecological study of both the water column and the benthos generates strong interest in the vertical flux of particulate matter from the productive upper layers to depth. Particle trapping is a standard approach to quantification of vertical flux, with traps of many sizes and configurations in current use. In all cases there is concern for ease in deployment and recovery systems.

Phytoplankton Research:

Older techniques continue in use, usually with refinements that make little difference in operations. Phytoplankton are collected and suitably preserved for direct examination. On the whole CTD rosette samplers are the current method. These scream for improvement. Because of increasing emphasis on tiny phytoplankters, some of the preservation is for electron microscopy. Typically this involves reagents of greater toxicity and volatility. Thus, it is critical to have adequate fume hoods in shipboard laboratories. This requirement has been met on most UNOLS vessels.

Carbon-14 uptake measurements are still widely applied. These have reached new levels of sophistication as study of incorporation of label in molecular species has become popular. The main change this makes for UNOLS logistics is the requirement for handling much higher specific activities of ^{14}C. On the whole that does not affect ship design, but requests for special ^{14}C vans, problems with university licensing requirements, and needs for special dockside disposal facilities should all continue to increase. Measurements of Nitrogen-15 uptake (as NH_4, NO_3, and other molecular forms) continue to be important. This is a stable isotope, used in very high ratios to ^{14}N without danger.

Both ^{14}C and ^{15}N techniques, as well as trace nutrient addition studies, are moving to larger incubation volumes with requirements for larger incubators. The interest in natural illumination forces these incubators onto open, upper decks with minimal shading by ship superstructure. Usually deck incubators flushed with surface seawater are used. These reach substantial proportions at times. UNOLS ships have been seen with tank farms on several decks, each incubator tank holding a cubic meter (a ton) or more of water. Availability of pump capacity to exchange water in incubator tank farms at the appropriate rate is important. Use of firefighting pumps must be resorted to in many cases. Ship stability considerations are usually done on an *ad hoc* basis for these phytoplankton farms. The general issue of stability with large volume tanks at high levels in the ship needs serious consideration.

New techniques for study of phytoplankton ecology involve various optical instrumentation ranging from satellite colorimeters, to moored fluorometers, flash fluorometers (moored and profiling), and fluorescence microprofilers. All of these instruments treat the phytoplankton as a bulk quantity suitably quantified by the effects of cell pigments and cell numbers on the transmission of light in water, or by the fluorescent response of pigments to stimulating light. The over the side instrumentation requires conducting winches and in some cases winches with optical fiber pass-through ("optical commutator") capability. When ordinary CTD winches won't serve, scientists have been seeing to their requirements themselves. On the whole no capability has been required yet that exceeds those of the UNOLS general oceanographic ships. Some biological instrumentation is suitable for operation on porpoising towed bodies such as the Sea-Soar.

Several of the optical techniques lend themselves to automatic data accumulation on long term moorings. Transmissometers, irradiance meters, flash fluorometers, and optical plankton counters have all been adapted for this. This increases the importance of having mooring deployment capability on UNOLS ships.

Zooplankton Research:

The major trend in zooplankton research is enhanced interest in protozoans, which have been shown to play a much greater part in ocean ecology than realized a decade ago. Not much special equipment is required for work on protozoans, although the experiments again increase the demand for deck incubators and pumping of surface seawater.

Very large, multiple net systems, such as the popular MOCNESS, have been in use for more than a decade. Most ships and crews are accustomed to towing this gear. Some of the larger versions (up to 20 m^2 mouth opening) present launch and recovery difficulties that have been solved only on the larger vessels. These largest systems require heavy cable (0.68" electomagnetic of 9/16 wire rope) and the largest trawl winches. Because we have a good stock of large vessels, the UNOLS fleet is handling the requirement for towing of large nets adequately.

There is expanding interest in both diver and submersible observations of marine plankton. Many UNOLS ships are now well outfitted to management of divers in mid-ocean, with good UNOLS guidelines in place. The greatest difficulties are with getting divers and boatmen into and back out of dive boats bobbing alongside much larger vessels. Considerable agility is required for all current arrangements.

Excellent submersibles for observation of zooplankton, particularly gelatinous forms, are available. These include the Johnson SeaLink, operated by the Harbor Branch Foundation, which has attracted great user interest for this purpose. Special and successful collecting equipment has been developed for this facility. Similar work has been done from several submersibles operated commercially and chartered for the scientific community by NOAA-NURP.

Acoustic assessment of zooplankton abundance and patchiness has seen increased interest in recent years with increasing use of multi-frequency and dual-beam techniques. Most systems currently under development are packaged in lowering frames or on towed bodies. Apart from conducting cables of ordinary sizes, no special requirements are involved. There are some systems under development for long-term, moored deployment. Again, there will be increased interest in mooring capability.

One of the new optical techniques applies to zooplankton, the optical plankton counter or OPC. These are small packages which provide counts of small refractile objects passing through their central opening. The utility of the data remains to be demonstrated for most purposes, but their popularity is increasing anyway. They can be lowered, towed, or placed on moorings. Again, mooring capability is of greater interest.

Benthic Ecology:

Apart from continuing interest in submersible studies, including those addressing submarine hot vent and cold seep communities, benthic ecology has turned away from deep-sea studies in recent years. Trends have been toward functional studies of shallow water forms using special laboratory habitats (flumes and tanks). Continuing work at sea has emphasized very heavy samplers, particularly large box corers, and a variety of instrument packages lowered or dropped to the seafloor, which then gather data autonomously. Data include sedimentary oxygen and redox profiles, oxygen consumption rates, and repeated photographs. Landers generate increased interest in excellent launch and recovery capabilities for UNOLS vessels.

Fisheries Oceanography:

A recurring complaint of fisheries oceanographers has been that UNOLS vessels are not suitably equipped for pulling heavy trawls. That is so. The requirements are such that a vessel which is suitably equipped becomes a sole purpose ship. UNOLS experience shows that we cannot keep sole purpose vessels fully occupied. The requirements are double warp towing gear aft (two very large winches, hangers port and starboard for trawl doors, complex cable fairleads), a stern ramp from below water level to the working deck at a modest angle, capacious catch handling spaces inside, specialized processing machinery, and substantial steam production capacity for cleaning. Equipment of these sorts is available on NOAA-NMFS experimental fishing vessels or can be obtained by charter of commercial fishing boats. NOAA welcomes academic scientists on their ships, and commercial charters are well handled under policies recommended by

UNOLS. This aspect of biological oceanography cannot be carried on UNOLS vessels supporting general oceanographic work.

E Current Trends in Marine Geoscience

During the past decade marine geoscience has undergone a profound transformation from worldwide global reconnaissance surveying using underway geophysical techniques and widely-spaced sampling stations to detailed and in depth studies of specific geological targets and processes. Global reconnaissance led to the "plate tectonic" framework, within which critical problems can now be defined. In some cases, such as the axial regions of mid-ocean ridges, or the actively accreting zones of subduction complexes, the required level of detail in mapping and sampling approaches that of classical field geology on land. In other cases such as defining subseafloor magma chambers or the deep structure of the continental margins, elegant seafloor experiments and sophisticated geophysical techniques are required.

Overarching Needs:

Much of the research in deep-sea marine geoscience is carried out from large and often specialized ships, which are required because of long transits to the study area and/or requirements for large-instrument systems, such as multibeam echo sounding, multichannel seismics, or deep submersibles. When transits are not too long intermediate-sized ships can and have been used when the specialized equipment is transportable (e.g. SEAMARC systems) or is not required .

Four types of specialized ships are essential to modern studies of the geology of the sea floor:

1) Ships that carry a near state-of-the-art multichannel seismic system;

2) Ships with superior dynamic positioning capability and over the side handling equipment for deploying deep-towed systems, ROV's and seafloor packages;
3) A submersible support ship;
4) The deep ocean drilling ship, JOIDES RESOLUTION, is the prime tool of marine and marine geoscience. In addition to deep sampling of sedimentary and igneous rock of the ocean crust, it provides opportunities for measurements and experiments in the drill holes.

An important requirement for modern geological studies of the sea floor is precision navigation. Thanks to the Global Positioning System (GPS), high precision is now available for all UNOLS ships at modest cost. Currently, the full precision of GPS (±10m) is not available on all large ships, but may be soon if plans to make P-code (full accuracy GPS) available to UNOLS vessels are realized.

A special requirement of seafloor studies is precision bottom navigation of submersibles, ROV's, tethered instrument packages, and deep-towed vehicles. At the present time acoustic ranging using an array of bottom transponders is the most widely used technique, and under ideal conditions provides an accuracy of 5 to 10 m relative to seafloor features. In the future it will be more efficient to use GPS navigation of the ship and a ship-based short-baseline system to the location of instrument packages on or near the sea floor.

Another increasingly important general need is a computer-based data handling and display system. Typically, data are acquired from a large number of sensors, some of which are providing data at very high rates. Thus, high speed data transmission capability and fast computers are needed. Data displays in "real time" are essential for many types of surveys. Offline computer manipulation and analysis of the data on board the ship is also required for many marine geology field programs. It is now possible for chief scientists to carry reduced and integrated data collected during their cruise with them when they leave the ship.

Major Problems in Marine Geoscience and Facility Needs:

A major focus of marine geology and tectonophysics is the geological and tectonic evolution of plate boundaries and associated processes.

Mid-Ocean Ridges (Accreting Plate Boundaries).

There are three broad areas of study - 1) the morphology, structure and tectonics of the oceanic crust at all scales; 2) the petrology of crustal rocks in space and time; and 3) hydrothermal activity at the ridge axis and associated phenomena such as metallic sulfide deposition and biological communities that are sustained by the hydrothermal vents.

Tools being used to study the periaxial zone of mid-ocean ridges:

Deep-towed imaging systems - optical and acoustical. These systems require precision bottom navigation and dynamic positioning. Intermediate-sized ships can be used to deploy these systems in many cases.

Manned deep-submersibles provide opportunities for human guidance of video and photographic documentation of sea floor features, as well as limited sampling and in situ experimentation. A specialized submersible support ship is required.

Remotely Operated Vehicles (ROV's), are coming into use. Ultimately these vehicles should be able to duplicate the capability of deep submersibles, but with the human observer on board the ship. ROV's can be deployed from Class III research ships.

Shipborne geophysical systems are in wide use include - multibeam echo-sounding systems. Multibeam bathymetry has become virtually indispensable for large scale studies of mid-ocean ridge morphology. Multi-channel seismic systems (MCS) and other special seismic sounding systems (for example, the NOBEL near bottom seismic refraction system) have proven to be powerful techniques for defining the structure of the igneous crust and axial magma chambers. (MCS) systems are best deployed from large specialized research ships. Commercial operators are sometimes employed when it is more economical to do so, or when required specialized capability is unavailable in the UNOLS fleet .

Long-term, time-series measurements using ocean floor observatories are becoming an important component of ridge studies. Arrays of ocean floor seismometers and electromagnetic sensors are being deployed across the axial zone of mid-ocean ridges to monitor natural and man-made events. Long term emplacement of instruments to monitor strain across a spreading center or make a video record of hydrothermal vents are now a reality. Emplacement of such instruments requires large ships with excellent over the side handling equipment, dynamic positioning and bottom navigation capability.

