Oceanus

REPORTS ON RESEARCH FROM THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

Vol. 40, No. 1 · 1997 · ISSN 0029-8182

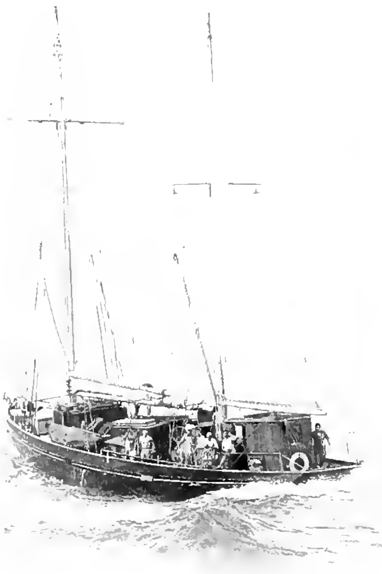
Access to the Sea

WHOI Ships

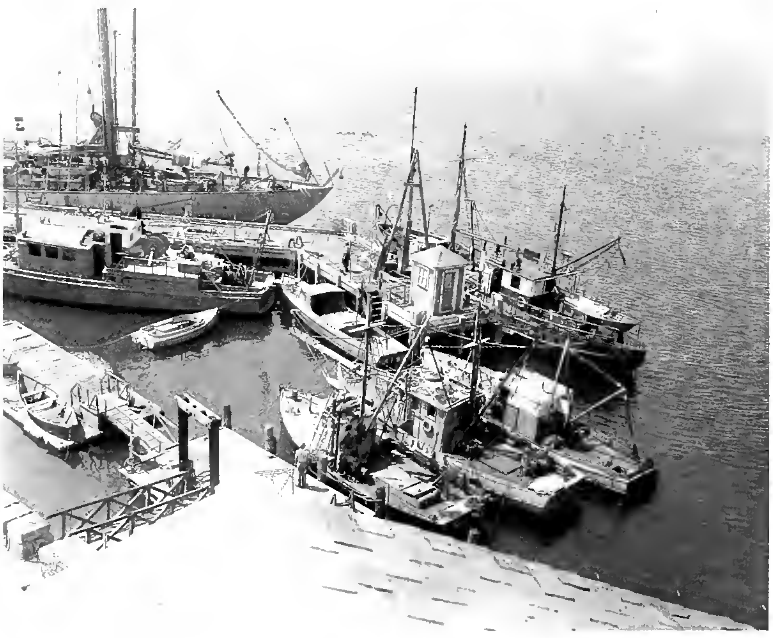
A Look Back

Atlantis, 1931-1964

Reliance, 1943-1954



Caryn, 1948-1958



WHOI Pier, 1945

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Access To The Sea

Cover: All three WHOI ships were in home port in a rare moment on April 21, 1997—*Knorr* is in the foreground with *Oceanus* and *Atlantis* on the opposite side of the pier. Photo by Doug Weisman.

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Editor: Vicky Cullen • Designer: Jim Canavan

George Tupper

A conductivity/temperature/depth rosette sampler is lowered into the cold and stormy Labrador Sea from R/V *Knorr*. See articles on pages 18 and 26.

Printed on recycled paper

Access to the Sea

Encompasses Ships, Submersibles, Autonomous and Remote Vehicles, Observatories, Drifters, Extreme Climate Capability, and Drilling

Richard F. Pittenger
Associate Director for Marine Operations

Shelley Lauzon

R/V *Atlantis*, Voyage 1, Leg 1, March 1997.

Oceanographic fieldwork has traditionally meant going to sea on a ship. In recent years, it has expanded to include activities that may require a ship for a short period but then continue independently. Floats that drift with ocean currents, periodically reporting their positions via satellite, for example, are generally launched from ships but do most of their work independently. Long-term seafloor observatories may need ships to set them up and service them occasionally, but, again, they are designed to collect data for long periods without needing a ship. We have come to think of the body of ways oceanographers glean information from the ocean as "access to the sea," and so that is the topic for this issue of *Oceanus*.

Ships are a critical element of access to the sea, but because they cost so much, take so long to plan for and build, and then last 30 years, they still occupy a dominant role in access to the sea. However, long-range planning should also take into account other means of doing ocean research, using a variety of observational methods and technological tools.

The US academic research fleet, known as UNOLS for University-National Oceanographic Laboratory System, has never been in better (physical) condition. This year marks the completion of an unprecedented UNOLS modernization and replacement program, which began to take shape in 1984 under Navy Secretary John Lehman, according to Steven Ramberg, head of the Office of Naval Research (ONR) Ocean, Atmosphere, and Space Department. "It's a national interest to make sure the oceanographic community has world-ranging access to the oceans to do good research, whether it's for the National Science Foundation or for the Navy," he says. Under this program, old

UNOLS Research Vessels

Operating Institution	Ship	Owner	Length (ft.)	Science/Crew
LARGE VESSELS (over 200 feet) • Daily Cost: $15,000-17,000				
Scripps Institution of Oceanography	*Melville*	Navy	279	38/23
Woods Hole Oceanographic Institution	*Knorr*	Navy	279	34/25
University of Washington	*Thomas G. Thompson*	Navy	274	36/22
Scripps Institution of Oceanography	*Roger Revelle*	Navy	274	37/22
Woods Hole Oceanographic Institution	*Atlantis*	Navy	274	37/22
Lamont-Doherty Earth Observatory	*Maurice Ewing*	NSF	239	32/18
University of Hawaii	*Moana Wave*	Navy	210	19/16
INTERMEDIATE VESSELS (150 to 200 feet) • Daily Cost: $9,000-12,000				
Oregon State University	*Wecoma*	NSF	185	20/13
University of Rhode Island	*Endeavor*	NSF	184	18/12
Texas A&M University	*Gyre*	TAMU	182	23/10
Woods Hole Oceanographic Institution	*Oceanus*	NSF	177	15/12
Scripps Institution of Oceanography	*New Horizon*	SIO	170	12/12
SMALL VESSELS (less than 100 feet)				
Moss Landing Marine Laboratories	*Point Sur*	NSF	135	12/9
Duke University/UNC	*Cape Hatteras*	NSF	135	12/10
University of Alaska	*Alpha Helix*	NSF	133	15/9
Scripps Institution of Oceanography	*Robert G. Sproul*	SIO	125	12/5
University of Delaware	*Cape Henlopen*	UD	120	12/7
Bermuda Biological Station for Research	*Weatherbird II*	BBSR	115	12/10
Louisiana Universities Marine Consortium	*Pelican*	LUMCON	105	15/5
University of Texas	*Longhorn*	UT	105	12/4
Smithsonian Tropical Research Institute	*Urraca*	Smithsonian	96	10/5
University of Michigan	*Laurentian*	UM	80	8/6
University System of Georgia	*Blue Fin*	UG	72	8/5
University of Miami	*Calanus*	UM	68	6/2
University of Washington	*Clifford A. Barnes*	NSF	66	6/2

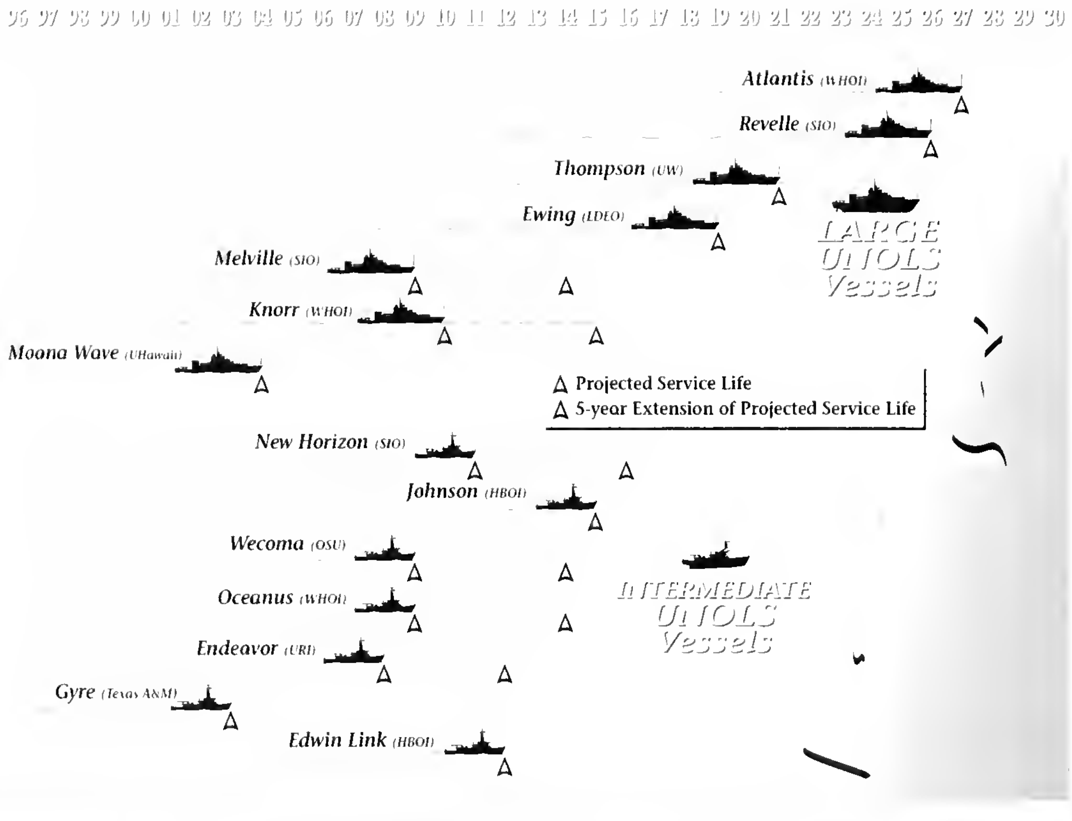
Jayne Doucette

Scientists and crew cooperate aboard *Oceanus* during a 1996 Coastal Mixing and Optics Experiment cruise.

vessels have been retired (*Atlantis II, Conrad, Thompson, Washington**). Four new vessels have been acquired (*Thomas G. Thompson, Roger Revelle, Atlantis, Maurice Ewing*) and six others (*Knorr, Melville, Oceanus, Wecoma, Endeavor,* and *New Horizon*) have undergone major overhauls and upgrades. (See chart of UNOLS vessels at left for operating institutions.)

The ocean science community is well-served today with a fleet that is well-equipped and skillfully operated. It consists of the full spectrum of ships from large to small and from general to special purpose. (*Ewing* does mostly multichannel-seismic projects, and *Atlantis* is largely devoted to supporting deep submergence activities.) These vessels are frequently inspected and updated. They represent the essential facilities that enable oceanographic research, and, through the UNOLS process, they are efficiently and equitably scheduled.

Still, this fleet faces challenges: One comes from the national research budget squeeze, which effectively reduces the funds available for at-sea operations. This problem is being addressed vigorously by UNOLS. A December 1995 UNOLS report entitled "Projections for UNOLS'



**Atlantis II* was operated by the Woods Hole Oceanographic Institution, *Conrad* by the Lamont-Doherty Earth Observatory of Columbia University, *Thomas G. Thompson* by the University of Washington, and *Thomas Washington* by Scripps Institution of Oceanography, University of California, San Diego.

Future—Substantial Financial Challenges" considers a variety of scenarios including fleet reduction and user-base expansion, with cautions about the importance of maintaining a balanced mix of capabilities.

The second challenge may come as a surprise to some: It's time to begin another fleet replacement/ modernization program.

As discussed in "Replacing the Fleet" (p. 12), it took almost 15 years—one and a half decades—(from 1984 to 1997) to complete the process of modernizing the UNOLS fleet. This was true despite the fact the program had almost universal support and suffered no major setbacks or stoppages from start to finish. Thus, if we consider 15 years a conservative planning window and use that time frame as a yardstick against the age of the existing fleet, we can determine when the next major modernization effort should begin. The projected service life figure on page 3 indicates that the time is now. Within the 15 year planning window, eight large and intermediate ships will near the end of their expected useful service lives: *Moana Wave*, *Melville*, *Knorr*, *Gyre*, *New Horizon*, *Oceanus*, *Wecoma*, and *Endeavor*. Note that the actual service life of a ship is somewhat flexible. The yellow triangles in the figure show a five-year extension of the projected service lives of UNOLS ships that have undergone extensive mid-life overhauls. Although this listing only includes the large and intermediate ships, it is germane to note that the following smaller vessels will also be refitted in this time frame: *Alpha Helix*, *Cape Henlopen*, *Cape Hatteras*, and *Point Sur*. While this gives us more time to consider the options for the next major fleet upgrade, it only delays facing the problem.