Deep ocean drilling has provided opportunities to emplace sensors in drill holes. Crustal drilling at mid ocean ridges has proven to be difficult except where the ridge axis is covered by a blanket of sediment. Future developments in drilling technology may achieve penetration in unsedimented ridge axes and provide opportunities for downhole measurements and experiments.

A major NSF program called "RIDGE" was initiated in late 1980's to carry out a multidisciplinary studies of mid-oceanic ridges on a global scale.

This program currently has significant international participation under the umbrella "InterRidge". Also see Section II-G on large programs.

Convergent Margins

Subduction zones and the large submarine prisms of deformed seafloor sediment that develop at the leading edge of the overriding plate have generated great interest in the geological community because of the active deformation taking place at the toe of the prisms and their analogy to fold and thrust belts on land. Over-pressured porewaters in the prism due to rapid thickening of low permeability sediment in the prisms and its role in abetting large displacement detachment faults have attracted a great deal of attention. The transport of fluids through the prism due to the large pore-pressure gradients is another important target of current research. The complexity of structures in the deforming prisms make these a difficult objective for exploration. At the present time there is no large organized program to study convergent margins.

Many of the tools described above to study mid-oceanic ridges are also employed to study accretionary prisms. High resolution, and 3-D multichannel seismic reflection profiling are among the most powerful tools. Multibeam bathymetry is indispensable for defining the complex morphology typical of accretionary complexes and is a valuable complement to seismic work.

Deep-towed seismic systems and side-scan sonar have proven to be valuable tools for defining fault and fold structures at shallow depths below the sea floor. Multiple penetration thermal probes and instruments to detect pore pressure gradients in situ have been extensively employed to explore fluid fluxes subbottom. Deep-ocean drilling has proven to be a powerful tool for exploring accretionary complexes, although drilling conditions are often difficult because of the large stresses and over-pressures in the prisms. There is great interest in measuring pore pressures in the boreholes, and installing long term monitoring systems to quantify fluid flow, in situ stress and associated physical properties of the sediment, but such measurements remain to be achieved.

Submersibles and ROV's have found application for the study of seeps, mud volcanoes and exposures of sediments at fault scarps in subduction complexes.

Commonly large specialized ships that are equipped with MCS and multibeam sounders are used for studies at convergent margins. However, intermediate-sized ships also find frequent use because most accretionary complexes (e.g. the Cascadia Margin) are close to shore.

Passive or Rifted Margins

Continental shelves and slopes of rifted margins have been studied since the early days of marine geophysical exploration in 1940's and 50's. Considerable interest stems from their hydrocarbon potential. More recently the interpretation of "sequence stratigraphy" in terms of sealevel changes and tectonic subsidence has proven to be a fruitful area of research. In addition, there is renewed interest in the development of the morphology of the slope and rise areas through the use of computer modeling and observation.

Critical tools used to explore rifted margins are long array multichannel seismic systems to image the deep structure of continents and high resolution seismics to define sequence stratigraphy. Large aperture long array MCS require specialized ships, which are frequently chartered from commercial exploration companies. High resolution reflection seismics can be carried out from intermediate and even small (<150) ships.

Multibeam bathymetry, and deep-towed imaging systems are used to define the morphology of the slope and rise. Even though these systems can be deployed from intermediate sized ships, no ship in this class is equipped with multibeam echo sounding.

Needs of Paleooceanography and paleoclimatology

It has long been realized that the deep sea sediments contain an invaluable record of past climates, marine life as well as oceanographic and geological processes. The ocean drilling program has given us almost complete access to that record, and our ability to interpret that record continues to improve rapidly.

Deep sea drilling and long piston coring are the tools of paleooceanography and paleoclimatology. Long piston coring (LPC), with more than 30m penetration, has not been widely used because of persistent equipment and deployment difficulties. The LPC however has great potential for detailed studies of the historical record contained in sediments. These systems require a large ship to safely deploy them. A ship dedicated to piston coring to about 300m has been frequently proposed. A SWATH ship might make a practical platform for a long coring facility.

F Physical Oceanography

Trends in scientific focus:

A dominant trend is towards the study of climate--of interannual, interdecadal, and even longer time scales, and of basin-wide and global space scales. Long time scales dictate emphasis on moored and drifting sensors and on taking better advantage of volunteer observing ships.

In addition to the climate-related thrust there is a trend related simply to the maturing of the field. Geographically, as regions close to home become more intensively studied, attention turns to more remote and data-poor regions and regimes such as the South Pacific, the southern Indian Ocean, and high latitudes. Even in low latitudes, there was little US work in the western Equatorial Pacific, for example, until about 8 years ago. Now it is under intensive study. Comparable, and increasingly intensive, regional studies will be common in the next decades.

The importance of numerical models has increased rapidly during the past decade, and will continue to increase in the coming decade. One of the biggest challenges in numerical modeling is the adequate parameterization of sub-grid scale processes, typically through eddy diffusion coefficients. The theoretical and observational basis for such parameterizations is presently inadequate. Observing and understanding the temporal and spatial variability of meso- to micro scale processes will be a major goal of the coming two decades.

Trends in the way research is organized and executed:

One obvious trend in physical and chemical oceanography has been the growth of big programs such as TOGA, WOCE, and JGOFS. Big programs are not new--witness IDOE in the 50's-- but they have been getting bigger and lasting longer. Programs in the current generation are typically 5-10 years in duration. Some now in the planning stages, such as GOOS and GOALS, are envisioned for 10-20 year periods. Their long duration is a necessary consequence of their focus on long time-scale processes. Regardless of whether these particular programs develop as planned, the quest for longer time series will undoubtedly continue as long as oceanography remains healthy. We will return to this point in the discussion of new technologies and their effects on demand for ships.

Another possible trend is toward increased integration of biological, chemical, and physical studies. If such a trend exists, it is clearly not linear--early oceanography such as the Challenger Expedition was often highly integrated. Nevertheless, many projects of the present and last decade, such as Warm Core Rings, WOCE, and JGOFS, seem to point to increasing collaboration at sea among the subdisciplines. Such collaboration will not increase indefinitely--many parts of oceanography will remain specialized and independent--but interdisciplinary work may still become more common than at present. As understanding and measurement capability improve in each of the subdisciplines, so does the degree to which they can contribute to each other. Cooperation may also be driven by the composition of the fleet and the availability of ship time--it may become increasingly necessary or desirable for unrelated or marginally related projects to share a cruise so as to use a large ship more efficiently.

Along with the trends to big and, to a degree, interdisciplinary programs comes a trend toward greater international collaboration. Much of the ship time as well as the scientific talent for WOCE and TOGA has come from foreign countries. This is an important point: international collaboration does not imply a reduction in demand for the US research fleet. Rather, it expands the capability of the world oceanographic community to execute large programs and long-term studies.

Trends in techniques:

Several trends in techniques are mentioned in the section on the impact of new technologies. Those most relevant to physical oceanography are satellites, moored and drifting sensors, and autonomous underwater vehicles. These techniques may not cause a major change in the aggregate demand for ship time, but certainly will cause some changes in the optimum characteristics of ships.

As mentioned above, a major trend is toward increased use of numerical models: in highly idealized process studies, in more realistic simulations, and in the data assimilation mode. Observation programs are increasingly being designed in tandem with modeling studies. Specific observations may be needed to supply boundary conditions for a model; to validate or illuminate the weaknesses of a model; or to continually nudge a model toward reality. Conversely, models can effectively multiply the value of data by interpolating or extrapolating it in a physically consistent manner. In summary, there is no sign that increasing use of numerical models will reduce the total demand for ships.

G. Current large oceanographic programs and the need for ships over the next 5-10 years

National Science Foundation:

The largest single program in terms of funding, but not in term of UNOLS ship use is the Ocean Drilling Program. The primary facility for ODP is the drilling vessel JOIDES-RESOLUTION, but UNOLS ships have been involved over the years in carrying out a substantial fraction of the pre-drilling site surveys. Recently, the requirements for adequate pre-drilling surveys have become more sophisticated as the drilling objectives have become more ambitious. Multibeam echo sounding, multchannel seismic reflection, and deep-towed imaging are routinely required for drilling at mid-ocean ridges and in subduction complexes . This means that future site surveys will require the larger ships in the UNOLS fleet that are equipped with these technologies.

Program development at NSF-OCE has consistently lagged behind even pessimistic projections throughout the 1980's and early 1990's, despite heroic efforts to implement its Long Range Plan (LRP) for substantial increments in research funding.

RIDGE:

The RIDGE program is an ambitious major research initiative to make a comprehensive, interdisciplinary study of the global mid-oceanic ridge system. The participation of academic researchers in RIDGE is primarily supported by the National Science Foundation. The Office of Naval Research (ONR) is supporting a component to establish "Natural Laboratories" at the Kane Fracture Zone and the East Pacific Rise. NOAA is vigorously pursuing its "VENTS" program to develop a census of vents and quantify the emissions of fluids and heat from axial vents. NOAA is also developing a global system for the detection of volcanic, hydrothermal and tectonic events. RIDGE has a significant international component, which, together with the U.S. efforts, will constitute "InterRidge". Currently, some 15 nations have expressed interest in participating in this program. These nations may provide a significant amount of shiptime to field programs.

Recently, the RIDGE program published a Science Plan covering the period from 1993-1997. This plan envisions a rapidly growing effort comprised of five components: "Global Structure and Fluxes", which has ambitions of mapping nearly all of the mid-oceanic ridge system; "Crustal Accretion Variables", which will take a close look a three major segments of the Ridge; "Mantle Flow and Melt Migration", which will carry out special experiments to define the geometry of melt and flow below the axis; "Event Detection and Response", which will establish a network to detect volcanic and tectonic events and when appropriate, follow up with fast response field work; and "Temporal Variability of Ridge Crest Phenomena", which will establish long-term monitoring observatories at two to three ridge localities. Figure II-2 shows the hoped for ramp-up of funds to support participation by academic researchers for each of these components over the next six years. Total funding, which is currently about 7 $M per year, is projected to increase to 20 $M by 1999. Achieving the above goals will require significant inputs from non-US partners and the government agencies.

Based on the funding outlook and the strategies for implementing the five aspects of the program it is possible to make a rough estimate of the number of U.S. field programs that will be carried out and therefore the amount of shiptime required. Starting in 1994 the amount of shiptime required will be about 6 ship months per annum. Over the next 5 years the demand will slowly increase to about 9 months per annum. The RIDGE program has spawned and in the future will spawn other related, but independent field projects that are funded out of CORE programs in OCE-G&G. The amount of shiptime for these spin-off projects is estimated as about 3 months per annum in 1994 and may increase to 4 months by 1999.

Most of the RIDGE field programs will employ ships with swath-mapping systems (i.e. the larger ships in the UNOLS Fleet), ships with advanced geophysical capabilities such as multichannel seismic capability (e.g. EWING), or ships to handle submersibles and deep towed devices (e.g. KNORR). Intermediate ships may find infrequent use to service long-term observatories or arrays of bottom instruments.

In summary, if the RIDGE program and related CORE projects are successful in obtaining the funding projected in their planning document then approximately 9 months of large shiptime will be needed starting in 1994 and this demand will increase to about one full year of shiptime for large ships in 1999. If the funding levels are below expectations then the amount of shiptime needed to implement RIDGE will probably decrease proportionately.