Desired Characteristics for Projected 200-Foot Research Vessel

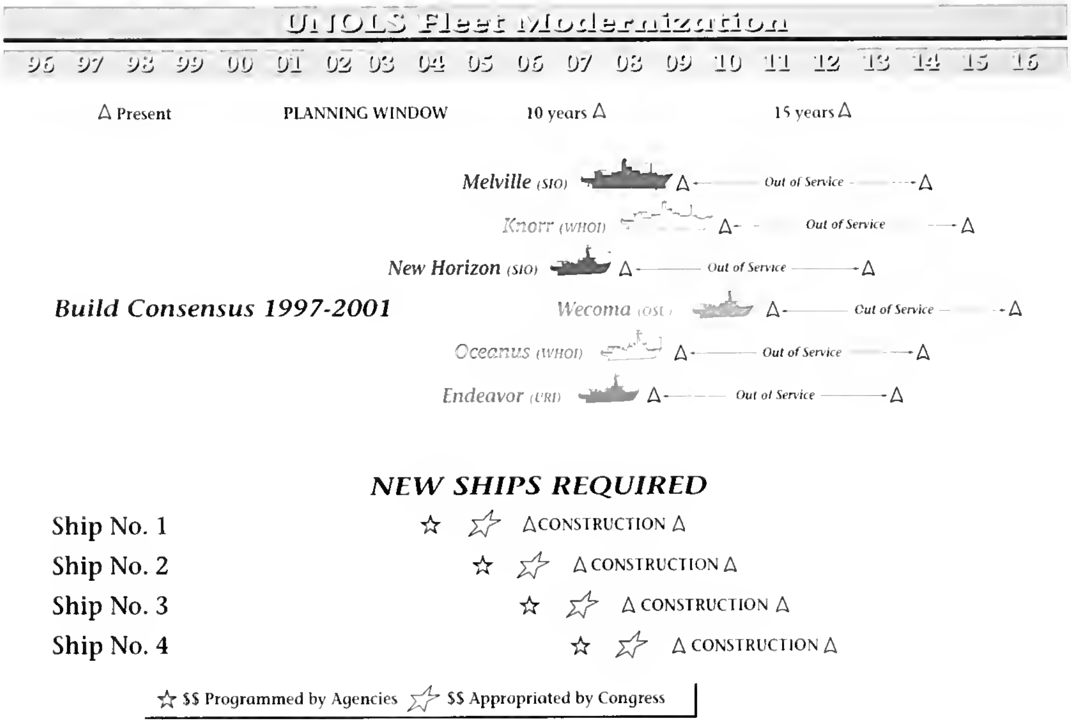
Priority	Requirements	Minimum	Desirable	Maximum
1	Seakeeping			
	Pitch	4°	3°	
	Roll	8°	4	
	Heave	6 ft. (?)	3 ft.	
	Vertical Accel.	.4 g	.09 g	
	Horizontal Accel.	.2 g	.11 g	
2	Deck Space *Arrangement of deck more important than total space available.*	2,000 sq. ft.	3,000 sq. ft.	
3	Station Keeping *50 meters at best heading in 35 knots wind, 2 knots current. Survivable through SS9.*	Sea State 6	SS7	SS7
4	Science Payload *(variable or itinerant)*	60 tons	100 tons	120 tons
5	Dimensions *Max. beam 104 ft. (Panama Canal) Max Harbor Draft 18-24 ft.*			
6	Lab Space	2,500 sq. ft.	3,000 sq. ft.	3,500 sq. ft.
7	Science Berths *Crew: Minimum Coast Guard requirement plus 2 or 3.*	20	25	30
8	Cruising Speed in SS6	12 knots	15 knots	20-25 knots
9	Range	9,000 nm	10,000 nm	NA
10	Endurance *Generally food and stores limited.*	40 days	50 days	50 days

It is important to emphasize that the best solution to maintaining a robust research fleet is not necessarily, or even likely, a "one-for-one" replacement program. The ocean science community must assess its scientific goals in a 40 to 50 year time frame, and then formulate plans for achieving the access to the sea capabilities needed to achieve those goals. The lengths of useful ship lives set forth in the projected service life figure set absolute deadlines for having those plans bear fruit.

One approach that might be taken is to assume that the large ship needs will be served by the AGOR-23 class (*Thompson*, *Revelle*, and *Atlantis*) well into the 21st century and well beyond our 15 year planning window. It is reasonable to plan for vessels of size and capacity that fall between the large- and intermediate-size classes. As a first approximation planning factor, these new vessels should be about 200 feet long, more seaworthy than any existing ships, carry science and crew complements that fall somewhere between *Knorr* (34/24) and *Oceanus* (18/12), and have the design factors listed at left.

Circumstance may be presenting the community with an opportunity to design, test, and program for the next generation research vessel. The Navy's FY'97 budget includes $45 million for a SWATH (Small Waterplane Area Twin Hull) vessel for use in general purpose oceanographic research. The first such vessel is to serve in the central Pacific and will probably be operated by the University of Hawaii as a replacement for *Moana Wave*. The UNOLS community has contributed to the design of this vessel, whose time line appears in the figure opposite below. A SWATH offers a remarkably stable platform. It has two submerged hulls with thin struts supporting an above-water platform. Its characteristics of not following surface wave motion, reduced buoyancy force changes because the lower hulls ride below the wave motion field, and longer natural roll periods make it very attractive for ocean science and environmental monitoring.

The figure opposite above combines the information on expected lives of current research vessels and the time planning window needed to plan for and construct new vessels. It indicates when agencies would need to program acquisition funds for new vessels in order to have the funds appropriated, contracts let, and the ships built in time to support a continuous and vigorous US oceanographic research program. Planning and construction time lines may seem excessively long, but the recently aborted National Oceanic and Atmospheric Administration fleet improvement program failed because it was started too late, when the ships had already reached the end of their service lives.



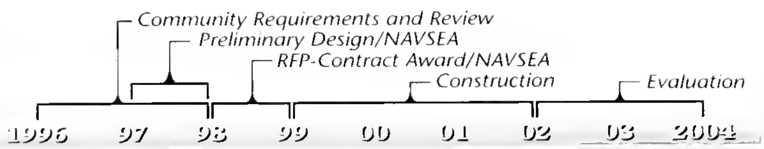
There is also a need to examine the seagoing facilities (small ships/large boats) that service the coastal realm. This matter has been discussed by many interested people for a number of years. Most recently, with NSF support, UNOLS conducted the "Workshop to Assess the Future Vessel and Facility Needs of Coastal Marine Science" in February 1993. The workshop report concluded that the need for improved vessels to support coastal research varied from region to region because of the wide variety of environmental conditions, ranging from the craggy, high sea-state, cold conditions of New England to the warm water, back bay estuaries of the Carolinas and Gulf Coast. This wide variety of environmental regimes dictates that coastal research vessel designs be tailored to the individual region.

Another major factor in coastal vessel design is the cost of operation, as most coastal research projects are relatively "poor" and cannot afford to pay the cost of larger research vessels, even though in many instances large and intermediate UNOLS vessels are fully capable of doing the work. This leads researchers to demand cheap, high capacity vessels. Resolving this apparent oxymoron will not be easy.

In the case of the New England region, an affordable vessel is needed with the general characteristics shown on page 6. We believe that a monohull will never fulfill these characteristics. We are looking instead for a "big" little, reasonably priced ship. It should be capable of safe operations year-round in New England weather and water conditions and be able to make safe, short duration (several-day) surveys with perhaps one mooring to set or a single instrument to deploy repeatedly (CTD or ROV) or continuously (towed side-scan/multibeam instrument, acoustic Doppler current profiler, or biomapper—a towed acoustic device for measuring biological stocks). This vessel should have a daily operating rate less than half that of the intermediate-size vessels.

At present this niche is inadequately filled with monohulls that have serious shortcomings in seakeeping, seakindliness, payload, science facilities, and accommodations. WHOI marine personnel and scientists have discussed these deficiencies with their counterparts at several major regional oceanographic-related organizations including University of Massachusetts, University of Rhode Island, the consortium of the Gulf of Maine researchers, Newport Undersea Warfare Center, and US Geological Survey. There is enthusiastic support among these groups for the small SWATH concept, and consensus (so far) that WHOI should take the lead in securing such a community-use vessel. As a result, WHOI has engaged a naval architect to design a vessel that fits the plan outlined overleaf. The timeline for such a vessel appears on page 7.

Planning for such a regional-use vessel is one step toward the next US fleet modernization and replacement. The UNOLS fleet is the best in the world, providing the nation's oceanographers access

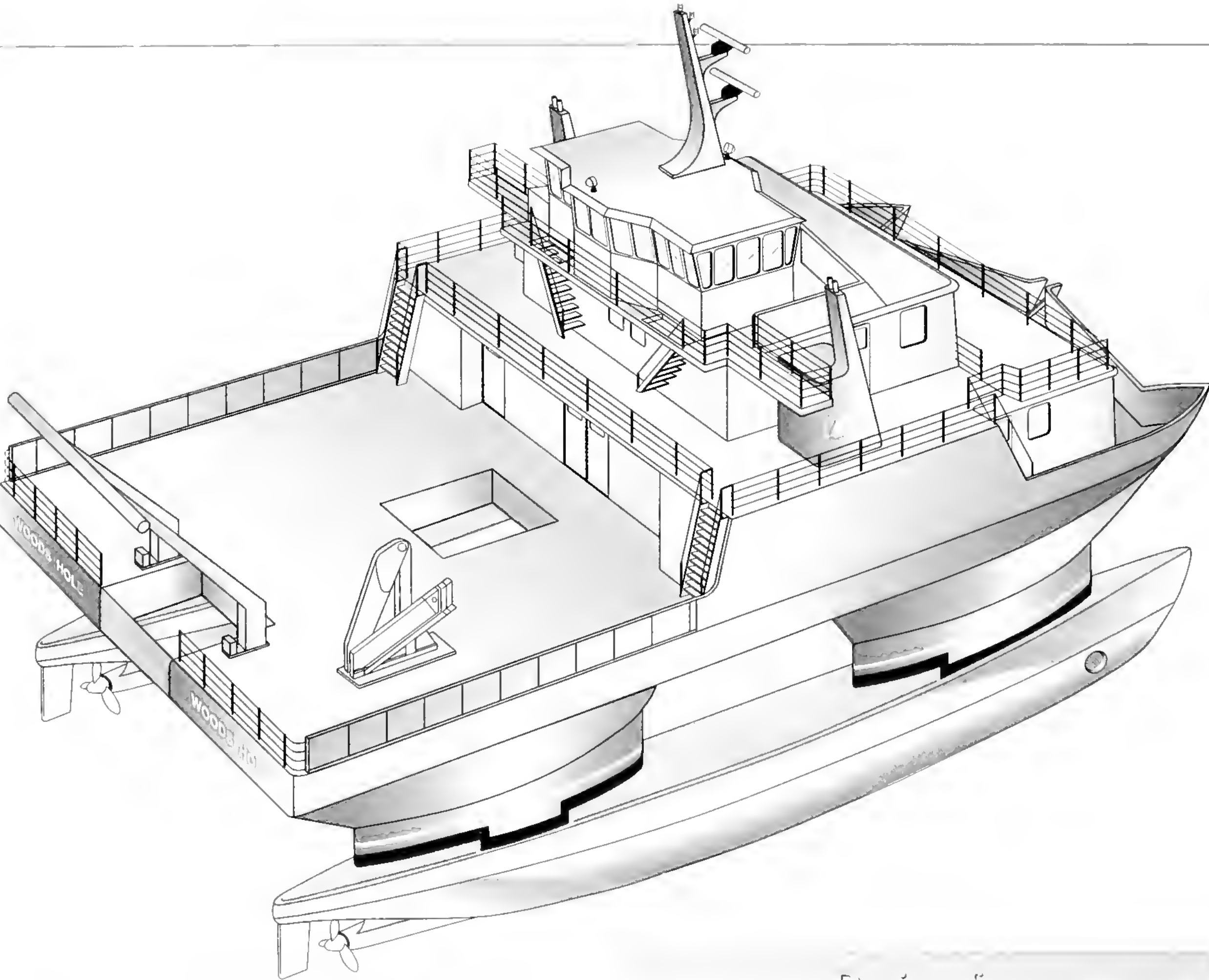


Time Line* for Central Pacific SWATH

*Note: The FY '97 Defense Appropriation included $45M for "a SWATH" research vessel.

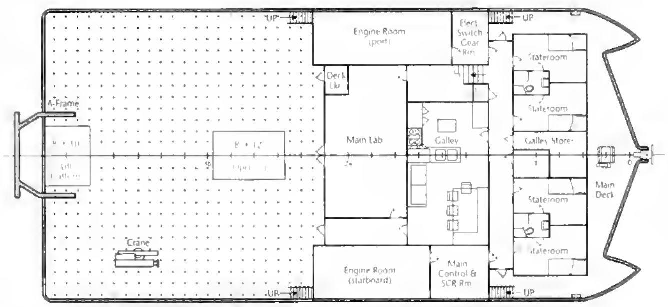
to the sea both globally and regionally, and it is vitally important that members of the ocean science community begin to work now on maintaining that capability for the 21st century. WHOI has long been an enthusiastic contributor to the configuration and operational modes of UNOLS as well as serving as the operator of some of the system's ships and we look forward to a continuing role in UNOLS.

The following paragraphs briefly discuss some other areas of "access to the sea" that are of growing interest to the oceanographic community.

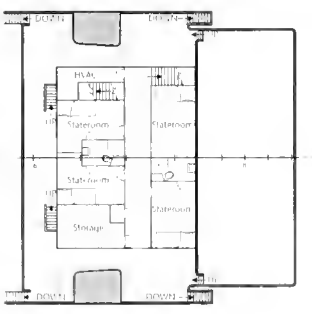


Design for Northeast US SWATH Coastal Research Vessel

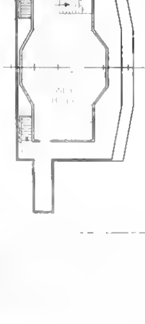
(SWATH: Small Waterplane Area Twin Hull)



MAIN DECK



01 LEVEL



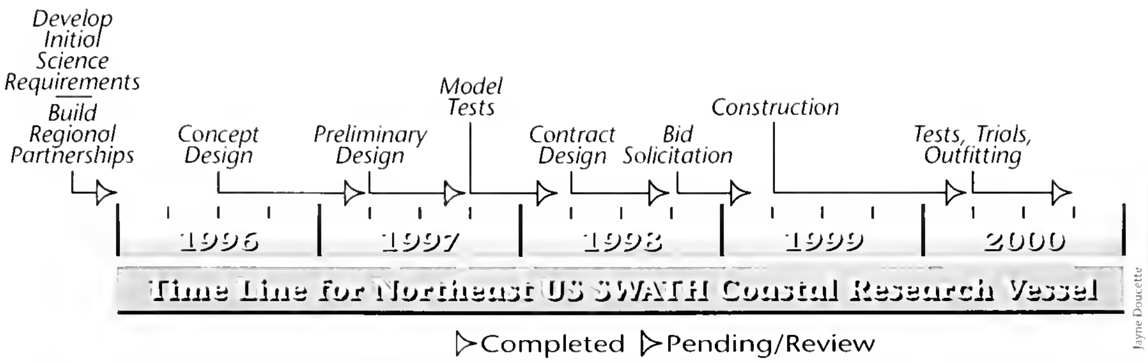
02 LEVEL

Science Mission Requirements

Seakeeping:	Sea State 5 *Able to work on Georges Bank in the Winter*
Endurance:	15 days
Cruise (transit): Speed in Calm Water	14 knots
Accommodations:	16 total in 2-person rooms; 6 crew, 10 science *(4 & 12 in some operations)*
Variable Deck Load:	20 long tons
Lab Space:	At least 300 square feet
Working Deck Area:	At least 2,000 square feet
Range:	1,000 nautical miles

Vessel Characteristics

Length, Overall:	102 feet
Beam	50 feet
Draft:	
Transit	8 feet
Operations	11.5 feet
Displacement:	
Lightship	260 long tons
Transit	315 long tons
Operations	385 long tons
Power:	
Main Engine (2)	2,200 shaft horse power
Auxiliary	1,260 kilowatts
Speed:	
Maximum:	15 knots
Transit-cruising:	14 knots
In-service Sea State 4:	11 knots
Construction:	
Upper Hull:	Aluminum
Lower Hulls:	Steel
Range:	1,100 nautical miles
Endurance (stores):	15 days
Accommodations:	
Science:	10-12 persons
Crew:	4-6 persons

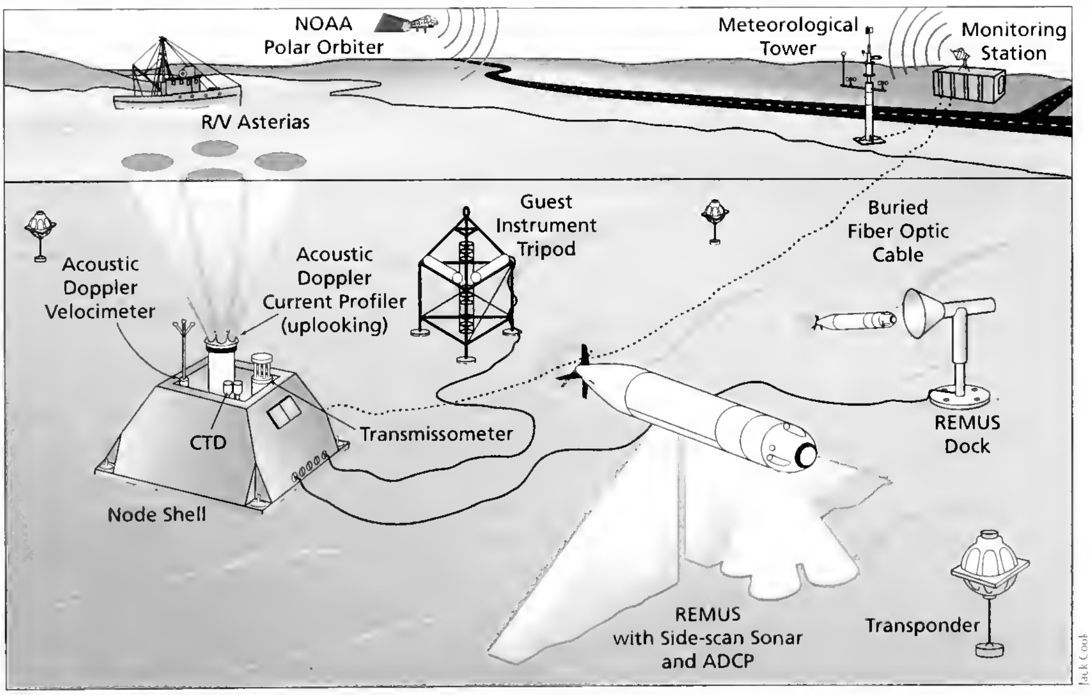


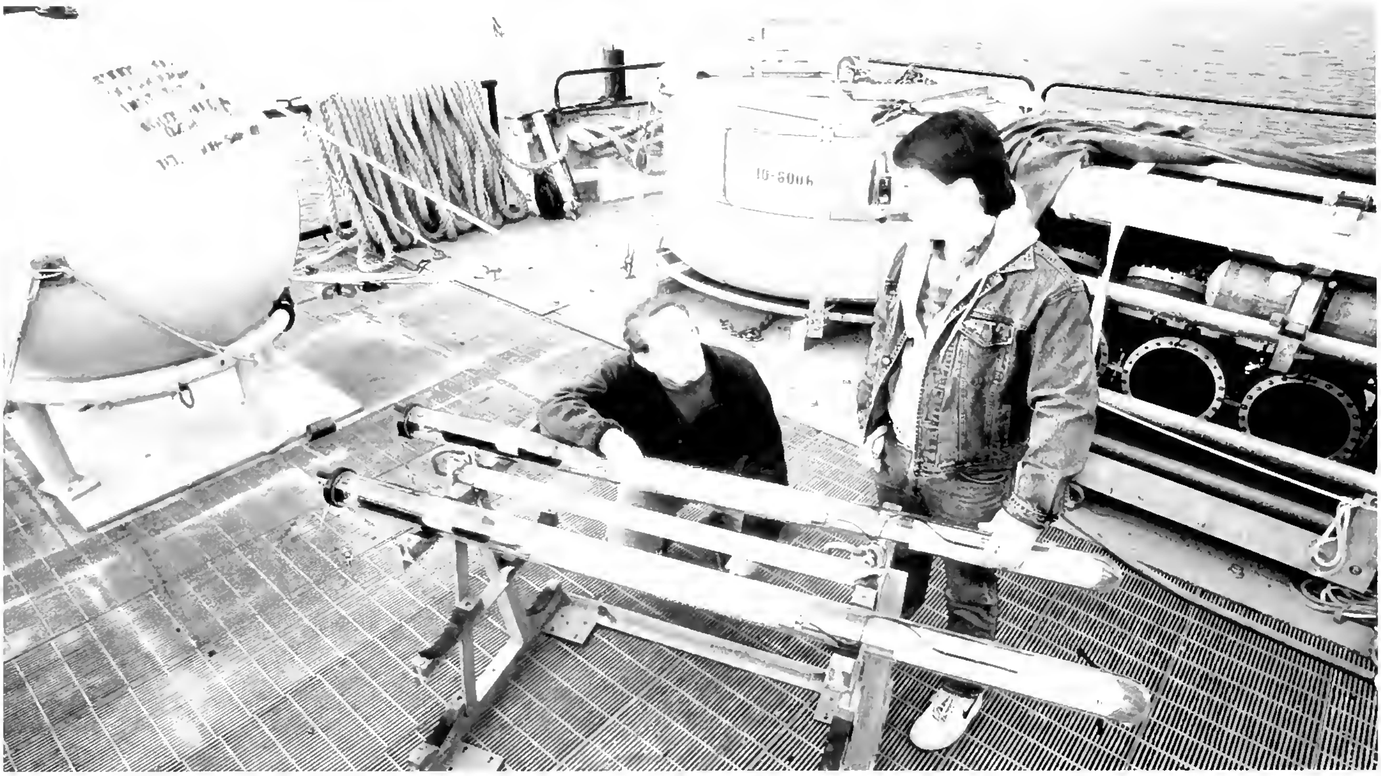
Deep Submergence. UNOLS is also well-served in the area of deep (1,000 meters and more) submergence. The Harbor Branch Oceanographic Institution operates three ships and three submersibles. The submersibles are *Johnson Sea Link I* and *Johnson Sea Link II*, with depth capabilities of 3,000 feet and each accommodating a pilot, a technician, and two scientific observers, and *Clelia*, a three-person vehicle with an operational depth of 1,000 feet. (The Monterey Bay Aquarium Research Institute also offers the oceanographic community ship and submersible capabilities that are not part of the UNOLS system.) The period from mid 1996 to mid 1997 marked a major transition in deep submergence: *Atlantis II*, support ship since 1983 for the submersible *Alvin* (14,764-foot depth capability), was decommissioned, and the new *Atlantis* was commissioned as its replacement. *Atlantis* represents a major upgrade in deep submergence facilities: The ship has four times the laboratory space of *Atlantis II*, accommodates eight more scientists, can stay at sea nearly twice as long (up to 60 days), and is equipped with dynamic positioning, a SeaBeam swath mapping system, and state-of-the-art electronics and computer systems.

Arctic Capabilities. There is growing sentiment in Washington, particularly in Congress, that arctic oceanographic research is underfunded. The US Coast Guard is constructing a large icebreaker (*Healy*) and, in response to considerable pressure from the National Academy of Sciences and others, has asked for advice and scientific input. UNOLS has established a new committee to provide this oversight. Given present Congressional interest and alignment, it is possible that an arctic research vessel will also be funded soon, and this would make arctic research a growth area. (See *Oceanus* Fall 1994 issue for a discussion of "Arctic Infrastructure.")

Ocean Drilling. The Ocean Drilling Program (ODP) is entering a period of transition. Though it is closely allied with the academic fleet user community, this program is not part of UNOLS, but rather an international partnership formed to explore Earth's origin and evolution through retrieving and studying long cores of sediment and rock from beneath the seafloor. ODP's seagoing component is the drilling ship *JOIDES Resolution*. The present ODP international agreements expire in 2003, and a follow-on program is being intensely discussed, with the US, Japan, and the European Union playing major roles. It will probably sort out to an international, two-ship program, with Japan building a new ship offering riser capabilities and the second ship possibly being an upgraded *JOIDES Resolution*. (A riser surrounds the drillstring and offers environmental protection by capturing drilling debris as well as oil or gas from deposits that may be encountered during drilling. Riser capability would extend the possibilities for scientific drilling on continental margins.)

Seafloor observatories, like the one conceptualized here for WHOI's Oceanographic Systems Laboratory (OSL), are expected to play increasingly important roles in ocean science with further development of such autonomous vehicles as OSL's REMUS (REMote environmental sensing UnitS).





Phil Richardson, left, and Brian Guest prepare RAFOS floats for a *Knorr* research voyage.

Autonomous Underwater Vehicles (AUVs). These vehicles are just now emerging from the early development stage, and progress is dramatic and rapid. They can be programmed to conduct repeated data-gathering surveys with a variety of instruments over many months from a base on the seafloor. In the near-term, they have the strong potential to join *Alvin* and ROVs as the enabling tools of benthic science to complement other investigative systems. (See the *Oceanus* Spring/ Summer 1995 issue for a description of the *Autonomous Benthic Explorer* (*ABE*) developed by WHOI scientists and engineers.)

Long-Term Observatories. Over the past decade, there has been increasing interest in long-term (years to decades) observations of physical variables in and beneath the oceans in several oceanographic disciplines. For example, WHOI's Oceanographic Systems Laboratory (OSL), led by Senior Engineer Chris von Alt and working with Rutgers University scientists, installed two instrument nodes at LEO-15 (Long-term Ecosystem Observatory in 15 meters of water) off the coast of New Jersey in September 1996. Node instruments, which can be controlled via the Internet, measure conductivity, temperature, pressure, dissolved oxygen, optical backscatter, and other parameters of the coastal environment via sensors mounted on a buoy that makes preprogrammed or on-command vertical profiles of the water column. Repeating these profiles over time provides a three-dimensional representation of the ocean as it moves past the observatory.

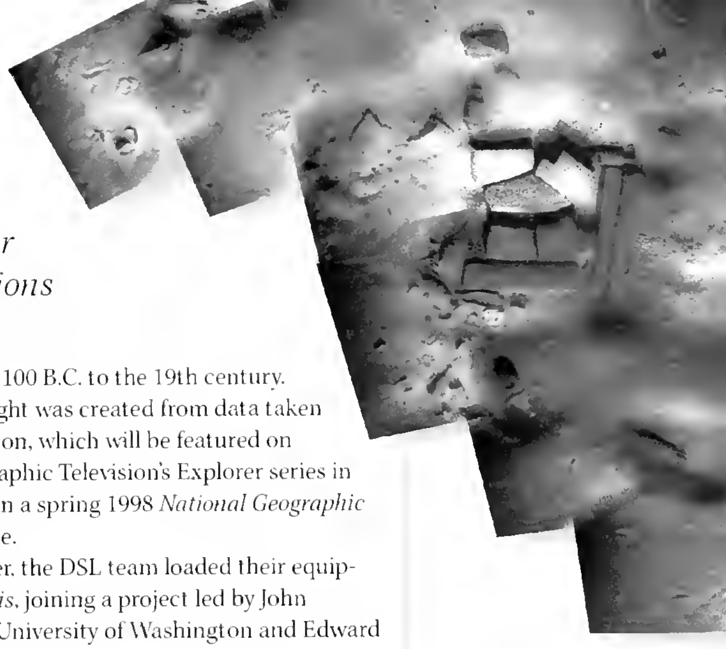
Such observatory efforts are driven by disparate scientific needs for long-term, time-series observations of oceanographic variables. The technological needs of all of the interested groups are very similar, and they push the oceanographic state-of-the-art. Specification of the observatories' scientific requirements and their technological fulfillments require a far tighter coupling of scientist and engineer than is usual in oceanography, and the sizes of observatory projects require team rather than individual approaches.

Drifting Profilers. New technology for profiling the water column using autonomous, freely drifting floats is now being used extensively by many oceanographers, and plans are accelerating to increase the number of variables that can be measured. This will greatly improve our ability to acquire regular water-column observations over large areas of the oceans, especially in remote and climatically unfriendly regions that have been undersampled or not sampled at all. This has important implications for collecting observations to aid ocean and climate modeling efforts.

Progress in all these areas of oceanographic interest, integrated with timely research vessel upgrades and replacements will support a vigorous US ocean science program well into the future. ■

Rear Admiral Richard Pittenger came to WHOI in 1990 after a prolonged (37-year) "apprenticeship" in the Navy. He says he has more or less settled into the niche of managing WHOI's Marine Operations department, which includes *Atlantis*, *Knorr*, *Oceanus*, *Asterias*, *Alvin*, and *Argo II*, *Medea/Jason*, and *DSL 120*, but reserves judgement on a final career decision. Dick is active in the oceanographic community, serving on the UNOLS Council and as a technical consultant to the Arctic Research Council.

"What A Year!"



WHOI's Deep Submergence Lab Brings Together Four Technologies to Serve Three Diverse Expeditions

Four technologies that have been developing separately for some time were brought together this year by WHOI's Deep Submergence Laboratory (DSL) to serve three very different user communities. With images from the towed vehicle *Argo II* and the remotely operated vehicle *Jason* (see vehicle illustrations overleaf), DSL scientists and engineers created mosaic images of a sunken British cargo ship and 20-meter-tall hydrothermal vent chimneys, both in the Pacific Ocean, and ancient shipwreck sites in the Mediterranean. The three expeditions thus served the marine safety, scientific, and archaeological communities.

The four technologies are precision navigation, automatic control or dynamic positioning of the vehicle, photo mosaicking techniques, and sonar imaging. DSL Scientist Dana Yoerger explains that the "geometrically accurate," but lower resolution sonar images combined with high resolution but less precise (because of camera physics) electronic photographs offer analytical accuracy that was never before possible.

Working aboard *Thomas G. Thompson*, an *Atlantis* sister ship operated by the University of Washington, a 13-member DSL team led by Research Engineer Andy Bowen left Guam March 9 for the wreck site of the 964-foot British bulk carrier M/V *Derbyshire*. The ship sank in 1980 with all 42 hands lost 400 miles off Okinawa. The DSL team was contracted through the National Science Foundation by the British Department of Transport to conduct a thorough survey of the ship, which rests at 4,300 meters, with the objective of determining the cause of the ship's loss and thus improving the future safety of bulk carriers.

The DSL team spent 57 days at sea first surveying the area with the towed vehicles *Argo II*, a high altitude imaging system, and *DSL-120*, a high resolution sidescan sonar system. Detailed photographic imaging of the site and examination of individual pieces of wreckage with *Jason* followed.