Programs in Chemical and Physical Oceanography:

WOCE Hydrographic Program (WHP) cruises are now planned through 1995. By the end of that year the Pacific and Indian Oceans will have been surveyed. It is not clear whether a quasi-synoptic one-time survey of the Atlantic will be done at all in WOCE. If it is, it will require at least one large ship-year. Of the WOCE process studies, only the Deep Basin Experiment continues beyond 1995. Its demand on UNOLS ship time appears to be small.

Three hydrographic time series have been started as part of GOFS: BATS (Bermuda Atlantic Time Series), HOTS (Hawaii Ocean Time series), and COTS (California Ocean Time Series). Each could logically be continued indefinitely into the future as part of a global climate monitoring effort, and as a framework for a continuing series of shorter-term studies that take advantage of the data and/or the logistics of the time series programs. If so, there would be a continuing need for a small to intermediate ship for BATS and an intermediate ship for each of HOTS and COTS, each at the level of roughly 60 days/year. Subject to the availability of ship time, each of these programs could provide the nucleus for more extensive local studies.

Apart from the mid-gyre time series stations, there is no obvious successor to WOCE, unlike TOGA. It was designed primarily as a one-time survey, not an investigation of interannual variability. Nevertheless, such variability is relevant to WOCE-related questions so it is reasonable to expect that WOCE will lead to follow-ons, perhaps a set of relatively independent projects. These are likely to include activities such as long-term moorings in key locations and repeat hydrography on a few sections. Given that these activities are not yet even defined, much less proposed, it is premature to estimate their ship requirements other than to speculate that they may fall into the background of core science.

The joint NOAA-academic Tropical Oceans-Global Atmospheres (TOGA) field program is ending officially in 1995, but that is not expected to be the end of field work begun in TOGA. The TOGA-TAO array will be fully implemented by the end of 1993; it will be maintained into the future, so as to capture a full ENSO cycle, and would be one element of an operational capability to predict ENSO events. A new program is being planned as the successor to TOGA. It is GOALS, the Global Ocean Atmosphere Land System program, expected to run from 1995-2010. It may involve not only the maintenance of the TAO array, but its expansion into the Indian and Atlantic oceans.

The future demand on the UNOLS fleet by TOGA and its successor(s) may be minimal, however. Plans for the TAO array involve an essentially full-time NOAA ship plus contributions of ship time from several foreign countries. If the array is indeed expanded, the additional ship time may also come from non-UNOLS sources. Because of the TOGA and GOALS focus on air-sea interaction and climate, the observational programs tend to require broad long-term coverage of the upper ocean--drifters, VOS XBT lines, satellite observations, etc.--rather than the sorts of measurements that are best made from the academic research fleet.

The physical and chemical program parts of WOCE and JGOFS, although now fielding expeditions, were very slow to develop, and they are now substantially smaller than original projections. On the whole the

WOCE and JGOFS cruises are being serviced by the largest UNOLS vessels, with particular attention from the new THOMPSON. THOMPSON is carrying a major WOCE N-S transect in the North Pacific during mid-1993. It is seeking to be the flag ship for the JGOFS Arabian Sea Program in 1994-1995.

Global Ocean Observing System (GOOS) is in the early planning stage, so it is hard to estimate its future demand on ship time. Because it is intended as a monitoring system, analogous to the system for routine global weather measurements, it will be a long-term program if it is successful. Presumably it will rely on moorings, drifters, floats, remote sensing, and tomography. Ships of opportunity may play a large role, but there are many regions with none, and they cannot be used to service moorings--so there is potentially a very large long-term demand from GOOS for ships to deploy and recover moorings.

The laggard biological "recruitment" initiative, now called GLOBEC, is finally preparing for work on its first field study, the Georges Bank Program. That is going to be readily accommodated by one, occasionally two intermediate UNOLS ships, with the largest field component (the recurring broad scale survey of the bank) planned for the NOAA ship ALBATROSS IV. Other GLOBEC regional studies are being planned, but budget increases are so far behind initial expectations (and national financial problems are so pressing), that slow progress is to be expected.

Office of Naval Research.

Oceanographic research at ONR has not been growing in terms of total budget or proportion spent on marine work. There has been a recent (1993) spike to $7M in ship operations, but it is to be followed (1994) by a nadir of $2M due to a low number of ship requests. On average its typical level of UNOLS vessel use hasn't varied much in recent years from $5M. There is no obvious reason for expecting any substantial increase in the 1990's.

Programs at other agencies, particularly the DOE Ocean Margins Program, have been very small, and their coastal focus has allowed them to be fully and readily served by smaller and intermediate vessels. No major initiatives in ocean science seem likely from DOE, EPA, USGS or any other agency. Thus, the fleet expansions and improvements of the late 1980's and early 1990's will easily handling all increases in oceanographic activity due to large programs.

H. Impact of new technologies on the need for seagoing platforms

Several new technologies, and substantial improvements in old technologies, will be seen increasingly in the next two decades. They will affect the way we use ships, but it does not appear that they will have a major effect on the total demand for research ship time. Following are specifics:

Satellite data are increasingly important in many research projects, but tend to complement rather than replace shipboard work. Satellites need ground truth measurements, whether from ships, moorings, or drifters. Satellite data are inherently limited to the ocean surface, and much of it is further limited to clear skies. Satellite imagery can guide shipboard sampling by revealing the surface patterns of ocean phenomena. Hence there will be increasing demand for satellite receivers on research ships; a good view of the sky should be a design criterion for future ship designs.

Moorings are not new, but improved technology of moorings and their sensors has greatly increased their usefulness, just as scientific interest in long moored time series has increased. Maintenance of moored arrays such as TOGA-TAO and its successors will require substantial ship resources. Ideally, the ships servicing such arrays would be optimized for mooring work--good low-speed maneuverability, large fantail, good capstans and A-frames, propellers shrouded and/or distant from the deployment/recovery zone--but would retain enough general capability to perform ancillary work such as hydrography on mooring cruises.

Drifters and floats, like moorings, are becoming increasingly capable and useful. They are also becoming increasingly deployable from volunteer observing ships. This represents little change in demand for UNOLS ships, however, because drifters and floats have normally been launched as an ancillary rather than a primary ship activity.

Autonomous Underwater Vehicles are presently under intensive development. Within 5 years they may be available for short-duration (few days) excursions. If they work well and if funding permits the community to invest in them, such AUVs may reduce the demand for ships working near shore. It seems unlikely that AUV's that can do long range work (many-month deployments, basin-wide range) will come into use in the coming decade.

Advances in Remotely Operated Vehicles have been rapid, and we anticipate increasing use during the next decades. This will require ships with adequate deck space, generally not a problem with the present fleet. ROVs will use SWATH stability to good advantage when available.

Improved communications--continuous INTERNET connectivity--will change some aspects of the way work is done at sea. Coordination of multi-ship projects will be easier. The difference between working at sea and working at one's office will be reduced, for better or worse. It is unlikely, however, that this will greatly change the demand for ships or even the inclination of oceanographers to go to sea.

REFERENCES

Brink, K.H. and others, 1990. Coastal Ocean Processes (CoOP): Results of an Interdisciplinary Workshop. Contribution No. 7584 from the Woods Hole Oceanographic Inst., Woods Hole.

Brink, K.H. and others, 1992. Coastal Ocean Processes (CoOP): A Science Prospectus. Woods Hole Oceanographic Inst., Woods Hole.

CoPO Steering Committee, 1989. Coastal Physical Oceanography: Towards a National Plan. Report of a Meeting of the Coastal Oceanography Physical Oceanography Community, Gulf Park, MS.

Holligan, P.m. and H. deBoois (Eds.), 1993. Land-Ocean Interactions in the Coastal Zone (LOICZ) Science Plan. IGBP Global Change Report No. 25, Stockholm, Intl. Council Scientific Unions, 50p.

Holman, R. and others, 1990. Nearshore Processes Research, A Status Report Based on the Nearshore Processes Workshop. Results from the Nearshore Processes Workshop, St. Petersburg, FL.

Hooker, S.B. and W.E. Esaias, 1993. An Overview of the SeaWiFS Project, EOS, 74, p. 241, 245-246.

Interagency Arctic Policy Committee (1991). US Arctic Research Plan. Arctic Research 5: 2-89.

Moritz, R. *et al.* (1990). Arctic Systems Science Ocean-Atmosphere-Ice Interactions. Joint Oceanographic Institutions Inc., Washington, DC, 132 pp.

Orcutt, J.A. and K. Brink, 1993. The Future of Naval Ocean Science Research, EOS, 74:219-220.

Polar Research Board (1988). Priorities in Arctic Marine Sciences. National Academy Press, 73 pp.

Thiede, J. *et al.* (1992). The Arctic Ocean Record: Key to Global Change. Polarforschung *61/1*: 1-102.

III TRENDS AND ISSUES REGARDING THE UNOLS FLEET

A. Funding the UNOLS Fleet:

The operation of the UNOLS fleet and its composition are ultimately defined by the research demands of the national oceanographic research programs supported by funds from the various contributing agencies. One of the reasons that the UNOLS Council asked for an update to the Fleet Improvement Plan is anticipation of changing funding projections and changes in research directions within ocean science. A recent statement from the Secretary of the Navy published in Sea Technology January 1993 states emphatically that Naval research will be focused closer to shore.

> "..we have been realigning the entire structure of naval oceanography. The shift in focus from a Cold War, open ocean, blue water naval strategy to a regional, littoral, and expeditionary focus has changed the way we look at meeting our surveying and oceanographic requirements. Our operational oceanography program now reflects the Navy's strategic shift from a global, open ocean focus to a regional, near-shore spotlight."

With respect to budget projections the stated intentions of the Clinton administration to make serious attempts to reduce the federal budget deficit through reductions in spending coupled with the slow recovery from the prolonged worldwide recession strongly suggest that the ocean science community will be facing slowly rising or level funding during the remainder of the decade. Two new initiatives may change this projection; increased funding for coastal ocean science and increased focus on the research in polar regions particularly the Arctic. However, budget constraints may mean that funding for these new projects will come at the expense of other areas of oceanography.

B. Estimates of future operating costs

The trends and analysis of utilization and costs presented in Section I provide only a rough guide to future costs of the fleet, especially for the Class I & II vessels. The period from 1988 to 1992 has been a period of transition. The last of the AGOR-3 class vessels (≈210') was retired from the fleet in 1992. A new 274' research vessel, the AGOR 23 (THOMAS THOMPSON) and a conversion, the MAURICE EWING (238'), have been added to the fleet. During the same period two of the large vessels, KNORR and MELVILLE were stretched 30 feet. Despite these changes in fleet composition, the cost and utilization statistics over the past eight years still provides the best basis for estimating future costs.

In Tables III-1A and III-1B we examine two possible future evolutions of the UNOLS fleet over the next eight years and show likely operating costs using the 1992 average daily rates for Classes II through V. A $15,000/day rate was assumed for the Class I vessels to anticipate higher operating costs for the AGOR 23 class ships.

- •Model 1-Prosperity-The construction and retirement of ships follows the schedule shown in Figure I-1 of Section I.
- •Model 2-Austerity- The number of Class I general purpose ships is maintained at 4 ships, the Arctic Research Vessel is not built, and one of the intermediate sized ships is retired in 1995. Note- even if the Arctic Research Vessel is not built, there will probably be shiptime costs for the use of the Research Icebreaker being built by the Coast Guard which are not included.