In June, the DSL team traveled to the Mediterranean on an expedition led by Bob Ballard, WHOI Scientist Emeritus and currently President of the Institute for Exploration in Mystic, Connecticut. They surveyed and photographed a cluster of eight ships lying 2,500 feet beneath an ancient trade route and ranging in age from about 100 B.C. to the 19th century. The image at right was created from data taken on this expedition, which will be featured on National Geographic Television's Explorer series in early 1998 and in a spring 1998 *National Geographic* magazine article.

In September, the DSL team loaded their equipment on *Atlantis*, joining a project led by John Delaney of the University of Washington and Edward Mathez of the American Museum of Natural History. This marked the beginning of fieldwork for a collaboration between the two institutions whose goal is to recover a suite of large black smokers from the hydrothermal vent area on the Juan de Fuca Ridge off the Oregon coast for both scientific analysis and museum display. It also marked the first voyage that combined both occupied (*Alvin*) and remote vehicle operations from *Atlantis*. Multiscale mapping with the towed *DSL-120 Sonar* vehicle preceded *Jason* photography with the objective of precise imaging of a suite of smokers for recovery in 1998.

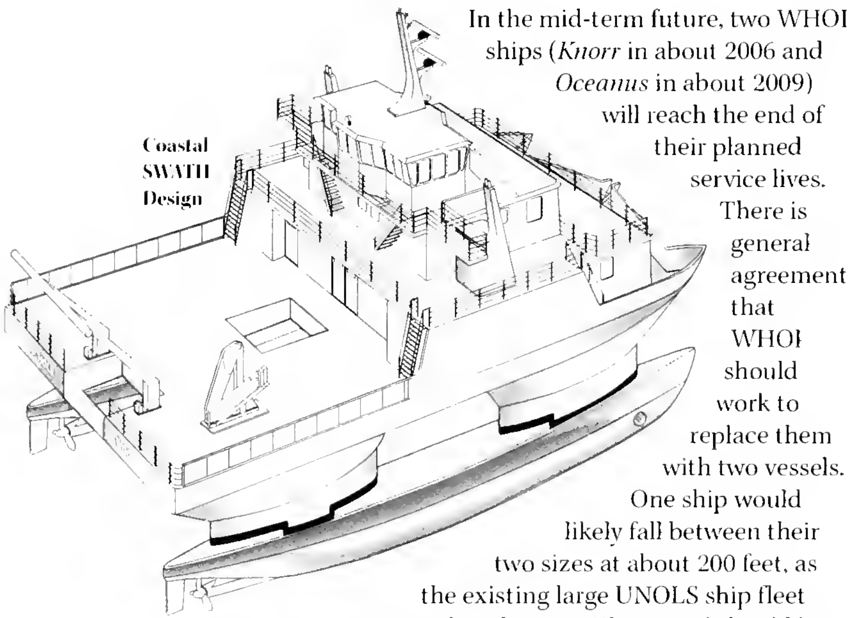
Martin Bowen

"What a year!" Yoerger comments. "We worked sites from a kilometer square at *Derbyshire* to centimeters at the Med sites and from flat, muddy seafloor to a real 3-D environment with overhangs and generally rough topography at Juan de Fuca. We've served widely varied user communities and have new data and engineering problems to tackle as a result of these expeditions."

—*Vicky Cullen*

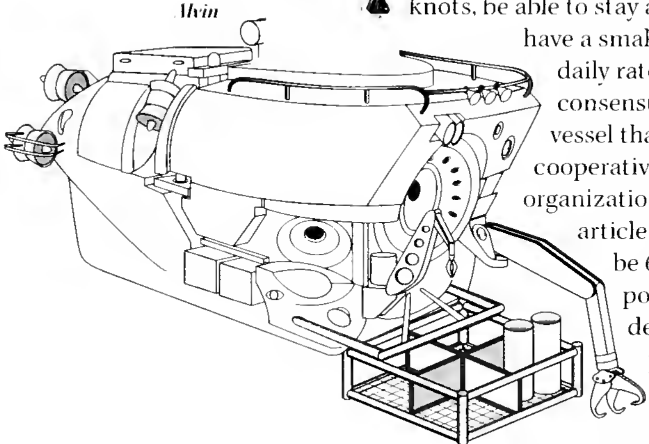
The photomosaic at the top of the page was created from sonar and photo data taken during Bob Ballard's Mediterranean expedition in summer 1997. It shows the cargo of a 1st century A.D. vessel that carried heavy building stones packed in at least two layers in a roughly square central section of the hold. The center photo was taken in the *Jason* control van during the Mediterranean expedition. The bottom image was constructed by Deep Submergence Laboratory Research Engineer Jonathan Howland during development of the photo mosaicking technology. It shows a 19th century Mediterranean wreck site surveyed and imaged in 1995 by the Navy's NR-1 submarine during reconnaissance for the 1997 expedition.

WHOI and Access



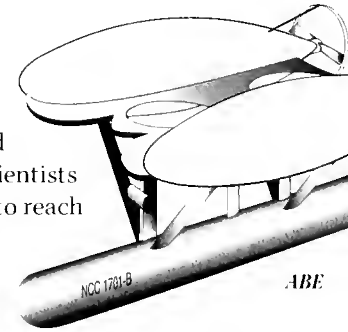
Coastal SWATH Design

In the mid-term future, two WHOI ships (*Knorr* in about 2006 and *Oceanus* in about 2009) will reach the end of their planned service lives. There is general agreement that WHOI should work to replace them with two vessels. One ship would likely fall between their two sizes at about 200 feet, as the existing large UNOLS ship fleet appears to be adequate. This vessel should have on the order of 25 scientific berths and offer plenty of deck space for vans and such operations as component-intensive moorings. It should cruise at about 12 knots, be able to stay at sea for 30 days, and have a small crew to reduce the daily rate. There is less consensus on a second, small vessel that is likely to be used cooperatively by several organizations (see preceding article). It should probably be 65 to 100 feet long, possibly of SWATH design, if that design proves appropriate for oceanographic research in the northwest North Atlantic. It should offer 10 to 12 science berths, a small crew (1 to 2 in port, 3 to 6 underway), seakeeping for safe year-round operations in the Northeast, and a dynamic positioning system.



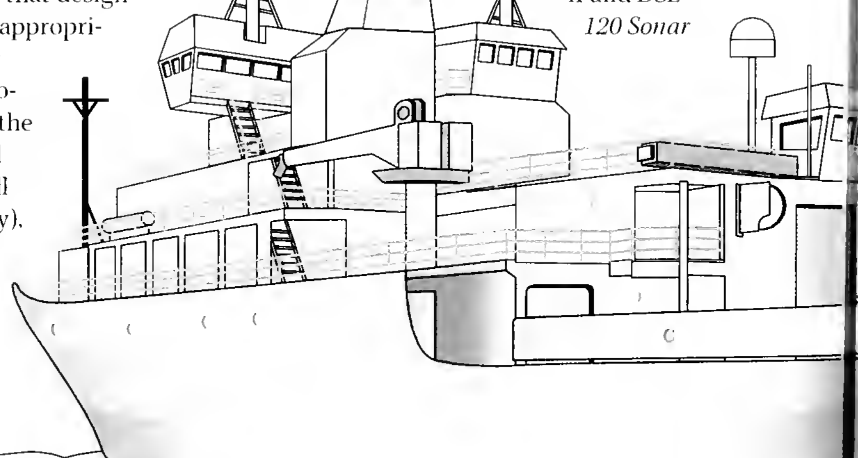
Alvin

The National Deep Submergence Facility operated by WHOI has consistently provided US and international scientists with the ability to reach and study the abyss for some three decades. *Alvin*, the first vehicle in the facility, is ageless, having been continuously modernized over its life span. It is currently rated to dive to 14,764 feet carrying two observers and one pilot. The submersible is overhauled completely every three years, resulting in a vehicle system that is the best in the world in terms of efficiency, ease of operation, reliability, safety, and cost effectiveness. One option for improving *Alvin's* capabilities would be to merge Navy's *Sea Cliff* with *Alvin* after *Sea Cliff* is taken out of service in 1998. *Sea Cliff* has a 6,100-meter sphere and considerable peripheral equipment that could upgrade *Alvin*. The Office of Naval Research and other federal agencies have indicated a desire to explore various options related to *Sea Cliff*.



ABE

Since 1993, the facility has included the fiber-optic based, tethered, remotely operated vehicle team *Medea/Jason* and the towed *Argo-II* and *DSL-120 Sonar*



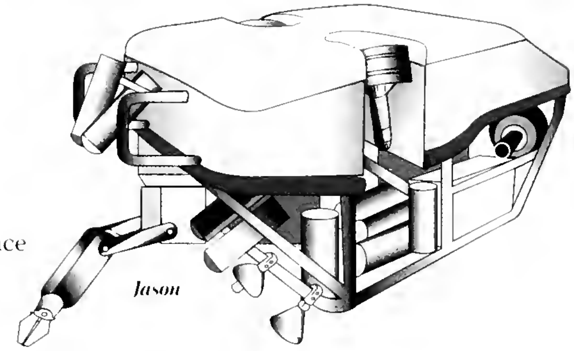
R/V *Atlantis*

SWATH and *Atlantis* Illustrations by Jayne Doucette. Vehicle illustrations by E. Paul Oberlander

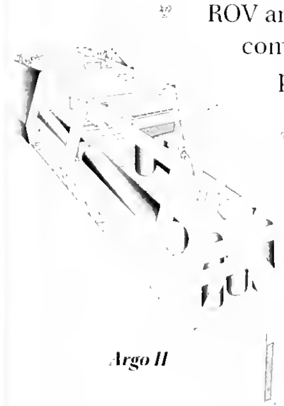
to the Sea

mapping system. These vehicles (developed with Navy and Institution funds) are now routinely requested by scientists, and supported by the funding agencies, to carry out multidiciplinary research in the oceans down to 6,000 meters. This suite of tethered and submersible vehicles is unique in the world, and offers US scientists investigative synergy that provides unprecedented access to the deep ocean to carry out a spectrum of biological, geological, physical, chemical, and technology related experiments. R/V *Atlantis* is uniquely outfitted to operate these vehicles as a suite of oceanographic tools.

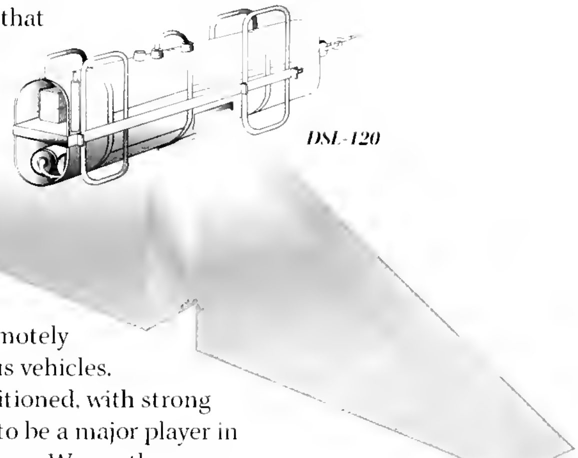
We believe that there will continue to be an important niche for *Alvin* and the ROV and tethered systems in the coming 10 to 20 years. Each vehicle provides a unique capability for carrying out different types and scales of oceanographic studies. These range from high-resolution seafloor mapping in all tectonic locales to site-specific mapping, sampling, and seafloor observatory installation and monitoring to provide key temporal components of oceanographic and magmatic processes at the seafloor and in the deep ocean. The areas of deep submergence facilities that will require focused attention in order to sustain a robust deep submergence program include *Alvin* upgrades and improvement of the sub's operational systems, ROV and tethered vehicle improvements, and integration of Autonomous Underwater Vehicle (AUV) systems such as *ABE*, the *Autonomous Benthic Explorer. ABE* proved its mettle in recent magnetic surveys on the Mid-Atlantic Ridge, while a prototype of the shallow-water *REMUS* (REMote environmental sensing UnitS) developed by the WHOI Ocean Systems Laboratory has been successfully tested in local waters as a tool for coastal seafloor mapping. It is important that we build on these successes in this rapidly moving and highly competitive technology. It is, in fact, appropriate to begin now to develop the next generation of remotely operated and autonomous vehicles.



Jason



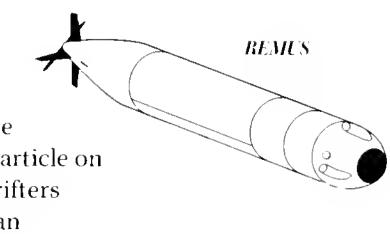
Argo II



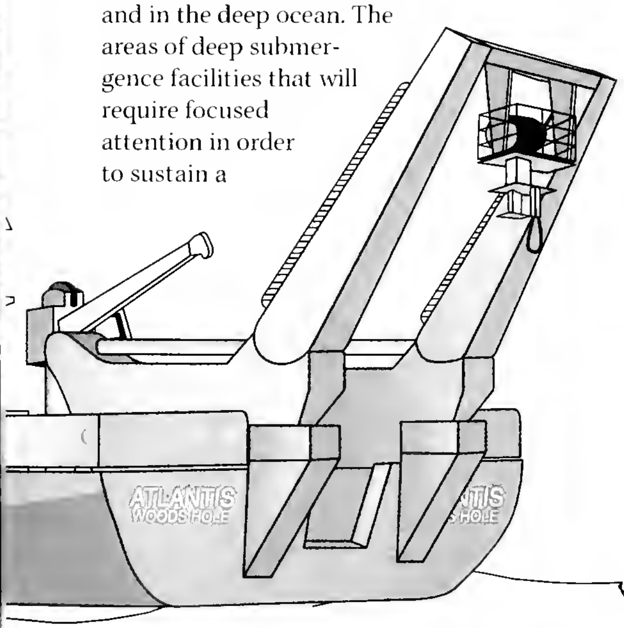
DSL-120

WHOI is uniquely positioned, with strong engineering capabilities, to be a major player in ocean observatory programs. We see these unmanned observatories as a very important element of future oceanography. They require some shifts from oceanography-as-usual, since their success depends on close cooperation and coordination between scientists and engineers, better than usual management skills from project leaders, and longer than usual planning cycles.

WHOI has played a major role in the evolution of drifting sensors from Swallow floats through SOFAR and RAFOS drifters to today's rapidly improving family of profilers (ALACE, PALACE, SLOCUM—see *Oceanus* Fall/Winter 1996 for an article on these instruments). Floats and drifters will be heavily used in future ocean sensing, and our involvement should continue. —*Dick Pittenger*



REMUS



R/V *Atlantis* arrives in home port for the first time in April 1997.

Replacing the Fleet

15 Years from Concept to Delivery

Richard F. Pittenger
Associate Director for Marine Operations

When R/V *Atlantis* arrived in Woods Hole for the first time on a bright, beautiful April 1997 day, it represented not only a welcome addition to the WHOI fleet but also the culmination of a 15-year UNOLS fleet modernization.