C. Innovative Funding for New Ships

Institutions have experimented with several new mechanisms for funding the acquisition of new research vessels over the past 5 years. Not all have been successful. A brief account of these acquisition programs is presented here.

Lamont-Doherty Earth Observatory of Columbia University acquired a 238' Canadian seismic vessel M/V Bernier, which it renamed the R/V MAURICE EWING, to replace the aging R/V CONRAD. Funds to purchase the EWING were provided by Columbia University. Conversion of the EWING for academic research as a general purpose R/V with special capability in marine geophysics was accomplished for the relatively modest cost of about 11.3 $M. Columbia University was reimbursed for the costs of the purchase and conversion over a period of 7 years through an agreement negotiated with NSF.

The University of Southern California undertook conversion of a 220' tuna seiner (OSPREY), which was donated to the University. USC renamed their ship the R/V VICKERS. Funds to cover conversion costs were raised from private sources. A commitment from NSF was not obtained by USC, and the conversion required >5 years because of the difficulty in raising money. The VICKERS operated for about 2 years. NOAA chartered the ship for significant periods during the two years and NSF provided limited support. However, continued improvements were required and without a substantial commitment from NSF, USC appears to have abandoned ship operations. The VICKERS is now on the market and no longer operating on the UNOLS schedule.

Private oceanographic institutions have also made substantial contributions to the oceanographic research fleet in the past 5 years. The submersible support ships EDWIN LINK, SEWARD JOHNSON AND THE SEA DIVER, which are owned by the Harbor Branch Oceanographic Institution, have been added to the UNOLS Fleet. These ships promise specialized support capabilities for the Johnson SEALINK submersibles. They are not general purpose oceanographic vessels, however. An innovative new vessel is now under construction by the Monterey Bay Aquarium Research Institute. The R/V WESTERN FLYER will be a 120' SWATH, which will serve primarily as a mother ship for a remotely operated vehicle that is being designed at MBARI. It will have general purpose hydrographic capabilities, but no trawling winch. It is not yet known whether the WESTERN FLYER will operate as a member of the UNOLS fleet.

Finally, the NSF Division of Polar Programs was responsible for construction and operation of a new ice capable research ship the R/V NATHANIEL PALMER, which is now operating in the Southern Ocean. The PALMER was obtained in a novel lease arrangement with its owner and operator, Chouest Offshore. Chouest Offshore financed construction of the PALMER. A 10 year lease was signed with NSF DPP, which will allow Chouest Offshore to recover construction and operating costs plus a profit. An option exists for NSF to purchase the PALMER at the end of the lease. The PALMER is now operating outside of the UNOLS scheduling framework.

In addition to these modes of financing new assets for the fleet, several other ideas have been considered, including long-term leases of Russian research vessels, particularly those which are ice capable.

D. Improving the U.S. Research fleet through interagency cooperation

The United States Oceanographic Fleet is distributed amongst a number of federal agencies, academic institutions, several private institutions such as Harbor Branch and Columbia University, and state-supported entities. The two major research ship brokers are the University National Oceanographic Laboratory System (UNOLS), with 26 vessels, and the National Oceanic and Atmospheric Administration (NOAA), with 18 research vessels. The main support for the UNOLS fleet comes from NSF with significant contributions from ONR and in recent years from NOAA. Other federal agencies that support oceanographic research vessels include: EPA, USGS, MMS, DOE and DOD.

Major components of the facilities that are owned and operated by federal agencies that are dedicated to mission or federally mandated data acquisition. Opportunities for cooperation with these components is very limited. However, many agencies have research arms and their personnel share interests and facility needs with academic researchers. It is between such groups that the best opportunities of coordination exist.

The need for greater cooperation:

Dwindling funds: It is painfully apparent from recent funding trends is that there is insufficient federal support to maintain the research fleets at the desired levels. NSF officials have pointed out that there is a chronic funding shortfall of about 10% in funding for the UNOLS Fleet during the past decade. NOAA has developed a multiyear fleet replacement and modernization plan involving an estimated 1.6 billion dollars in construction and repair costs, which is a key element in this agency's maintenance of its position as a leading oceanographic research, living marine resources, and nautical charting organization. NOAA officials indicated that ship support funds are short and currently one limitation on the amount of oceanographic research the agency conducts at sea. In addition, funding for their fleet modernization program is significantly behind the schedules initially planned. In a like manner, we have also witnessed an erosion of NSF's ability to support core (individual investigator) science, as well as less-than-projected growth in global science initiatives such as WOCE and JGOFS.

Currently we are in a period of austerity with respect to funding of ocean science and the operations of the oceanographic research fleet. Thus plans over the next few years must be tempered by the likelihood of slow growth or level funding. The anticipated growth in coastal ocean science and Arctic Ocean research, described elsewhere in this document (Section II A & B), may improve this projection, but it could also result in reductions in other sectors of oceanography. This is a challenging period for all oceanographic scientists, and it warrants close examination of the particular ways that we can use our precious resources most effectively and efficiently.

New needs: During the next decade it is anticipated that there will be an increase in funding for coastal ocean science in terms of large-scale, long-term programs such as GLOBEC and CoOP as well as small, single-investigator programs. The EPA, NOAA and the U.S. Navy have also stated intentions to increase their research efforts in coastal waters. The projected increase in coastal ocean research should increase the demand for ship time, particularly on smaller research ships, however there is increasing interest in using large platforms for large interdisciplinary programs on the shelf and slope. Coastal oceanographers also anticipate increasing use of other types of data acquisition vehicles such as aircraft, satellites, and moorings; which may change the role of ships in support of coastal science. The new initiatives for increased research in coastal waters present an opportunity to develop increased cooperation in the use of the fleets of academic institutions and government agencies.

There may be a similar increase in oceanographic research in the Arctic Ocean. Concern for degradation of the environment of the Arctic region and the sensitivity of the Arctic Ocean to global climate change should lead to a significant increase in support. The year-round ice cover of the Arctic ocean presents formidable obstacles to oceanographic research. Ice breakers with high endurance and a full complement of scientific equipment are required but none currently exist in the U.S. Fleets. NSF and the Coast Guard have plans to build large research vessel with significant ice breaking capability (see Section II-B). Because of the high costs of doing research in the Arctic we recognize yet another motivation for cooperative development and use of the facilities.

Benefits of optimum coordination of the federally funded oceanographic research fleets.

<u>Optimize the capability federal fleet:</u> Through coordination, oceanographic fleets and mix of capabilities could be structured to meet the needs of the entire community including academic, state or federal research partners. Proposed or imposed changes in the fleet (i.e. such as building a new or replacement vessel or an extended lay-up or retirement of a vessel from the fleet) could be made in this context. Successful coordination between academic and governmental resources would broaden the capability of the reconfigured fleet and could optimize the allocation of scarce resources.

<u>Increase accessibility:</u> Improved coordination of scheduling of all ships longer than 150' by academic groups and research arms of governmental agencies would provide researchers with a better match of their needs and

more options for scheduling. A necessary element of this is improved coordination among the major programs that depend on ship resources.

Common basis for operating costs: Major components of the current federal fleet use different accounting procedures and philosophies when determining and covering the costs of operating a research vessel. Despite these differences the fundamental parameter is the cost per day of ship time. For agencies and academia to share facilities would require agreements on how to transfer funds between agencies for basic ship operations.

Small vessels: Opportunities for cooperative use of vessels smaller than 150' could be explored on a regional level. Informal or formal consortia between institutions or local governmental research groups would allow sharing and optimum use of their facilities.

Current cooperative efforts:

Today, there has been a substantial shift from individual investigator programs to the large, globally-focused programs. This pattern is unlikely to change substantially in the future because the current global programs will probably engender continued or new large scale multidisciplinary research programs. The UNOLS and NOAA fleets are cooperatively involved in a number of large international programs (WOCE, JGOFS, GLOBEC, RIDGE, IGAC and TOGA). In fact, this unprecedented cooperation also involves oceanographic ships from other countries and a number of other federal agencies (NASA and DOE) that are applying substantial resources to support these globally focused science efforts. WOCE, JGOFS and GLOBEC are envisioned as decade-long initiatives, and as such will continue utilizing substantial amounts of ship time from the UNOLS and NOAA fleets.

There is increasing cooperation between NSF, ONR, NOAA, UNOLS, EPA, USCG, and USGS and recognition of mutual interest. Such cooperation between agency and academic researchers in response to specific emerging program needs is effective. We encourage further discussion among UNOLS, agencies, and interested parties such as EPA. The objectives of these discussions should be to identify additional areas for cooperation, to optimize the capability of the research fleet, to increase accessibility to the community, and to find (to the extent possible) a common basis for determining operating costs.

There are several scenarios that could bring about such coordination. Cooperative agreements must remain flexible enough to respond to emerging scientific goals. Each agency and institution has diverse missions, statutory responsibilities and "cultural" characteristics that contributes to our national strength. The challenge for our community is to enhance cooperation while respecting the diversity of capability.

In view of the potential gain for the U.S. ocean sciences community as a whole from increased coordination, this committee recommends that federal and academic colleagues who depend on ships for their research continue to examine ways to improve cooperation and coordination. The Fleet Improvement Committee supports collaboration that preserves distributed management of oceanographic facilities as opposed to central management of the research fleet. It has been amply demonstrated that distribution of assets and responsibility amongst UNOLS institutions and Federal Agencies contributes to the vitality of the U.S. oceanographic fleet and seagoing technology.

E. Regional Distribution of the Fleet

It is obvious that boats and small ships used primarily for cruises of no more than a few days need to be widely distributed geographically, but the optimal distribution of intermediate and large research vessels is not so clear. Here we will summarize the considerations that might go into determining such a distribution. To simplify, we may consider two models: a centralized fleet, with perhaps one base each on the east and west coasts; and the dispersed fleet we have at present, with large and intermediate ships based in Woods Hole, Rhode Island, New York, Florida, Texas, San Diego, Oregon, Washington, and Hawaii. We also need to distinguish two types of ship use relative to each base: local (within a few days transit) and remote.

The benefits of our dispersed fleet are:

1) Competition. With many ship operators competing for funded science, there is constant pressure to provide good service and respond efficiently to scientists' requests.

2) Diversity. If scientists at the home institution are actively involved in running a ship, monitoring its equipment and technical support, etc., then a dispersed fleet involves more scientists than a centralized fleet. More ways of doing things are likely to be tried, and better ways of doing things may therefore be found.

3) Reduced deadhead transit time and greater logistical convenience. It may be hard to quantify, but common sense suggests that the scheduling of funded science around the globe with minimal deadheading must be easier with broad geographic dispersal of bases. Ideally, this dispersal might be broader than at present--a base in Guam, for example, would improve access to the western Pacific, and many other such examples could be imagined. A

base of ship operations generally provides much better logistical support--shipping and receiving, shops, warehouses, communication--than a simple port stop, so dispersed bases increase the number of cruises with good support. This advantage accrues to the whole fleet, not just to each base's own ships.

4) Facilitation of local studies, particularly long-term ones. The world ocean will never be uniformly studied; the most intensive studies will always be localized. Whenever possible, such studies will be done near a ship base for logistical convenience and efficiency. The dispersal of bases increases the number and variety of such intensive local study regions.