We tell this story to illustrate the time and effort involved in acquiring (or modernizing) research facilities, like research vessels, with long lead times. Ships generally have a useful lifetime of 20 years without a major upgrade. A midlife refit, including refurbishing all major systems, will usually extend that lifetime by about 10 to 15 years.

In the early 1980s, the academic fleet was facing a crisis. All of its large research ships either needed immediate replacement or soon would (see top figure opposite). This fleet of large ships, built by the Navy as part of its long-standing policy of outfitting US oceanographers with quality research vessels, represented a huge investment. Its modernization would require considerable effort, commitment, and money.

The endeavor kicked off in grand fashion when in July 1984 Secretary of the Navy John Lehman and Chief of Naval Operations Admiral James Watkins announced their "Navy Policy on Oceanography." It stated, in part, "*Oceanographic research ship will be procured.* Navy will include $35M in the ...87 budget for the procurement of a Navy-owned oceanographic research ship to be utilized by the civilian academic oceanographic research community with

SHIP	Operator	Built	Age in 1983
Conrad	Lamont-Doherty Geological Observatory	1962	21 years
Thompson	University of Washington	1965	18 years
Washington	Scripps Institution of Oceanography	1965	18 years
Melville	Scripps Institution of Oceanography	1969	14 years
Knorr	Woods Hole Oceanographic Institution	1970	13 years
Gyre	Texas A & M	1973	10 years
Moana Wave	University of Hawaii	1973	10 years

a target IOC (Initial Operational Capability) of 1991... The Oceanographor of the Navy and the Chief of Naval Research will jointly develop an oceanographic research ship construction program to be submitted to the Chief of Naval Operations in time for (fiscal year 1987 budget submission). The objective of the program is to insure appropriate deep ocean research platforms are available to meet Navy operational and research requirements." In the following months, this initiative was fleshed out and developed by the Oceanographer of the Navy, the Office of Naval Research (ONR), and the Naval Sea Systems Command, with significant input from the oceanographic community through UNOLS (University-National Oceanographic Laboratory System), an association of ocean science institutions that operate and use the US academic research fleet.

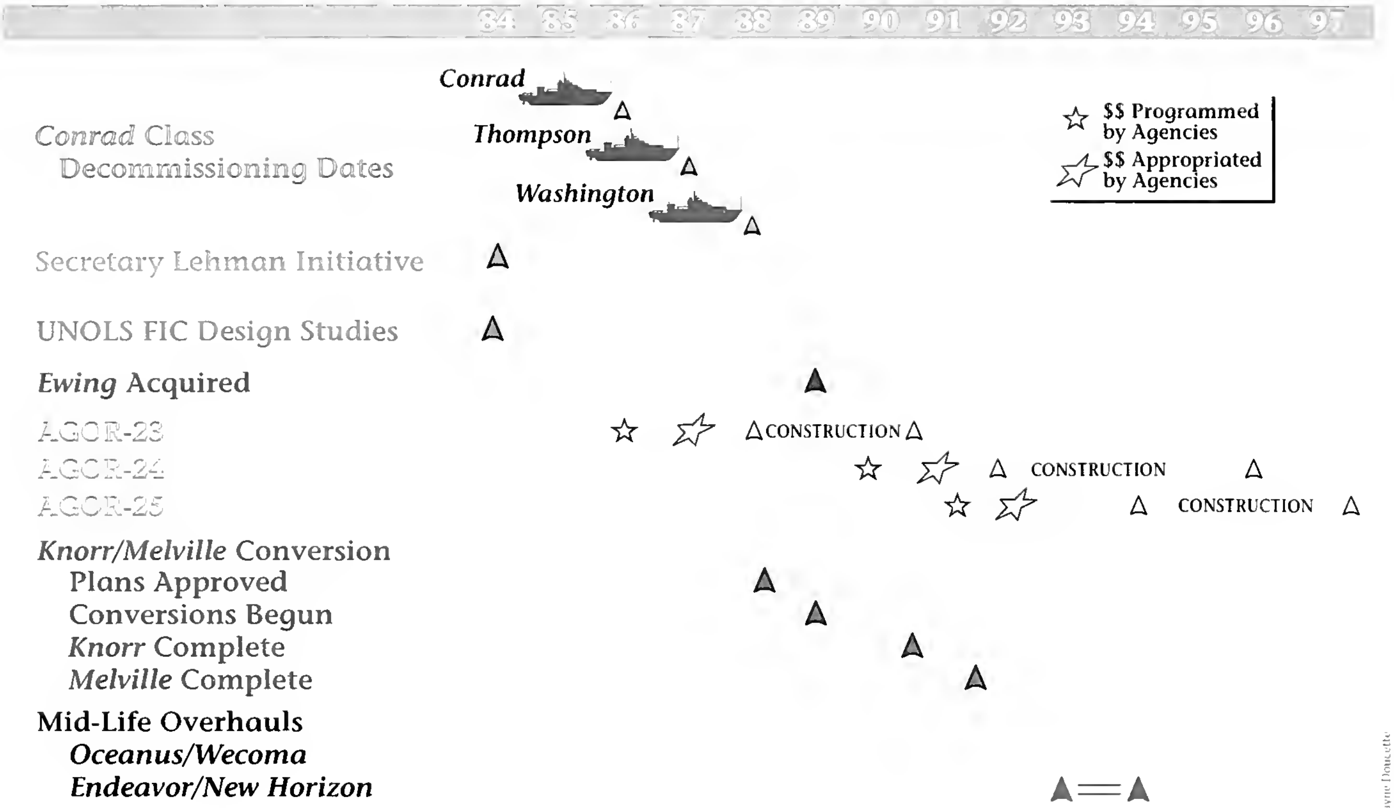
US Navy AGORs*

(AGOR: Auxiliary General-purpose Oceanographic Research vessels)

NO.	NAME	LENGTH	LIFE SPAN	OPERATING INSTITUTION
1	*Gibbs*	311'	1944-82	Seaplane tender *San Carlos* 1944-58, Hudson Labs of Columbia University 1958-68, Naval Research Labs 1968-82
2	*Manning* (ex T-514)	65'	1953-70s	Army T-514 cargo boat 1953-55, Hudson Labs and Crumb School of Mines, Columbia University 1955-70s
3	*Conrad*	208'	1962-89	Lamont-Doherty Geological Observatory, Columbia University
4	*Gilliss*	208'	1963-84	Military Sealift Command for West Coast Navy labs
5	*Davis*	208'	1963-80	Military Sealift Command for West Coast Navy labs
6	*Sands*	208'	1964-79	Military Sealift Command for East Coast Navy labs
7	*Lynch*	208'	1965-91	Military Sealift Command (MSC) for East Coast Navy labs
8	*Eltanin*	266'	1957-72	Navy cargo ship 1957-62, NSF Antarctic research 1962-72
9	*Thomas G. Thompson*	208	1965-91	University of Washington
10	*Thomas Washington*	208'	1965-92	Scripps Institution of Oceanography, UC–San Diego
11	*Mizar*	266'	1957-90s	Navy cargo ship 1957-64, MSC for various commands 1964-90s
12	*DeSteiguer*	208'	1969-92	Military Sealift Command for West Coast Navy labs
13	*Bartlett*	208'	1969-93	Military Sealift Command for West Coast Navy labs
14	*Melville*	279'	1969-2014	Scripps Institution of Oceanography, UC–San Diego
15	*Knorr*	279'	1970-2015	Woods Hole Oceanographic Institution
16	*Hayes*	246'	1971-pres.	Military Sealift Command for Naval Research Laboratory
17	*Chain*	213'	1944-79	Woods Hole Oceanographic Institution (1958-79)
18	*Argo*	213'	1944-70	Scripps Institution of Oceanography, UC–San Diego (1959-70)
19	} AGORs 19 and 20 were cancelled and not built			
20				
21	*Gyre*	182'	1973-2003	Texas A&M University
22	*Moana Wave*	210'	1973-2004	University of Hawaii
23	*Thomas G. Thompson*	274'	1991-2021	University of Washington
24	*Roger Revelle*	274'	1996-2026	Scripps Institution of Oceanography, UC–San Diego
25	*Atlantis*	274'	1997-2027	Woods Hole Oceanographic Institution

***Sources include: Office of Naval Research, Navy Contemporary History Branch, *Oceanographic Ships Fore and Aft* by Stewart B. Nelson (1971), *The Ships and Aircraft of the US Fleet* by Norman Polmar (1981), *Jane's Fighting Ships 1988-89*.**

Recent UNOLS Fleet Modernization



Elements of the UNOLS Fleet Modernization Plan included:

• Retiring four older AGORs, *Conrad*, *Thompson*, *Washington*, and *Gyre* (AGOR is Navyspeak for Auxiliary General-purpose Oceanographic Research—see figure on page 13 for list of AGORs),
• acquiring new vessels (AGORs 23, 24, and 25),
• initiating major conversions for *Knorr* and *Melville* (later this was extended, with National Science Foundation (NSF) funding, to include the intermediate-sized vessels *Oceanus*, *Endeavor*, *Wecoma*, and *New Horizon*), and
• a major overhaul for *Moana Wave*.

Time lines for most of this effort are shown above.

A giant crane lifts *Knorr* in 1989 as the ship's refit begins at McDermott Shipyard in Amelia, Louisiana.

The *Knorr/Melville* conversions were prompted by poor reliability of the ships due to propulsion plant design. Both were experiencing ten months mean time between drydockings. In addition, they were too noisy for acoustic operations, an essential element of oceanographic research, and too small and lacked the seakeeping qualities to accommodate large science parties for long periods to carry out the global scale programs then being contemplated, especially the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS).

The scope of the *Knorr/Melville* conversion effort was defined by representatives of the operating institutions (WHOI and SIO) and ONR with inputs from NSF, UNOLS, and the user community. This group recommended that the ships be:

• reengined (converted from direct-drive cycloidal to quieter, more reliable diesel electric engines with azimuthing Z-drives),
• repiped, and
• rewired. (*Note:* It is no secret that this project had a few bad moments and took longer and cost more than was planned—but it is not the purpose of this article to delve into those issues!)

The figure opposite above compares the pre- and post-conversion characteristics of the two vessels.

After their conversions (and a great deal of TLC from the operating institutions and their dedicated crews), these virtually new ships have performed magnificently. The proof of this assertion is in their post-conversion performance: Both ships have since spanned the globe reliably and served science capably. The objectives of the conversions have been tested and exceeded. Both vessels have carried large science parties on long cruises in waters that would have exceeded their preconversion capacities (see cruise track chart, below, and Labrador Sea article on page 18).

The Navy plan that grew out of the Lehman/Watkins initiative called for building three new ships and eventual replacement of all five existing AGORs. (This plan has gone through several modifications since its adoption—notably Lamont-Doherty Earth Observatory of Columbia University, operator of *Conrad* (AGOR-2), opted to acquire, with NSF support, a used vessel that was renamed *Maurice Ewing* for a noted geophysicist and Lamont Director. *Gyre* was transferred to the state of Texas and remains in service. The fate of *Moana Wave* is pending, but it will probably be replaced by another AGOR currently in the design stages.

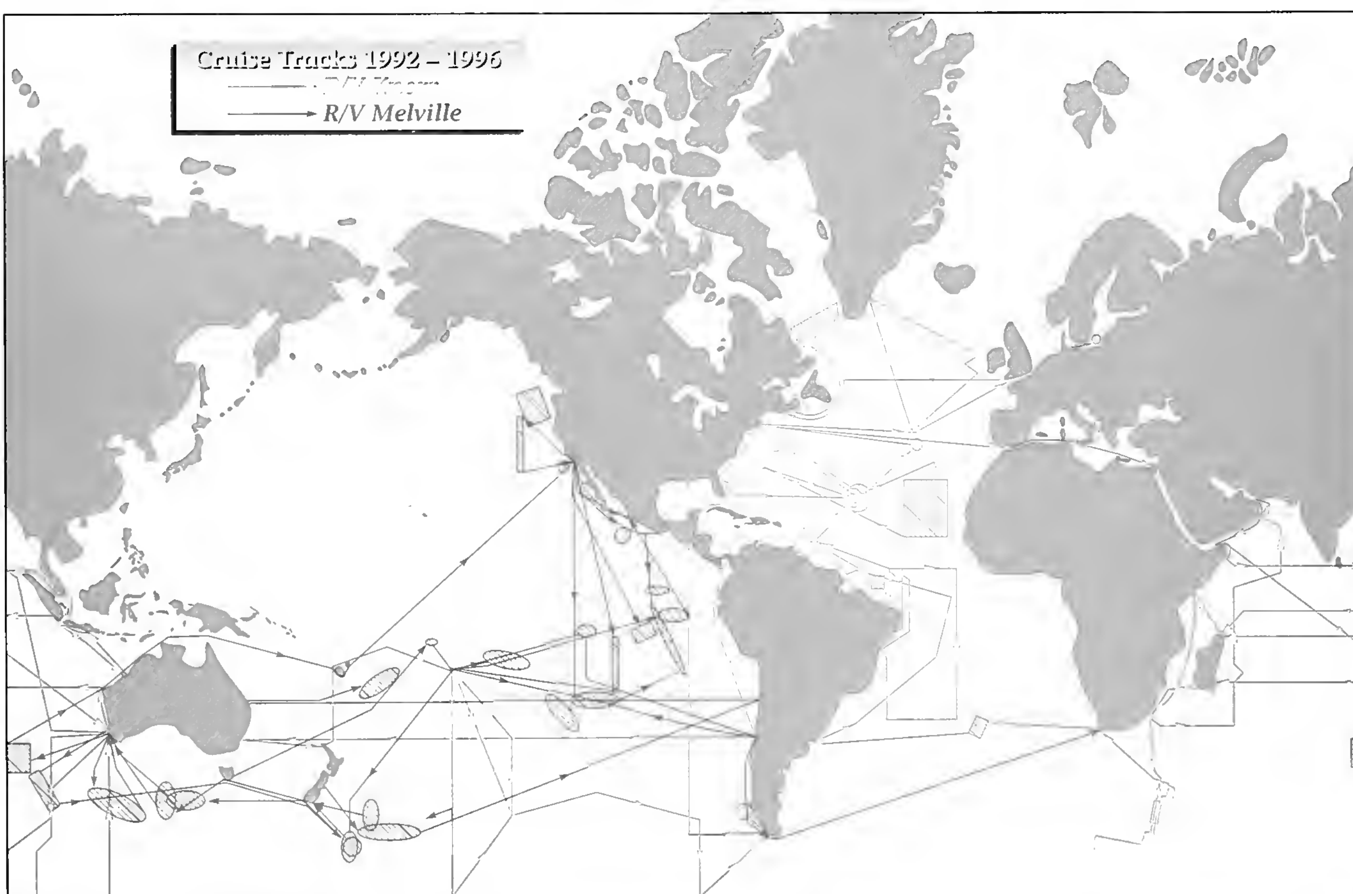
The Lehman/Watkins oceanography initiative had enthusiastic community support. The UNOLS Fleet Improvement Committee (FIC), with major inputs from potential users, wrote a series of scientific mission requirement statements that were used by Navy officials to compose documents that led to awarding of a contract to Halter Marine Inc. of Moss Point, Pascagoula, Mississippi, for construction of the lead ship in the new AGOR-23 class. Through competitive bidding, ONR selected the University of Washington as the operator of the new ship. It would replace and bear the same name as

R/V Knorr Characteristics Before and After Refit

	Former	New	Change
Length Overall (feet)	245	279	+34
Beam (feet)	46	46	-
Draft (feet)	16	15.5	-.5
Full Load Displacement (tons)	2,415	2,670	+255
Propulsion Horsepower	2,800	3,000	+200
Cruising Speed (knots)	10	12	+2
Maximum Speed (knots)	12	14	+2
Fuel Capacity (gals)	122,000	155,000	+33,000
Cruising Range (miles)	10,000	12,000	+2,000
Crew	25	23	-2
Scientists	24	34	+10
Lab Space (sq. ft.)	1,540	3,130	+1,590
Science Storage (sq. ft.)	1,020	1,776	+756
Main Deck Working Area (sq.ft.)	3,424	3,764	+340

Fritz Heide

***Knorr* and *Melville* have ranged the world ocean since their refits.**



Jayne Doucette

AGOR-9, *Thomas G. Thompson*. The contract was let in June 1988 and the ship was completed and put into service on 8 July 1991.

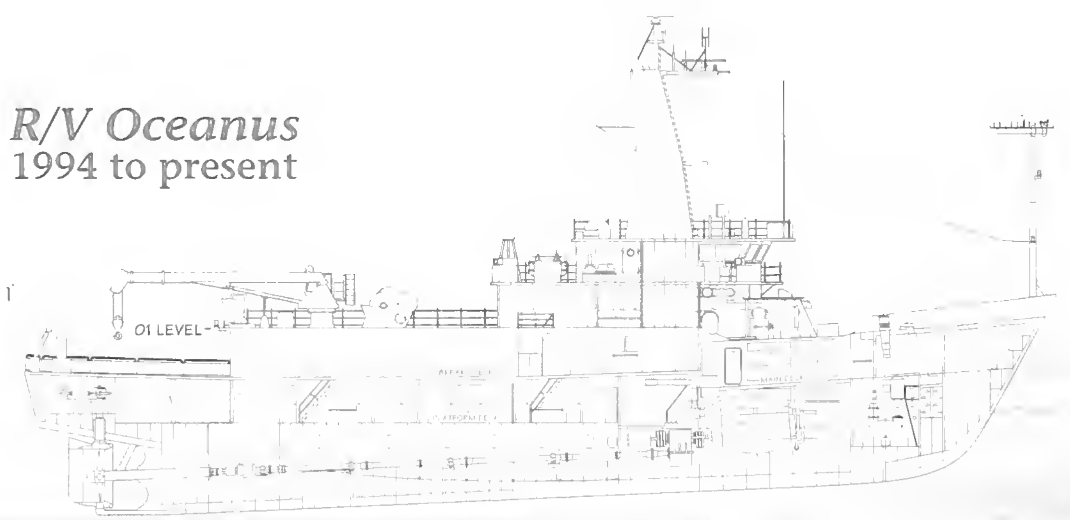
In FY '91 and FY'92, Congress appropriated funds for AGORs 24 and 25 respectively to complete the class. Again ONR solicited bids for operator institutions. The Scripps Institution of Oceanography, University of California, San Diego, was awarded operation of AGOR-24 to replace *Thomas Washington*. The new ship was named *Roger Revelle* after Roger Randall Dougan Revelle, a distinguished Scripps graduate (Ph.D., 1936) and former director (1951-1964), who died in 1991 at age 82.

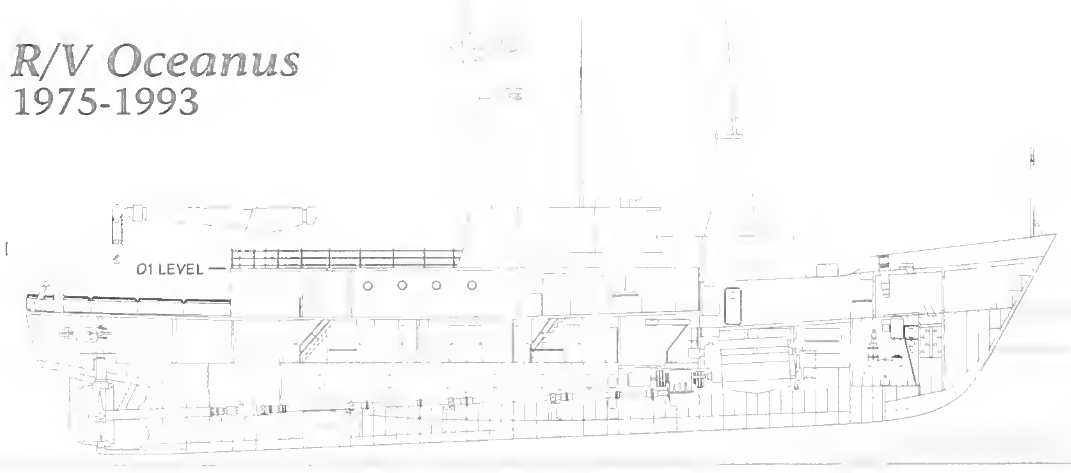
Courtesy of University of Washington

R/V *Thomas G. Thompson* (AGOR-23) was the first of the new class of AGORS to be built. The ship was delivered to the University of Washington in 1996.

Woods Hole Oceanographic Institution also submitted a bid for one of the AGORs. Our proposal involved taking *Atlantis II* out of service, selling it, and converting *Knorr* to be the support ship for *Alvin*. Eventually this plan was modified at the Navy's behest to make the new *Atlantis* the National Deep Submergence Support Ship instead of *Knorr*. There followed some remarkable cooperation and rapid action between federal agencies (especially ONR and NSF), the Naval Sea Systems Command, the shipbuilder, and WHOI to change the ship's mission statement and the associated SOR (the governing document for building *Atlantis*) to develop a ship change proposal and negotiate a price. All this was accomplished without delaying completion of the ship. In fact, *Atlantis* was completed ahead of schedule. In my experience, this sort of major change late in the construction of a ship with the customer (WHOI) providing equipment (the *Alvin* A-frame) as well as technical and design advice and guidance is unprecedented. It is a tribute to all involved that this effort turned out so well.

During the construction of the large ships, WHOI Marine Operations Manager Joe Coburn and the other operators initiated a plan for major





Lynne Doucette

Midlife refit upgrades to *Oceanus* completed in 1994 included a one-third increase in laboratory space, from 1,054 to 1,390 square feet. Science berthing increased from 12 to 15, and an additional 4 berths are also available in a portable van. The heating-ventilation-air conditioning system was fully replaced, and new refrigerators and a freezer were installed along with new main and auxiliary exhaust systems. The ship was equipped with a rebuilt reduction gear, a new crane, a bigger A-frame, a new capstan, a new anchor windlass, and a new emergency generator. The main engine was overhauled and upgraded, and a new structure (forward shaded area) was built to house the pilot house, chart room, and communications room.

midlife refits of the *Oceanus* class ships: *Oceanus* (WHOI), *Endeavor* (University of Rhode Island), and *Wecoma* (Oregon State University), built in the mid 1970s. This effort was vetted by the UNOLS Fleet Improvement Committee and supported, at a fixed cost of $3 million each by NSF, owner of these ships. The figure opposite below shows the work involved for *Oceanus*.

AGOR-24 was delivered to Scripps Institution of Oceanography in 1996 for operation as *Roger Revelle*.

WHOI and URI cooperated in developing detailed design and contract specifications. NSF and the operators agreed to space these midlife overhauls over three years. They were completed in 1993 (*Endeavor*) and 1994 (*Oceanus* and *Wecoma*). The work packages were tailored to the individual ships (each ship of the class had differences) and to the ships' perceived clientele. WHOI emphasized open deck area to support mooring work and physical oceanographers. The work on *Endeavor* was similar to that on *Oceanus*, except that *Endeavor's* afterdeck was also extended. *Wecoma's* refit was limited to work below the 01 deck.

In 1996, the Scripps ship *New Horizon* was overhauled, completing the UNOLS intermediate-class modernization.

There is a very important lesson here. This process took 13 years to complete from the time it was endorsed by Navy leaders, who were responding to oceanographic community suggestions. Even with full support and high priority in Washington from both the Federal agencies and Congress, replacement of ships is a decadal process. Given a nominal ship service life of about 30 years, planning for ship replacement must begin before the ships to be replaced are 20 years old. ■

AGOR-25 was launched in February 1996 and delivered to WHOI in 1997. It continues the *Atlantis* tradition begun when the Institution was founded in 1930.

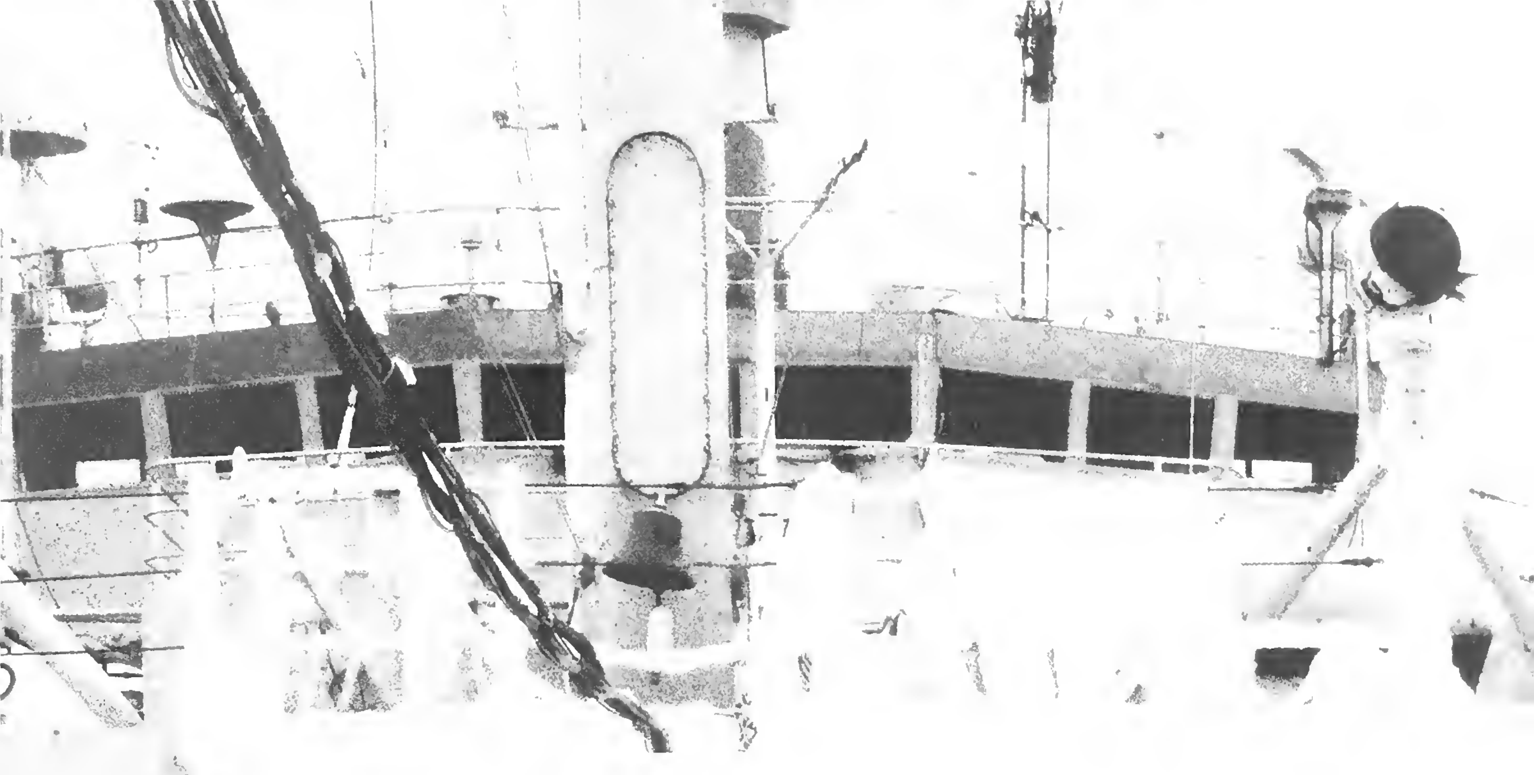
On the Naming of US Navy Ships

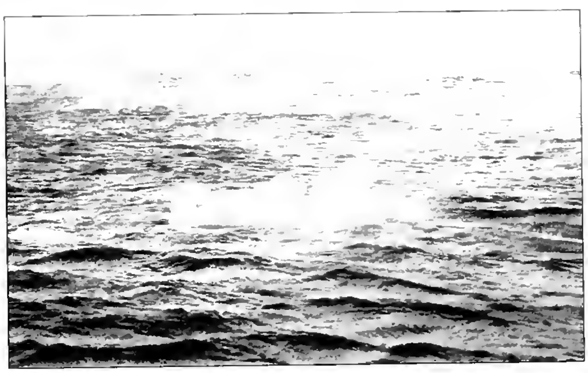
Generally, the Secretary of the Navy authorizes the naming of a Navy ship based on recommendations from the Naval Historian and a board convened to review naval vessel names. Individuals involved with Navy oceanography, meteorology, mathematics, and astronomy have usually been favored in the naming of ships. In the cases of the three newest AGORs, this tradition was expanded to include the traditions and sentiments of the operating institutions: Thomas G. Thompson founded oceanography at the University of Washington, Roger Revelle was long-time director of the Scripps Institution of Oceanography, and the Woods Hole Oceanographic Institution has had a ship named *Atlantis* since its founding in 1930. Because Navy tradition does not include the numbering of ships, the WHOI vessel is called simply *Atlantis* rather than *Atlantis III*.