5) Education of students and recruitment of seagoing scientists. There is clearly a strong sense in the US oceanographic community that running a ship at a given institution makes it much easier for that institution to involve students in work at sea, to recruit seagoing scientists, and to maintain a vigorous seagoing observational program. If so, then our dispersed fleet strengthens oceanography in the country as a whole, as well as in the ship operating institutions; and reducing the degree of dispersal would be tantamount to reducing the priority of seagoing science in the US.

Possible disadvantages of a dispersed fleet compared to a more centralized one are:

1) Reduced efficiency from lack of standardization. This is the other side of diversity. Scientists must adjust to different shipboard instrument systems, etc. This may mean that they need to maintain a larger stock of their own equipment than would be the case if instrumentation were standardized on all UNOLS ships of a given class.

2) Possibly increased average cost per day of ship use. The dispersed fleet may have higher costs than a centralized fleet because of the fixed costs

of the additional marine centers and because of reduced flexibility for temporary lay-ups. These issues of economy of scale could be quantified by a careful economic analysis.

3) Possibly reduced minimum standards of performance. With a centralized fleet it might be possible to run and maintain all ships to the highest possible standards; in a dispersed fleet, some operations may be marginal.

Compared to the advantages of geographic dispersal, the costs appear relatively minor. The first of these problems--lack of standardization--can be addressed directly. Indeed, there is a committee of UNOLS, RVTEC, designated to improve exchange of ideas among ship technical support groups and to promote standardization where desirable. The second problem is inherent, but cursory comparison among UNOLS institutions shows no strong correlation between the cost per day and the number of ships the institution operates. This suggests that the economies of scale are small. The third problem should be self-limiting because of the competition inherent in the dispersed fleet.

Most of the advantages of the dispersed fleet vary with particular characteristics of ship operators. The minimization of deadheading and the maximization of logistical convenience come from a broad rather than a dense distribution of ship bases. This applies to the advantage for local studies as well. Other advantages depend not on the distance between ship bases but on the characteristics of each operator. The greatest benefits come from institutions in which ship operations are tightly integrated with active seagoing research and educational programs.

The conclusion is that any change in the present geographical distribution of ships should be approached cautiously and deliberately--it should not occur by accident or by default, because it has important ramifications for the entire US marine science community. Changes, if any, should be made based on the criteria discussed above so as to maximize the cost-effectiveness of the US fleet. If a reduction in the number of ship operators becomes imperative for financial reasons--and it is accepted that this represents a contraction in the overall size and strength of US seagoing science--then priority for retaining or acquiring ships should go to institutions that contribute to a broad geographical distribution, and that have strong in-house seagoing groups and good histories as effective ship operators.

F. Modes of operation of research vessels: Operation by UNOLS institutions vs. long-term, third-party leasing arrangements

Long-term leasing from commercial companies has been suggested by some as a method of operating the academic research fleet and in particular the proposed Arctic Research Vessel. A typical arrangement is for a shipbuilder to lease vessels to a federal funding agency, such as NSF, and operate the vessel for the duration of the lease. This is the mode of operation of Antarctic research and supply vessel R/V NATHANIEL PALMER which is operated for NSF's Division of Polar Programs by Edison-Chouest Offshore, Inc. After two years of operation, reviews on the effectiveness of the PALMER as a research platform are mixed.

Under normal circumstances oceanographers (and not just academic oceanographers) prefer working on UNOLS ships operated by academic institutions. The reasons were described in the previous Section but are worth repeating and amplifying here. The first is superior responsiveness to the science requirements. The operators of UNOLS vessels work closely with scientists to maintain a high standard of operation and modern equipment that serves all scientists that use their ships. Academic operators survive by serving science. The management style of UNOLS operators is from the bottom up rather than the top down, with scientists playing an active role in all aspects of ship operations- scheduling, technical staffing and detailed cruise planning. If a problem arises the scientist has direct access to the marine superintendent, where the buck stops.

The relationship between scientists and crew on a research vessel is a delicate one, that has evolved over many decades. The scientist does not consider him or herself as a client, but is instead a working partner with the ship's crew to achieve a successful scientific expedition. The additional levels of management that would accompany long-term leasing of research platforms do not nurture this important relationship. The obstacles that might arise are illustrated by the following hypothetical case. Suppose a scientist identifies a need to change a ship procedure on a leased vessel, he must first contact the prime contractor who more than likely would have to confer with subcontractors before any decision is made. If for some reason the prime contractor or the subcontractor decides it is not in their interest to make the change (e.g. it might eat into their profits) the long chain of command makes it easy for the leasor to muddy the waters and reject the idea. Furthermore, if a funding agency manages the financial incentives there is little cause for the leasor to respond to a scientist's needs. This is in contrast with the more direct UNOLS procedure of the scientist going to the marine superintendent of the home institution.

A second reason that oceanographers prefer UNOLS ships is cost. UNOLS vessels operate on very tight budgets in harmony with the level at which science operations have been funded during the past five or so years. Studies and experience have shown that in general academic institutions operate their vessels as economically or more economically than leasing a ship with comparable scientific capability. With the increased levels of management involved with a leasing company and the fact that the leasor must make a profit to stay in business, leasing cannot under normal circumstances cost less money without skimping on the vessel's research capability or safety. In addition; many UNOLS operators subsidize their ship operations in the form of institution funded ship days, institution-furnished equipment, staff and "free" technical advice.

Nationwide support for UNOLS operations comes about because of its distributed resources. The argument that it is more economical to have one operator for all of the academic fleet is not supported by data. There is no evidence that centralizing operations would be more economical than distributed operations by UNOLS institutions. In addition, distributed ship operations promotes a high level of competition that enhances the level of service. Researchers at academic institutions deem it important to operate ships in the UNOLS fleet. In addition to being a means of getting staff, faculty and students out to sea, operating a successful research ship creates a highly visible profile in the national and world oceanographic community.

G. Special Platforms

Semisubmersible Platforms and Spar Buoy Vessels

The UNOLS Fleet does not at present include any of these special purpose platforms. However, the operation of the Navy's FLIP is closely associated with the Scripps Institution of Oceanography, and it has frequently been towed by UNOLS vessels and used by academic oceanographers. Thus, it is important to UNOLS and the science it supports. FLIP is a 290 ft. tube, classified as an uninspected barge, which can be towed to station in horizontal attitude, then flooded at one end. This causes it to flip into vertical attitude leaving a small suite of living quarters and laboratories riding above the water. The advantage of this design is the small motions of the deep column relative to the turbulent surface layer, providing a stable base for observation of surface motions.

FLIP is now old, about 30 years, and has been showing obvious signs of its age. There has been talk of replacing it; however, that has not proved possible. An alternative was a thorough refit of the existing FLIP, but funds initially provided for this were cut from the fiscal '94, '95 and '96 budgets. Despite these setbacks the Fleet Improvement Committee recommends that a refit of the FLIP be given the highest priority future ONR budgets.

There is interest in the UNOLS community in fielding larger, more capable semisubmersible platforms. In particular, Wiebe et al. (1987) continue to seek support for a semi-permanent, mid-ocean station to be based on a modified semisubmersible oil drilling platform. The concept is for a Deep Sea Observatory (DSO Workshop Report, 1990). Buoyancy for these platforms is provided by two submerged hulls of ca. 260 ft length, each supporting three cylindrical caissons. The six caissons support a multideck platform from which drilling derricks extend up and drill strings hang down. The breadth is on the order of 200 ft. Underway the platform is deballasted such that the upper hull surfaces are at the water plane. Speeds of 7 knots are typical. On station the hulls and caissons are ballasted down to place the decks at any desired distance above the surface. Huge laboratories, heavy lifting equipment, day boats, and very large scientific staff could all readily be accommodated.

The scientific goal for the Deep Sea Observatories is very high resolution time series of oceanographic variables extending for 3 to 5 years.

The scientific rationale for this is excellent (Wiebe et al. 1987), and eventually "DSO's" will be outfitted and deployed. UNOLS and UNOLS institutions should take a leading role in developing this new scientific application of well established commercial technology.

A Nuclear Research Submarine

In 1993 a much sought after oceanographic research capability for the Arctic Ocean was made available to the U.S. science community by the US Navy- a nuclear submarine. During the summer of 1993 the USS PARGO, a "Sturgeon class" attack submarine, made a scientific cruise to the Arctic Ocean which was open for participation and planning by civilian scientists. The data collected that was collected is openly available to the US oceanographic community. UNOLS played the major role in the design of the science plan.

Nuclear powered submarines, because of their ability to work safely under the ice cap for extended periods of time anywhere in basins of the Arctic Ocean where the depth of water is greater than 200 m, are remarkably effective vehicles for Arctic oceanography. The cruise of the PARGO, called SCICEX-93, was carried out without compromising the military capability of the submarine and normal security precautions were exercised prior to and during the cruise. Maintaining the submarine's military preparedness greatly constrains the scientific personnel and equipment that can be put on board because the crew must be maintained at full strength and the space for scientific equipment is very limited. Nonetheless, despite these constraints the amount of data collected is impressive. On the SCICEX-93 cruise hydrocasts were made to 400m, expendable CTDs were launched from the submarine while submerged, water samples were collected using bottlecasts and by drawing water through the ship's seawater system while submerged

TABLE III-2A: ESTMATED COSTS OF THE FUTURE UNOLS FLEET

(PROSPERITY MODEL 1992 $)

	CLASS 1		SPEC. PURPOSE SHIPS		CLASS 2		CLASS 3		CLASS 4 & 5		1992	4% INC.
YEAR	NO. SHIPS	ANN. COST $M	NO. SHIPS	ANN. COST $M	NO. SHIPS	ANN. COST $M	NO. SHIPS	ANN. COST $M	NO. SHIPS	ANN. COST $M**	FLEET TOTAL	FLEET TOTAL
1992	4	16.50	1	4.13	1	2.70	7	13.46	8	12.05	48.83	48.83
1993	4	16.50	1	4.13	1	2.56	7	13.46	8	11.51	48.16	50.08
1994	4	16.50	1	4.13	1	2.56	8	15.39	8	11.51	50.08	54.17
1995	4	16.50	1	4.13	1	2.56	8	15.39	8	11.51	50.08	56.33
1996	4	16.50	1	4.13	1	2.56	8	15.39	8	11.51	50.08	58.59
1997	5	20.63	1	4.13	1	2.56	8	15.39	7	10.23	52.92	64.39
1998	5	20.63	2	12.33	1	2.56	8	15.39	7	10.23	61.12	77.34
1999	5	20.63	2	12.33	1	2.56	8	15.39	7	10.23	61.12	80.43
2000	5	20.63	2	12.33	1	2.56	8	15.39	7	10.23	61.12	83.65

*AVERAGE DAILY RATES ASSUMED;	DAILY RATE
CLASS 1 INCLUDING THE KNORR	$15,000
SPECIAL PURPOSE SHIPS (EWING AND	$15,000
ARCTIC RESEARCH VESSEL	$32,800
CLASS 2 (MOANA WAVE)	$9,800
CLASS 3	$9,050
CLASS 4	$7,500

CLASS 5 SHIPS ARE LUMPED TOGETHER AT AN ESTIMATED
COST OF 1.25 $M PER YEAR IS ADDED TO THE CLASS 5 ESTIMATE

TABLE III-2B: ESTMATED COSTS OF THE FUTURE UNOLS FLEET
(AUSTERITY MODEL 1992 DOLLARS)