In honor of 1998 as the United Nations-designated Year of the Ocean and to encourage young people's interest in ships, oceanography, maritime studies, and use of the Internet, Oceanographer of the Navy Rear Admiral Paul Tobin initiated a different ship naming procedure for the Navy's newest T-AGS 60 class oceanographic survey ship. Teams of elementary and secondary school students are encouraged to submit names for the ship, scheduled for launch in late 1998, along with educational projects to support and justify their proposed name. Projects were to begin in September 1997 and be submitted to a state Navy League office by December 31, 1997.

Further information on the contest is available on the World Wide Web at the following address:

http://oceanographer.navy.mil/TEXT/contest.html





A picturesque natural ice sculpture floats in the Labrador Sea.

A Wintertime Cruise to the North Atlantic

Robert S. Pickart

Associate Scientist, Physical Oceanography Department

The sound of the general alarm bell reverberated through the ship. At 2:30 AM, this couldn't be a drill. Even more puzzling, we were still dockside in Halifax, four hours from our scheduled departure for the Labrador Sea.

Almost immediately, I heard the captain's phone ringing in the adjacent stateroom—a sound that would become familiar over the next seven weeks.

I wondered: Is this an omen? Should we reconsider this attempt to study wintertime oceanography in one of the harshest areas of the world ocean?

As it turned out, four of *Knorr's* six preheaters had failed, and WHOI's port office delayed our departure to allow necessary repairs. This was the first of many challenges we would face during this difficult experiment. It was also the first of many instances of good luck that would impact our

Adventure in the Labrador Sea

Captain A.D. Colburn, right, crew member Bill Dunn, and others wield their ice mallets on *Knorr*'s foredeck during the Labrador Sea cruise.

Watchstanders Gwyneth Hufford and Mike Ohmart, tethered to a safety line, await word from the Main Lab to launch an expendable bathythermograph (XBT) through the tube at right. The photo was taken on the day that marked both the coldest weather of the cruise (2-4) and the ship's closest approach to the Labrador ice edge.

success (had the heaters failed in the middle of the cruise, the consequences could have been severe).

The goal of our experiment was straightforward enough: Observe wintertime convection in the Labrador Sea. This had been done only once before, nearly 20 years ago, by a group from Bedford Institute in Nova Scotia, at the end of the winter season. Convection is the sinking of dense surface water to great depths where it forms a newly replenished water mass.* It occurs in only a few locations, but is crucial in driving large-scale ocean circulations that affect Earth's climate system. In the Labrador Sea, bitter cold winds blowing off the Canadian coast chill surface waters and remove enough buoyancy to cause convection. This harsh weather is, of course, the very reason for the dearth of direct observations of this phenomenon. Our cruise's objectives included characterizing the atmospheric forcing as well as the ocean's response. Thus we needed to be present during the heart of the winter season. Our primary at-sea operations included Conductivity/Temperature/Depth (CTD) rosette sampler deployments, shipboard and weather-balloon atmospheric measurements, and drifter launches.

Despite many months of preparation by both science party and *Knorr* crew, we would be leaving Halifax with a bit of uncertainty. This was perhaps fueled by many of our peers' perception of the experiment as one of high risk that included the possibility of complete failure. Indeed, a relentless effort had been required over several years to acquire funding for the cruise. The common opinion was that, while the scientific objectives were worthwhile, we would spend a good portion of the cruise hove to because of the weather and the ice, and thus accomplish few (if any) of our goals. In the end, two factors played major roles in allowing us the chance to investigate the wintertime Labrador Sea: The cruise was part of a cooperative experiment that would provide a platform for numerous collaborations,** and it was funded by the Office of Naval Research, which has a history of supporting high-risk science.

We departed Halifax on February 2, 1997. The weather quickly soured shortly after we rounded the

*Articles on convection and associated phenomena can be found in *Oceanus* issues Spring/Summer 1994 (Atlantic Ocean Circulation) and Fall/Winter 1996 (Oceans & Climate).

**The Labrador Sea convection program is comprised of an international group of scientists who combine theoretical and numerical modeling with observational work. The cruise included participants from seven different institutions making a variety of oceanographic and atmospheric measurements. There were also aircraft overflights by the US National Aeronautics and Space Administration and the Canada Centre for Remote Sensing at various times during the cruise.

tip of Newfoundland on our way north. Before reaching our first station, we encountered a band of pack ice blocking our path. Thus occurred our second challenge on this young cruise, one that addressed the central issue of the experiment: Was the 278-foot *Knorr* really capable of operating in such an environment? While an ice breaker was not appropriate for our work, since most of the Labrador Sea is ice-free, we did consider the possibility of an ice-strengthened vessel. However, the vast majority of research vessels are not of this class, and logistics prevented such an option for our experiment. While *Knorr* had certainly operated in adverse conditions often enough and had recently undergone a major conversion, the combination of so many different factors—intense storms, icebergs, pack ice, subfreezing temperatures—made the Labrador Sea uniquely challenging. It was the lack of experience in such conditions, as much as the design of the vessel, that lay at the heart of the issue.

Sarah Zimmermann

First mate George Silva takes a break from pounding ice to admire his work. This section of the starboard bulkhead was particularly susceptible to ice buildup.

Our encounter with the ice pack brought this point home just three days into our cruise. But rather than put a damper on our prospect for success, Captain A.D. Colburn and his crew turned the experience into a positive one, and from it emerged a proper and safe strategy for working in the vicinity of the ice pack. In the end, this type of positive reaction to a difficult challenge more than made up for any lack of experience working in such climes.

During the planning stage of the experiment we needed to estimate how many stations would likely be occupied. We cautiously put the number somewhere between 60 and 80, with the latter considered somewhat optimistic. The prospect of frequent storms traveling across the Labrador Sea prompted a liberal prediction of "weather days," when we would be hove to, unable to work. We ended up planning on one weather day for every four working days, which was part of the reason for the 47-day length of the cruise. We were, of course, hoping to do a bit better than this, in part because long-term predictions called for a fairly mild winter in the Labrador Sea. In fact, the month preceding our cruise *was* abnormally warm, and there was widespread belief that the entire winter would be the same. This was a bittersweet prospect: While we might obtain a multitude of measurements in fair weather, we might also never witness the deep convection we hoped to see. However, by the end of the first week of the cruise two things became evident: Winter 1996-97 would *not* be weak, and R/V *Knorr* and its crew would prove resilient to every challenge thrust upon them.

George Tupper

Chief Scientist Bob Pickart, center, Sarah Zimmermann, right, and Dan Torres launch a profiling vertical current meter in 45 knot winds. Float launches are typically done over the fantail, but the Labrador Sea's harsh conditions required a safer, more controlled procedure using the starboard hydroboom.

During the five-week period of occupying stations in the Labrador basin, we experienced classic wintertime convective conditions. The air temperature rose above freezing only once, on our last working day (the average was 18°F). Not until our fourth week did we experience a sunny day—one of two during the entire cruise. It snowed constantly. One of the conditions we had hoped to observe during the experiment is known as a cold-air outbreak, in which bitter cold air blows from the west off the continent and cools the relatively warm ocean water. The mild predictions made us wonder whether we would witness even one of these events, but our worry was unwarranted. As one of the meteorologists on board put it, we experienced these conditions almost continually during the cruise. What did this mean in terms of working on deck? While the sea-state wasn't as bad as one might imagine based on the strength of the winds, which averaged 23 knots, the combination of extreme temperatures with sea spray and wash made it an ongoing struggle to conduct safe operations.

Crew and science party members work together to clear the fantail of ice.

Sarah Zimmermann

Under these conditions it doesn't take long for ice to build up on the exterior of the ship. This causes two problems: a dangerously slick deck and a potentially top-heavy ship. The sand we brought along to spread on the deck lasted only until the next wave washed it off. During the most difficult periods we set up a safety line to tether those who had to work outside. One memorable example of the foul-weather deck procedure occurred during our first approach to Greenland, on a day that was harsh even by Labrador Sea standards. As we crossed over the continental slope steaming towards shore, we wanted to drop expendable temperature probes to determine where to sample more thoroughly on our way back offshore. Every 6 minutes two watch-standers would radio the bridge, step out onto the fantail into the horizontally driving snow, and hook themselves onto the safety line. Watching this scene, I couldn't help but wonder in amazement that we were actually taking measurements in such conditions. This is what so many people thought would be impossible, yet here we were, in full operation, with the ship steaming at 10 knots.

The second (and less obvious) danger associated with ice buildup was the added load to the ship

Ice chunks and bands populate the region just offshore of the Labrador ice edge. *Knorr* was navigated through such ice fields in order to occupy the most shoreward stations.

Sarah Zimmermann

above the water line, which impacts the stability of the vessel. To deal with this we brought along a supply of wooden mallets, which were used extensively by the crew (with occasional help from the science party). This was a new experience for everyone on board, and it proved to be grueling work. It would take a group of six to eight people the better part of a day to bang all the decks, bulkheads, and bulwarks free of ice. During one such session, we estimated that roughly 15 tons of ice—over 10 inches thick in some places—were cleared from the ship. Not surprisingly, the novelty of this task wore off quickly. To make matters worse, the supply of mallets dwindled due to breakage and loss overboard. However, the crew's resolve never faltered. And their dedication to the success of the experiment was exemplified by the fact that all the ice removal was done within the framework of the science operation: Never once was the timing of our measurements impacted.

Our successful science operations in light of the harsh weather and difficult conditions on deck depended on a combination of factors: well-established procedure, proper equipment, efficient layout of the ship, and a positive attitude. The *Knorr* crew had spent the better part of the last five years participating in the World Ocean Circulation Experiment (WOCE), perfecting their capability for hydrographic operations. This expertise had a huge impact on our experiment. Simply put, when you are that good at something it is less daunting to do it under adverse conditions. This applied to everyone, from the captain and watchstanders on the bridge to winch operators.

A member of the science party had wondered prior to the cruise about the potential for instrument package sensors to freeze on deck before deployment, but this proved not to be a problem because launches were carried out quickly and efficiently. The package was moved out of a heated hanger on a set of rails, and moments later the seaman on watch would jointly maneuver the winch and hydroboom, lowering the package into the water at the proper moment according to the timing of the swell. This, of course, was facilitated by skillful station-keeping on the bridge, crucial under such circumstances. Then there was the can-do attitude that prevailed among both crew and science party. It seemed as if nothing could stop us, not the repeated freezing of blocks or air-tuggers, not the relentless pounding, not the dreariness of day after day with no sun. Maybe some of this was good luck. Without a doubt, much of it was sheer determination.

During our five week tour of the Labrador Sea, we zigzagged repeatedly between the Labrador and

CTD chief Marshall Swartz and watchstander Shelley Ugstad help guide the CTD package off the deck during a Labrador Sea deployment. The staging area, including the two rails used to bring the package out of the hanger, needed to be cleared of ice before virtually every cast.

Greenland coasts. On the Greenland side the biggest worry was icebergs. As the winter season progresses, the West Greenland Current tends to carry icebergs around the tip of Greenland up along the coast. This winter was no exception. During our second visit to Greenland, icebergs cluttered our study area. The threat is not from the large bergs, which are easily detected on radar, but from the smaller pieces known as bergy bits, particularly at night. Factor in strong surface currents, unpredictable snow squalls, and our need to occupy stations only a few kilometers apart, and it added up to a constant challenge for the bridge. At one point we had to change plans because an iceberg was occupying our proposed station!

George Tupper

Sections of the forward bulkhead took on the appearance of an igloo as ice accumulated.

On the Labrador side we were faced with the ice pack, perhaps the most difficult obstacle of the cruise. The goal had been to occupy stations right up to the edge of the pack, for there the atmospheric forcing is largest and very few wintertime measurements existed (none in harsh conditions). We knew that the ship wasn't capable of penetrating the pack ice—but there was never a clearly defined edge. Several miles before the true pack we would encounter chunks (called growlers) and bands of ice, in some cases tens of yards wide. With an ice-strengthened hull we could have cruised right through the bands, but with *Knorr* we had to work our away around them.

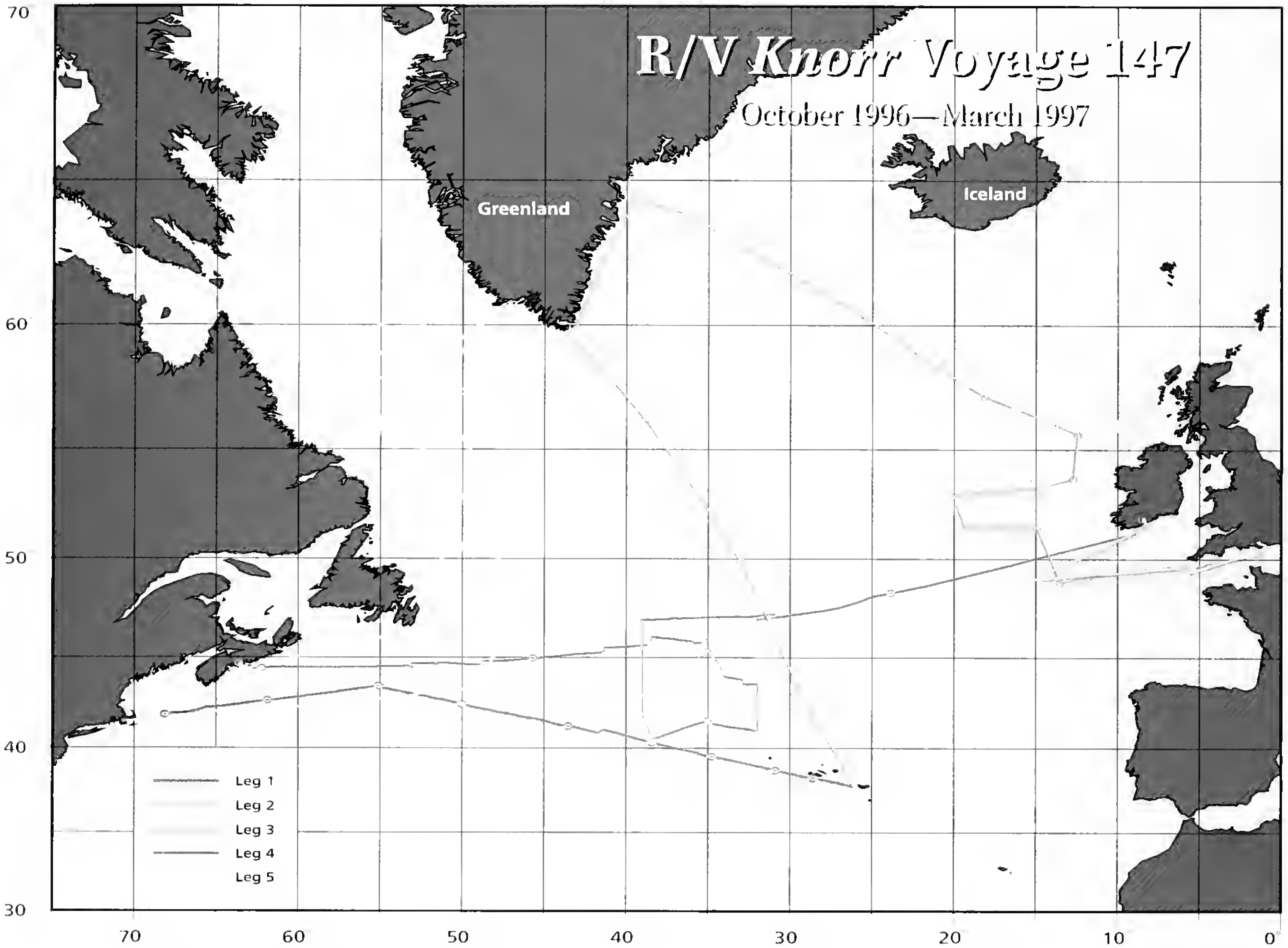
It was here that we encountered the coldest weather of the cruise, down to 2°F. And contrary to common belief, the sea state was not calm in this area. In addition, surface currents were as strong as on the Greenland side. On our third and final approach to the ice edge, near the end of the cruise, the bridge made a special effort to reach the continental shelf, our desired goal. After spending several hours steaming around the ice-bands and growlers, the Captain signaled to us that this was as far as we would go. As we occupied our station—with a sense of urgency—ice chunks and growlers drifted by the ship. Had one of them hit the cable holding our package, it would have cut the wire in an instant. The bridge constantly juggled the tasks of keeping the ship oriented properly with the wind and avoiding the onslaught of ice (some pieces as big as cars). Halfway through our cast the captain radioed down to urge us to speed things up—we didn't need to be told.