YEAR	CLASS I NO. SHIPS	CLASS I ANN. COST $M	SPEC. PURPOSE SHIPS NO. SHIPS	SPEC. PURPOSE SHIPS ANN. COST $M	CLASS 2 NO. SHIPS	CLASS 2 ANN. COST $M	CLASS 3 NO. SHIPS	CLASS 3 ANN. COST $M	CLASS 4 & 5 NO. SHIPS	CLASS 4 & 5 ANN. COST $M**	1992 FLEET TOTAL	4% INC. FLEET TOTAL
1992	4	16.50	1	4.13	1	2.70	7	13.46	8	12.05	48.83	48.83
1993	4	16.50	1	4.13	1	2.56	7	13.46	8	11.51	48.16	50.08
1994	4	16.50	1	4.13	1	2.56	8	15.39	8	11.51	50.08	54.17
1995	4	16.50	1	4.13	1	2.56	7	13.46	8	11.51	48.16	54.17
1996	4	16.50	1	4.13	1	2.56	7	13.46	8	11.51	48.16	56.34
1997	4	16.50	1	4.13	1	2.56	7	13.46	7	10.23	46.87	57.03
1998	4	16.50	1	4.13	0	0.00	7	13.46	7	10.23	44.31	56.07
1999	4	16.50	1	4.13	0	0.00	7	13.46	7	10.23	44.31	58.31
2000	4	16.50	1	4.13	0	0.00	7	13.46	7	10.23	44.31	60.65

*AVERAGE DAILY RATES ASSUMED;	DAILY RATE (1992)
CLASS I INCLUDING THE KNORR	$15,000
SPECIAL PURPOSE SHIP (EWING)	$15,000
ARCTIC RESEARCH VESSEL	$32,800
CLASS 2 (MOANA WAVE ONLY)	$9,800
CLASS 3	$9,050
CLASS 4	$7,500

CLASS 5 SHIPS ARE LUMPED TOGETHER AT AN ESTIMATED
COST OF 1.25 $M PER YEAR WHICH IS ADDED TO THE CLASS 4 ESTIMATE

for chemical and biological analysis. Gravity and bathymetry were measured all along the track. The submarine also carries an upward looking sonar that measures ice draft and a side-scan sonar that produces an image of the bottom of the ice. It is hoped that success of the SCICEX-93 cruise will encourage the Navy to sponsor similar cruises in the future.

A nuclear submarine that is dedicated to science would make an extremely powerful oceanographic tool for academic as well as military research. A submarine of the Sturgeon class with its weapons removed could be operated with a smaller crew and it would have much more "lab" space and thus would allow more scientists and scientific equipment to be carried. A submarine would find use not only in the Arctic, but many other regions that are inaccessible to surface ships. In 1990 FIC sponsored a study of the science that a nuclear submarine could do and published a brief report (SOONS report) describing some of the research that could be done.

The operating costs of a nuclear submarine are not public information, but undoubtedly are high, too high for existing academic research budgets. A nuclear submarine for science only becomes possible if the NAVY operates the ship, and operating costs are covered by the defense budget. If we are to achieve the goal of having a nuclear submarine for science, one of the first steps would be for high level officers in the Submarine Command to meet with Navy and civilian scientists to develop a scientific program around the remarkable capabilities of nuclear powered submarines. UNOLS, which assisted with planning and preparations for SCICEX-93, could play a role in encouraging future use of these defense assets.

IV. RECOMMENDATIONS

In this section we make recommendations or comments relative to specific issues that were raised in the preceeding sections of this report.

Funding of the future UNOLS Fleet

Table IV-1 we compare the recommendations of the 1990 Fleet Improvement Plan with the composition of the Fleet as it will be in the year 2000 if all current plans go forward. The total number of ships in the UNOLS Fleet will increase by one over current levels by the year 2000, however the total displacement of the Fleet will increase by about 13,000 tons (equivalent to three AGOR 23 class vessels!). Two thirds of the increase in displacement will be due to the 12,000 ton Arctic Research Vessel. The other one third is due to a net gain of one large high endurance research vessel (AGOR-25) in the fleet. If these projections are fulfilled then the UNOLS Fleet in the year 2000 will be significantly more expensive to maintain than at present (Also see Table III-1A).

Data presented in Section I (Table I-3A) shows that currently approximately 95% of the available large ship time is being used. This implies that funded ship time on UNOLS ships must increase by one ship operating year (275 days) or increase 25% by 2000. Table I-3B shows that the utilization of intermediate sized vessels is only 80%, and that this low usage has been chronic for nearly a decade.

1. Will there be a sufficient increase in funding for shipboard science by the year 2000 and beyond to warrant an increase in the number of large ships from three to four?

2. Will the demand for shiptime on intermediate-sized vessels increase to fill the current excess capacity?

These questions can only be answered in vague terms because we have no credible way of projecting ship demand for more than a year or two into the future. However, we believe that data exist to do a much better job of projecting ship needs.

Hopes for substantial increases in future funding for oceanography are pinned on prospects for large programs that garner major new research dollars. Programs such as WOCE, JGOFS and RIDGE use and will use a lot of UNOLS shiptime in the near future (see Section II-G). There is also the prospect of major increases in coastal ocean science and Arctic Ocean research. Unfortunately, many of the published plans for these programs do not give a clear indication of their facility needs or when the needs are required. Estimates of ship use could be greatly improved if there were an annual update of future facility needs, especially those related to large programs.

Our first recommendation addresses this need.

- *FIC recommends that Federal Oceanographic Fleet Coordinating Committee (FOFCC) establish a mechanism for annually updating projections of future oceanographic facility needs looking 5 to 10 years ahead. Resources for developing this report are the facilities management centers at the agencies, UNOLS Office data as well as directors and principal investigators of large programs. This assessment should include needs of the oceanographic research components of NOAA, the Navy and other federal agencies..*

Arctic Research Facilities

Of all the world oceans the Arctic Ocean is the least explored, and yet critical issues of climate change, climate prediction and pollution have underscored the need for a major increase in oceanographic research in the Arctic region. Currently, the United States has a very meager oceanographic capability for the Arctic Ocean. US scientists interested in working in the Arctic Ocean have been making observations from camps on the pack ice or hitching rides on Coast Guard ice breakers or non-US research vessels as opportunities a rise. These methods and vehicles will not suffice for future research in the Arctic Ocean if the U.S. is to play a prominent role, which its national interests require.

To gain access to the Central Arctic Ocean and carry out state-of-the-art observational programs will be expensive; much more expensive than traditional ocean going research. To adequately address the critical problems in the Arctic Ocean facilities to work in and below the ice new types of platforms are required. Powerful ice breakers, such as the ARV, that are fully equipped as research ships are required to work in the central Arctic Ocean. A major commitment of new federal funds to acquire and operate this ship will be required.

In view of the need for a strong commitment of resources to Arctic research in next two to three decades. The Fleet Improvement Committee identifies the urgent need:

The development of a community-wide, interdisciplinary program of research in the Arctic of ten or more years duration [Decade of Arctic Oceanography . The program should involve as many disciplines as apply- hydrology, ocean chemistry, ice dynamics, as well as meteorological, climatological, geological, geophysical and biological research. It should involve academic and agency scientists. The program plan should include an assessment of facility needs. Much of the background material for such a *program has already been published in the form of workshop reports and articles.*

Efforts to obtain improved facilities for the Arctic are already underway. The Coast Guard is building a capable Class A4 or A5 ice breaker (See Table II-1), which will be equipped as an oceanographic research vessel. This ship, which will operate in the Antarctic as well as Arctic regions, will be an important addition to the U.S. oceanographic capability in polar seas.

A scientifically successful cruise in the Arctic Ocean aboard a nuclear powered submarine, the USS PARGO was carried out during the summer of 1993. However, the future availability of submarines for research and how the large costs of operating them will be covered is unclear at this time

The NSF is pursuing the construction of an Arctic Research Vessel (ARV). The University of Alaska working with the Fleet Improvement Committee and the Arctic research community has developed a conceptual design for the ARV and has just completed the preliminary design. The design of the ARV incorporates the very latest ice breaking technology, which has the potential to make a significant improvement in fuel efficiency and ice trafficability compared to conventional hull forms. Model tests of its modern hull form in an ice basin indicate a superior ice breaking performance.

The ARV will serve as the primary Arctic platform for U.S. scientists. Its operations will be enhanced by the Polar Research Vessel (PRV), being constructed by the U.S. Coast Guard, because the ARV and the PRV working together will make it possible to carry out expeditions deep into the permanent Arctic ice pack. Excursions deep into the central Arctic requires two or more ships. Since the Coast Guard PRV will spend part of each year in the Antarctic, it is unlikely to be available for winter cruises in the Arctic region. The ARV will be able to work safely in many marginal ice zones during the Arctic winter, and carry out critical cryological and hydrographic studies in winter conditions.

The Arctic Science Community is very enthusiastic about the proposed Arctic Research Vessel, and the FIC recommends that it be given the highest priority acquisition for Arctic Research.

•*The Fleet Improvement Committee strongly supports the addition of the Arctic Research Vessel to the UNOLS fleet and recommends that it be operated by a UNOLS institution. The ARV will give Arctic oceanography a stature comparable to Antarctic oceanography that is now enjoying the luxury of two U.S. ice-capable or ice breaking research vessels in addition to the future Coast Guard's Polar Research Vessel.*

The FIC and UNOLS have taken the position that the Arctic Research Vessel should be built only if sufficient new funds are available for its construction and operation.

Coastal Oceanography Needs

The February 1993 workshop on facility needs for coastal oceanography identified a specific need to investigate a new generation of shallow-draft vessels with superior sea-keeping ability, that carries a large >20 scientific complement that can support multi-wire operations, that can do 3-point anchoring at depths less than 100m, that can launch AUVs, ROVs and moorings and can do flow-through sampling.

•*The FIC recommends that Scientific Mission Requirements be established and a conceptual design study be carried out for a "shallow-water high capability research vessel".*

The Coast Workshop also recognized that because of the large number of ships of all sizes that are used for coastal research, it will be impossible to equip all ships with state-of-the-art technology. This situation can be ameliorated to a significant degree by sharing expensive equipment and facilities on a national basis.

•FIC recommends that funding agencies encourage regional and national arrangements to share certain expensive equipment and facilities used by coastal oceanographers. Oceanographers should develop commonality between institutions for routine and widely used instrumentation, instrument calibrations, technician training, and computer applications.

Inter-Agency Cooperation

The recent increase in cooperation between oceanographers at government agencies and UNOLS institutions has greatly benefited both parties and is applauded by FIC. Current cooperation has been acheived through joint scheduling activities, coordination of assets within large interagency programs and understandings and agreements between government agencies.

•FIC recommends that federal and academic scientists who depend on ships and other seagoing facilities for their research continue to examine ways to improve cooperation via the mechanisms described above. The FIC recommends collaboration that preserves the distributed operation of oceanographic facilities, but recommends against central management of the U.S. research fleet by the federal government or private industry. The distribution of assets and responsibility amongst UNOLS institutions and federal agencies contributes to the vitality of the U.S. Oceanographic fleet and seagoing technology.

Modes of Operation

FIC recognizes that under certain circumstances leasing ships may be preferred because of logistical convenience or need for a capability that is not available on a UNOLS ship; however for most funded research the direct feedback by scientists into operations, a research-centered management style and lower cost of operations are advantages that the UNOLS mode of operating research ships has over centralized management or long-term leasing from a commercial operator.

- *FIC recommends that UNOLS vessels, operated by universities and academic research institutions, continue to the primary source of seagoing facilities for the academic oceanographic community.*

Distribution of the Fleet:

Evolution of the UNOLS Fleet with time can lead to an unfavorable distribution of ships relative to regions of the ocean of greatest interest or the demographics of the oceanography community. Such imbalances can adversely affect the efficiency of the fleet, accessibility of certain research centers to seagoing facilities, and the strength of oceanography in the United States. This problem can become especially acute in the U. S. because of the long transit times between the Atlantic/Gulf Coast and the West Coast, and between the conterminous US and Hawaii and Alaska. The possible retirement of the University of Hawaii's MOANA WAVE and the University of Alaska's ALPHA HELIX from the UNOLS Fleet in next 5 to 10 years would create such an imbalance and threaten the existence of one or both of these operational bases for oceanographic ships. The consequences of such an eventuality deserve serious consideration now.

•*FIC recommends: Agencies that support the UNOLS research ships should evaluate the projected geographical distribution of the year 2000 UNOLS Fleet. They should reassign existing and/or new ships to maintain a balance among operating institutions that best serves the U.S. oceanographic community as a whole. In particular we stress the need to maintain Hawaii and Alaska as an operating base for one or more ships of the UNOLS Fleet.*

Table IV-1 Comparison of FIP-90 recommendations for UNOLS Fleet size and composition with projected Fleets in 2000.

(Reference Table 5 FIP-90, p. 33, Table I-1 of this report)

Class	**FIP-90**	**Displ.**	**2000**	**Displ.**
Large High Endurance (LHE)	3	9,200	4	12,450
Med. High Endurance	2	4,500	2	4,500
Intermediate 150<LOA<200'	6**	6,000	6	6,000
Small 100<LOA<150'	9	2,780	9	2,780
Submersible Support	1†	2,300	1	2,700
Polar Research Vessel	1††	1,000	1	12,000
Totals	22	25,780	23	40,430

* The three LHE ships will be MELVILLE, THOMPSON and REVELLE.

** The Harbor Branch Ships JOHNSON AND SEALINK are not included.

† KNORR was included in the FIP-90 plan as a LHE ship will be converted to submersible support ship and the AII retired.

†† FIP-90 recommended a small ice-capable ship to replace the ALPHA HELIX. The ARV with Class A3 icebreaking capability recommneded in this update will be the largest ship in the UNOLS Fleet (340 feet LOA).

APPENDIX I

Primary characteristics of a Large, General Purpose, Shallow Draught Coastal Research Vessel:

Equipment storage. Interdisciplinary studies will require a large scientific complement. The minimum science berthing capacity should be 20 berths. Interdisciplinary studies require a diverse mix of science groups to be physically present on-board to collect, process, and curate, samples and real-time sensor data; and, because sample collection is fast in shallow settings. Storage, deck, and laboratory space must be provided in proportion to the large scientific complement. Adequate temperature controlled storage and laboratory space must be included.

2. Shallow Draught. Existing large vessels adequately meet coastal research requirements where water depths are sufficient for them to operate safely. To operate in shallower areas, new coastal research vessels should have the shaallowest draught possible (≤ 3 meters) and still be seaworthy.

3. Sea Keeping/Stability. Future coastal studies will require sampling in all seasons and during episodic events. Although maintaining operations during major storms and hurricanes may not be possible, sea-keeping ability should have a priority in the coastal ship's design.

4. Station Keeping Capabilities. Strong gradients and spatial variability are encountered in coastal areas. The ship must be designed to hold station in strong currents and changing wind and current conditions. This will require powerful and responsive propulsion and thruster systems and possibly dynamic positioning. Also, the ship must be capable of 3-point anchoring at water depths of <100 meters.

5. Multi-wire Operations. To facilitate and speed interdisciplinary studies, the ship should be equipped with multiple winches that are positioned such that they can be used simultaneously in water depths of ≤ 100 meters.
6. Launching Capabilities. It is anticipated that there will be an increased use of freely launched vehicles such as AUV's, ROV's, seafloor mounted observing systems, moorings, and surface buoys. The new coastal research vessel should be provided with ample deck space and over-the-side handling equipment to facilitate both launching and recovery of these systems.
7. Shallow Water Sampling Techniques. In coastal regions the ships hull may occupy a substantial portion of the water column, consequently flow-through intakes cannot be haphazardly located in the hull and some towed systems (e.g. nets) cannot be towed astern. The design must include the capability of towing these devices from booms off the side of the vessel in order to sample uncontaminated or undistrubed water.
8. Endurance. Coastal vessels will generally operate near a port. Therefore, endurance capabilities can be scaled-down from comparably-sized blue-water research vessels.
9. Ship to Shore Communications. State-of-the art ship-to-shore communications should be installed to allow high rate data transfer to and from the ship.

APPENDIX II

SCIENTIFIC MISSION REQUIREMENTS FOR THE ARCTIC RESEARCH VESSEL
JULY 1993

The following is the revised version (21 July 1993) of the Arctic Research Vessel Scientific Mission Requirements as refined by the ARV subcommittee and the UNOLS Fleet Improvement Committee.

Size

•The size ultimately is determined by the requirements. However, it is intended that this be a high endurance, Class I, ship that has significant ice capability. Draft restrictions will be determined by the propulsion and seakeeping requirements. The vessel will be no larger than necessary to perform its identified mission.

Endurance

•An endurance of 90 days is required based on 2 science cruises anticipated in the Arctic between resupplying. Fuel required for this endurance should be determined assuming 45 full power days. The estimate of required full power days is intended to allow the vessel to actually operate for 90 days in varying ice conditions. The rule of thumb commonly applied in icebreaker practice is that actual endurance is twice the number of full power days. Full power days are based on installed propulsion power defined as 90% of the maximum continuous horsepower rating for the propulsion diesels plus the power associated with the average hotel load. Quantities of all other consumables (provisions, stores, spares, potable water, lube oil, aviation fuel, snow-mobile fuel, etc.) are to be based on 90 days between reprovision stops.

Ice Capability

• The ship shall be able to: 1) operate continuously in first year ice, 2) have limited operations in multi-year ice and 3) transit 7-foot ridges by ramming. Continuous operation is defined as maintaining a minimum speed of 3 knots in 3.5 to 4.0 feet of consolidated level ice. Limited operation is defined as controlled ramming, where necessary, and avoidance of heavy ice features wherever practical.

•The vessel is to be capable of independent, short-term, short distance entries into the Central Arctic Basin (multi-year ice) from July through September and of operations over the arctic offshore shelf from July through December. The vessel is to be capable of a broader range of Arctic operations, when escorted by a vessel having an ice classification of A4 or greater.

•The required operating range of the vessel is within the operating areas and seasons described for ice class A3 in the American Bureau of Shipping's guide to ice classification or to those of Det Norske Veritas Icebreaker Polar 10 classification.

•The vessel must meet the requirements of the proposed new Canadian Arctic Shipping Pollution Prevention Regulations (CASPPR), specifically Canadian Arctic Class 2 (CAC-2). Included in these regulations are requirements for double bottoms and/or cofferdams between shell plating and all tanks containing polluting liquids.

•The vessel is to have excellent maneuvering characteristics in ice to enhance science operations. In this respect, maneuvering characteristics similar to those of the latest generation of modern icebreakers, such as the Swedish ODEN, are required. Optimum maneuverability is to be achieved through hull design, high performance rudders, and a rapid heeling system.

•The mission profile of the vessel emphasizes operations in ice, dictating that the hull form be optimized around ice transiting performance. Ice capability is to be enhanced by the installation of a hull lubrication system and a rapid heeling system. A key feature of the vessel's design is propulsion efficiency for high thrust, low speed ice operations. High efficiency is required to meet the endurance requirements.

•The ship must be able to withstand being beset in ice. The design operating temperature range is -45? to +35?C.

Accommodations

•Thirty five scientific personnel with no more than 2 per stateroom.

•Twenty four to twenty six crew berths with fourteen being single staterooms.

•Provide a science library lounge with conference room capability.

- Provide a folding bulkhead in the library/conference room.
- There should be a science office with a chart table.
- Provide for a general ship's office.
- Provide a mud room with washer and dryer on the main deck.
- Provide a properly outfitted exercise room.

•All public spaces will be common use, that is, no segregation of scientists and crew.

Speed

•Speed requirements in open water: 14 kts cruising; 12 kts sustainable through Sea State 5. Speed control to plus/minus 0.2 kts in the 2-7 kt range and plus/minus 0.1 in the 0-2 kt range.

•Speed requirements in ice: 3 knots in 3.5-foot thick level first-year ice.

Seakeeping

- Maintain science operations with the following speeds in the

following sea states:

•..............12 kts through S.S. 5
•...............9 kts through S.S. 6
•............ 7 kts through S.S. 7

•Emphasis is to be on accelerations in vessel coordinates, deck wetness and slamming. Motion displacements are secondary. The vessel features are to be designed to minimize the effect of spray icing.

Station Keeping

•The ship must be able to maneuver in ice leads and maintain station in ice to deploy instruments over the side or stern. In open seas, it must maintain station and work in sea states through S.S. 5. Emphasis on ice operations will limit high performance station keeping, but vessel should have thrusters or equivalent maneuvering devices to maintain stations at best heading in 25 kt winds and one kt current. Thrusters should be installed with due regard to sonar and echo sounding requirements. The method used for deploying instruments in ice over the side or stern is to create a lee with the vessel. This means that the vessel must have the ability to "crab" sideways. Both sides of the vessel must be visible from the bridge. This implies enclosed bridge wings.

Deck Working Area

•The vessel's working decks should have a stern working area of 3000 sq ft minimum with about 1000 sq ft enclosed (minimum of 10 ft clearance overhead) for weather protection, contiguous waist-level work area along one side 8 x 100 ft minimum to allow piston coring, and an arrangement of deck equipment and cranes to permit core lengths to 100ft. The deck loading should withstand up to 1500 lbs/sq.ft. and an aggregate total of 100 tons. There should be removable bulwarks at selected locations and the dry main working deck should not be more than 7-10 ft above the waterline. There should be a clear foredeck area to accommodate specialized towers and booms extending beyond bow wave. All working decks should be accessible to power, water, air and data and voice communication ports. Two heated "Baltic" rooms are to be provided. The starboard side, midship Baltic room shall be approximately 500 ft2 and shall have a watertight exterior door having minimum clearances of 14 ft width and 18 ft height. The second Baltic room shall be located forward and to port. This forward room shall provide access to the ice surface for personnel, snow-mobiles, and other light equipment. Both Baltic rooms shall be provided with deck drains. Additionally, a means, other than by crane, shall be provided for personnel access to the ice surface from the aft working deck. This could be a portable gangway suitable of being rigged on either side of the vessel. Deck hatches should be hydraulically actuated and dogged. Space for incubators should be provided near the isotope van. Considerations should be made to minimize ice build-up on superstructure and hull during severe icing conditions. All weather decks should be either heated or be provided with deck surfaces such as wood to allow for sure footing during freezing conditions. Exterior decks should be cambered to provide for proper drainage. One inch flush bolt downs, on a 2 x 2 ft grid are to be installed on all working decks and hold decks.

Cranes

•A suite of modern cranes should be provided to carry out the following:

(1) reach working deck areas and off-load vans and heavy equipment up to 20,000 lbs;
(2) articulate to work close to deck and water/ice surface;
(3) handle overside loads at sea up to 5000 lbs 30 ft from the side and up to 10,000 lbs closer to the side;
(4) usable as overside cable fairleads for towing at sea;
(5) be rated for manned egress onto the ice surface.

There should be articulated cranes on both corners of the aft working deck for over-side work. These cranes should be arranged so that they can work in tandem and overlap. An articulated crane suitable for loading science equipment, vans and stores shall be placed on the foredeck.

Winches

•There will be oceanographic winch systems providing fine control (0.5 m/min), load compensation, constant tensioning and constant parameter following. There will be cable with multiple conductors and wire monitoring systems with inputs to laboratory panels and shipboard recording systems. Winch controls will be both local and remote. There will be the ability to string two wires at the same time at all overside handling locations.

•Permanently installed general purpose winches should include:

•two hydrographic-type winches capable of handling 30,000 ft of wire rope electromechanical cable having diameters from 1/4" to 3/8",

•One traction winch capable of servicing two drums with up to 30,000 ft of 9/16" wire /synthetic fiber rope; and 30,000 ft of 0.68 electromechanical cable (up to 10 KVA power transmission) or fiberoptics cable.

•Additional special purpose winches will be installed temporarily at various locations along the working decks. Winch sizes will range up to 30 tons (140 ft2) and have power demands up to 300 hp.

• Two capstans will be located on the aft working deck.

•All winches should be located below decks to limit their exposure to weather.

•There must be the capability for winch installation on the bow working deck.

Overside Handling

•Various frames and other handling gear must be provided to accommodate wire, cable and free launched arrays, one of which should have a safe working load of 30,000 lbs. They must be matched to work with winch and crane locations but capable to be relocated as necessary.

•There will be a stern A-frame with a 20 ft minimum horizontal, 25 ft vertical clearance; 12 ft inboard and outboard reaches.

•A heated staging and sampling area with overhead rail and 15 ft clearance will be provided at an optimum overside working area.

•There will be the capability to perform overside handling operations along the forward and aft working decks.

•Sheltered control stations will be used to give operator protection, provide communications and operations monitoring. They will be located to provide maximum visibility of overside work.

•A hydraulically actuated "hydro-boom" shall be installed in the overhead of the midship Baltic room. This boom shall be capable of extending approximately 13 ft over the side of the vessel and shall have a lifting capacity of 7.5 tons. A larger, extendible, 20-ton capacity, hydro- boom shall be located above the wet lab. This hydro-boom will be designed to handle heavy coring equipment up to 100 ft in length. Both hydro-booms shall be fully controllable from either an enclosed winch control station or via tethered controls from the side working deck. Both hydro-booms shall be capable of being served by the hydro winches.

Towing

•The ship should be capable of towing scientific packages up to 10,000 lbs horizontal tension at 6 kts and 25,000 lbs at 2.5 kts. It should have a relatively ice-free path aft, and thus be capable of towing scientific packages in ice-covered seas and of protecting those packages while towing.

Laboratories

•There should be approximately 4000 sq ft of laboratory space including:

Main lab area (2000 ft2) flexible for frequent subdivision providing smaller specialized labs;

Analytical lab (300 ft2) with no exterior bulkheads and stable temperature control and wet lab (300 ft2), both located contiguous to sampling areas;

Electronics/computer lab and associated user space (600 ft2);

Biology lab (300 ft2);

Meteorology lab (300 ft2);

Two climate controlled chambers (150 ft2) capable of maintaining -2 °C (one suitable for primary productivity measurements);

Freezer space (150 ft2).

•Labs should be located so that none serve as general passageways. Access between labs should be convenient with wide doors and passageways.

•Labs should be fabricated using uncontaminated and "clean" materials and designed to be maintained as such. Furnishings, HVAC, doors, hatches, cable runs and fitting should be planned for maximum lab cleanliness.

•Fume hoods to be installed permanently in the main lab and analytical lab. Wet lab shall have provision for temporary installation of fume hoods.

•A dive locker to UNOLS standards with air handling equipment should be provided.

- Lighting in labs will be per UNOLS standards.

- Space must be provided for ten 20-gallon aquariums.

•There must be a clean seawater supply with a small lab nearby. This seawater system should be insulated.

•There should be an anteroom to the constant temperature lab.

•Cabinetry shall be high grade laboratory quality, including flexible installation through the use of unistruts on bulkheads, overheads and decks.

•The heating, ventilation and air conditioning (HVAC) will be appropriate for laboratories, vans and other science spaces served. Laboratories must maintain temperature of 60-75 F, 50% relative humidity and 9-11 air exchanges per hour. Ventilation noise levels should be low in the labs and staterooms. Filtered air to be provided to analytical lab. Labs to be furnished with 110v and 220v AC electrical power with about 10-volt amperes per square foot of lab deck area. Total estimated laboratory power demand is 100 KVA, of which 15 KVA is to be uninterrupted clean power. Each lab area is to have uninterrupted clean power on a separate circuit. Uncontaminated sea water supply should be provided to most laboratories, vans and several key deck areas. Compressed air supply must be clean and oil free.

•All labs, except those spaces associated with the clean seawater supply, transducer wells, and meteorology lab are to be on the main deck.

•Labs on the main deck are to have direct access to a wide (minimum 8 ft) longitudinal passageway terminating at the aft working deck.

- A dark room (75 ft2) should be installed.

•Two locations are required for the meteorological equipment; one well forward of the mast for the IMET installation and one on top of the wheelhouse.

•A staging area should be provided with an aft facing door. This is to be suitable for housing ROVs, SeaMark and others.

•There must be provisions for handling biological collections and their preservations with formalin and other toxic chemicals. Heating, ventilation and isolation from ship's interior are all required. A wide, deep sink and adjacent counter in the aft staging bay could serve this purpose.

- Public heads are to be provided in the vicinity of the labs.

•All accesses to labs from the working deck are to have removable or dropdown sills. The central passageway between the labs is to access the aft working deck area.

•There must be a HAZMAT storage area on the main deck.

- There will be an explosives locker (1500 cu ft).

- A gravimeter room will be provided.

Vans

•The ship should be able to carry up to four standardized 8 ft x 20 ft portable deck vans which may serve as laboratory, storage or other specialized uses. There will be hook-up provisions for power, HVAC, fresh water, uncontaminated seawater, compressed air, drains, communications, data and shipboard monitoring systems. Vans must have heated water and sewage lines. Vans should have direct access to ship interior but located in wave sheltered spaces. Arrangements should allow two vans to be linked together. Vans should be capable of withstanding Arctic climate.

•There will be the capability to carry additional portable non-standard vans (200 sq ft) on super structure and working decks. Supporting connections will be provided at several locations around the ship including the foredeck.

Workboats

•There will be at least one 21 ft inflatable (or semi- rigid) boat located for ease of launching and recovery. A 20 ft Norwegian style ice boat should be included.

•Space will be provided for a 25-30 ft workboat as optional equipment in place of a van.

Helicopter

•Facilities including hanger for the carrying, landing, fueling and general servicing of a small helicopter such as an MBB BO 105, shall be provided. This will require a tank for storage of 12,000 gallons of aviation fuel and an associated pump room. The pilot and mechanic are to be considered as part of the science complement.

Science Storage

•Provide 20,000 cu ft of scientific storage accessible to labs by interior and weatherdeck hatches and elevators. Half the provided space is to include suitable shelving, ranks and tie-downs; the remainder is to be open hold space. The open hold shall be equipped with heavy duty hold-downs on 2 ft centers.

Acoustical Systems

•The ship is to be as acoustically quiet as practicable Design target is underway multibeam and conventional echo sounding through Sea State 5 and acoustical dynamic positioning through Sea State 5. All acoustic equipment provided shall be selected, located and installed to minimize noise, vibration and interference with other acoustical systems.

•A large pressurized sea chest (4 ft x 8 ft) will be located at an optimum acoustic location for at sea installation and servicing of transponders and transducers.

- Provide two 20" transducer wells, one forward and one aft.

•The ship shall have conventional 12 kHz and 3.5 kHz echo sounding systems with spare transducers for each system.

•A state-of-the-art multibeam echo sounding capability will be installed.

•There will be a state-of-the-art Acoustic Doppler Current Profiling (ADCP) system with two hull mounted transducers for redundancy.

•There will be space in the machinery room for two air compressors capable of generating 1000 scfm for single channel seismic work.

•A Doppler speed log will be installed.

Navigation

•Global Positioning System (GPS) with attitude sensor capability and appropriate interfaces to data systems and ship control processors will be provided.

•Radar suitable for navigation in ice will be provided.

Internal Communications

• There will be an internal communication system providing high quality voice communications throughout all science spaces and working areas.

•Data transmissions, monitoring and recording systems will be available throughout science spaces including vans and key working areas.

•There will be closed circuit television monitoring of working areas.

•Monitors for all ship control, environmental parameters, science and overside equipment performance to be available in selected science spaces.

External Communications

•Reliable voice channel must be established for continuous communications to shore stations (including home laboratories), other ships, boats and aircraft. External communications should include satellite, VHF, and UHF. Particular attention should be paid to the problems of access to communication satellites at high latitudes and placement of antenna.

•There should be the capability for facsimile communications to transmit high speed graphics and hard copy text on regular schedules.

•The ship should be capable of high speed data communications (via satellite) links to shore labs and other ships on a continuous basis.

Satellite Monitoring

•The ship should carry transponding and receiving equipment including antenna to interrogate and receive satellite read-outs of environmental remote sensing data.

Discharge

•All discharges will be on the port side with their holding tanks capable of holding for a minimum of 24 hours. Overboard discharges must meet all international and state requirements.

Ship Control

•There must be maximum visibility of deck work areas during science operations especially during deployment and retrieval of equipment. This could be supplemented with television monitors as well as direct, unobstructed stern visibility. Portable hand-held units may also be used at various after deck locations during overside equipment handling.

•The functions, communications and layout of the ship control stations should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude and positioning will often be integrated with scientific operations assisted by computer control from a laboratory or working deck area.

•Conning ability must be provided aloft with heat and an enclosed access.

Regulatory Standards

•This vessel shall be inspected and certified by the USCG as an oceanographic research vessel per 46 CFR Subchapter U and shall meet all of the associated regulatory requirements.

•This vessel shall meet the requirements of the proposed revision to the Canadian Arctic Shipping Pollution Prevention (CASPPR) regulations as a Canadian Arctic Class 2 (CAC-2) vessel.

•This vessel shall be classed by either ABS as an A3 Icebreaker or by DNV as an Icebreaker Polar Class 10 vessel.

•Arrangements and outfit are to meet UNOLS standards where applicable.

•USCG Certificate of Inspection, USCG approved Stability, ABS or DNV Classification, Loadline, U. S. Tonnage, International Tonnage and Panama Canal Tonnage and all other appropriate documentation are to be provided for the vessel. In addition, all documents required for outfit items, such as lifting gear, are to be provided.