Going to sea will never be routine; it is an inherently dangerous endeavor. But after many cruises one can begin to become complacent because of the familiarity of the operation, the deftness of the crew, the sophistication of the instruments used to run the ship. Our winter cruise to the Labrador Sea was an adventure. We didn't know if we would observe deep convection, or even to what extent we'd be operational. It was a striking reminder that oceanographic research is sometimes daring, and certainly carries risks.

As we approached the Labrador ice edge for the first time early in the cruise, it was the middle of a bitter cold night. The satellite maps had given us a prediction of the ice edge location, and as we neared this spot all eyes on the bridge intensely scanned the horizon. Then, in a shockingly brief amount of time, a storm blew up, bringing snow that reduced visibility to zero. On the bridge, feeling the ship heave up and down and knowing that we were just miles from the ice, a range of emotions came over me—complacency was not one of them. But, glancing at Captain Colburn, I could sense his extreme confidence in his ship and crew and their ability to deal with this situation. It was clear at that moment that we had indeed chosen the right vessel for this experiment.

Before the cruise ended on March 20, we would occupy more than twice our planned number of stations and take home a truly unique and fruitful data set. It is ironic that all this was done under the harshest of conditions and amidst significant skepticism. Our experiment will surely advance our understanding of convection in the Labrador Sea. I hope that it also advances the perception of our research fleet's ability to push new horizons. ■

Robert Pickart is an Associate Scientist in WHOI's Physical Oceanography Department. It has been unfairly claimed that he *always* sails in bad weather—a reputation that the Labrador Sea cruise did not help to dispel! As we were editing this issue, Bob, who lives in Falmouth, Massachusetts, with his wife and four children, was aboard *Knorr* again—on a *summertime* cruise for WOCE that began in Halifax, but steamed *south*, toward Trinidad.



Leg I: October 24 to November 1, 1996
Woods Hole to Ponta Delgada, Azores

Test lowerings of conductivity/temperature/depth (CTD) rosette sampler during transit to the Azores to embark scientific party for World Ocean Circulation Experiment/Atlantic Circulation and Climate Experiment (WOCE/ACCE) cruise to follow. WOCE/ACCE is a concentrated two-year international effort directed at understanding the seasonal cycle of the transformation from warm to cold of water in the North Atlantic's eastern subpolar gyre.

Chief Scientist: H. Marshall Swartz, Jr., WHOI

Leg II: November 2 to December 5, 1996
Ponta Delgada, Azores, to Southampton, United Kingdom

Collected hydrographic data along a triangular track in the central and eastern subpolar North Atlantic. Work included CTD/rosette stations, taking underway acoustic Doppler current profiler (ADCP) data, and deployment of numerous subsurface, current-following floats.

Chief Scientist: Michael S. McCartney, WHOI

Leg III: December 22 to December 28, 1996
Southampton, United Kingdom, to Cork, Ireland

Tested instruments, including atmospheric sampling, meteorological, and radar systems, for the International Fronts and Atlantic Storm Tracks Experiment (FASTEX).

Chief Scientist: Ola Persson, National Oceanic and Atmospheric Administration (NOAA)

Leg IV: December 29, 1996, to January 26, 1997
Cork, Ireland, to Halifax, Nova Scotia

Participated with three other vessels and five aircraft in the FASTEX field program designed to advance scientific understanding of the life cycles of eastern oceanic storms and their associated cloud and precipitation systems. Work included underway atmospheric sampling and collection of meteorological, ADCP, and radar measurements.

Chief Scientist: Ola Persson, NOAA

Leg V: February 2 to March 20, 1997
Halifax, Nova Scotia, to Woods Hole

Investigated the formation of deep water via open ocean convection in the Labrador Sea. Scientific activities included CTD/rosette stations; deployment of surface drifters, floats, atmospheric radiosondes, and waverider buoys; and underway meteorological, ADCP, and radar measurements. The primary objectives were to determine where convection occurs, help understand the dynamics involved, and better quantify the role of atmospheric forcing.

Chief Scientist: Robert Pickart, WHOI

Members of the scientific parties on these voyages hailed from Bedford Institute of Oceanography; Institut fur Meereskunde, Kiel; Lamont-Doherty Earth Observatory, Columbia University; National Center for Atmospheric Research; National Oceanic & Atmospheric Administration; Naval Post Graduate School; Princeton University; Scripps Institution of Oceanography, University of California, San Diego; University College, Galway; University of Hawaii; University of Lisbon; University of Miami; University of Southampton; University of Washington; and WHOI.

The freezing wash of large Labrador Sea waves like this one resulted in the ice buildup pictured on previous pages.

A Northern Winter

Preparing R/V Knorr *for the North Atlantic and Labrador Sea*

Captain A.D. Colburn
Master, R/V *Knorr*

As the 1996-1997 ship schedule began to take shape in 1995, we learned that Voyage 147 would take R/V *Knorr* into the North Atlantic from October '96 through March of '97. The various science missions would requre station keeping during CTD casts, deployment of current drifters, and expendable bathythermograph (XBT) launches, as well as weather system analysis designed to put *Knorr* in the path of the harshest weather conditions possible during the winter season. Long before the cruise, we began to tap all available assets that would help us with this challenge.

We were especially fortunate to benefit from the experience of Captain Robertson P. Dinsmore, retired manager of WHOI Marine Operations and also former US Coast Guard weather ship program manager. During a meeting in early October, prior to departure on the first leg of the cruise, Captain Dinsmore detailed his own experiences in the North Atlantic, and provided a wealth of information on ice accretion as well as movement of pack ice and icebergs throughout the changing seasons.

We also contacted the National Ice Center and the Canadian Ice Service by phone and selected a series of ice maps to be sent to the ship on a weekly update schedule. These ranged from charts showing the location of known icebergs to a map delineating the extent of all known ice as well as the edge of "sea ice."

The physical resources we assembled included such basics as hats and gloves, insulated work suits, shovels, and sand. We also began a search for what would become our next best friend—the ice mallet.

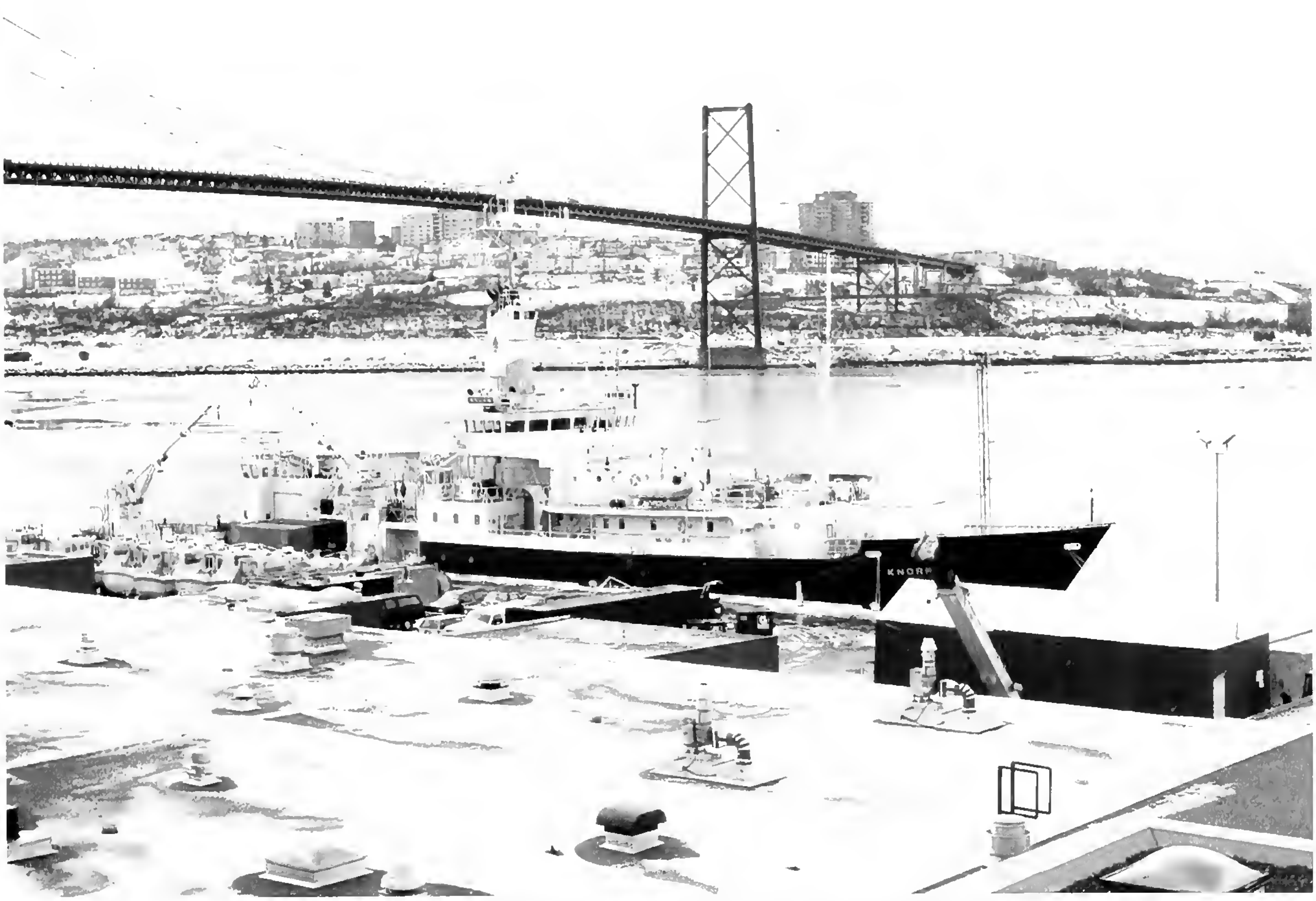
A real danger of working at sea in winter conditions is freezing spray. Given sufficiently cold temperatures, the spray that we might enjoy on a summer day instead becomes a threat to the vessel as it freezes on contact and grows in size and weight with blowing spray from each new crashing wave. In the most severe case, the ship's stability could be affected. Then there are two options: Head for warmer waters, or manually knock the ice off the ship.

While still in Woods Hole we attempted an exchange for all of WHOI's old softball bats. This didn't provide the number needed, so we continued our search in our next ports of call, the Azores islands, and Southampton, England. However, it wasn't until we arrived in Halifax, Nova Scotia, that we found just what we where looking for: The "ice mallet" is of stout wood construction including a head of sycamore (a wood with interlocking grain). We wielded the mallets frequently during the Labrador Sea work to break up ice that had formed on deck so we could shovel it overboard. This was grueling work! For example, on February 18 at 60°N, 52°39'W, a dozen crew members worked morning and afternoon to remove an estimated 30,000 pounds of ice. This is the rough equivalent of having two extra container vans on deck—and it was discouraging to see how fast the ice could build back up.

Mental preparation for the wintertime North Atlantic was also very important. Both crew and scientists would be subjected time and time again to both bitter cold and long work hours. Extra lookouts were needed while in the vicinity of ice. Fortunately, spirits were generally good, and scientists as well as crew turned to when it became necessary to use the shovels and ice mallets to remove ice from the ship.

Safety, always emphasized, became ever so much more important! We focused on the necessity for good communication during every phase of each operation. Are you going out on deck? Wear the proper clothing and flotation. Notify the bridge and science lab. Operation completed? Notify the bridge when all personnel are back inside. Due to the extreme conditions, science operations that had become old hat during our many World Ocean Circulation Experiment (WOCE) cruises received more scrutiny, and some adjustments were made to protect personnel.

The importance of these concerns was driven home one morning in December. *Knorr* received a distress call from a fishing vessel just six miles away. A man had been lost overboard while deploying



Knorr is at pierside in Halifax for final Labrador Sea cruise preparations.

Bob Anderson

Enthusiastic crew members pose for a picture before tackling the ice buildup on *Knorr* in the Labrador Sea. Author and ship captain A.D. Colburn is fourth from left.

George Tupper

gear. We joined the search, and a search and rescue helicopter was sent from Shannon, Ireland. When the helicopter ran low on fuel, *Knorr* was named as "on-scene coordinator" until the search was called off hours later by the Regional Command Center in Dublin. Waters this frigid draw life away in a matter of seconds. The fisherman was never found. I believe most of us felt the loss on board that vessel, and redoubled our efforts to make sure we avoided a similar fate.

Courtesy Karl Bunke, Institut für Meereskunde

Smiles abound on science party faces as *Knorr* Voyage 147, Leg V, nears home port, and the ice and cold temperatures become distant memories.

Our general plan was to work to *Knorr's* strengths. With the hydro boom located midships on the starboard side, minimizing ship's motion, and the starboard side hanger providing some protection for personnel, *Knorr* is particularly well suited for conductivity/temperature/depth (CTD) casts even as weather conditions start to deteriorate. By putting the wind to port, the starboard working deck is afforded a lee, and some CTD stations were completed as wind gusted 40 to 50 knots.

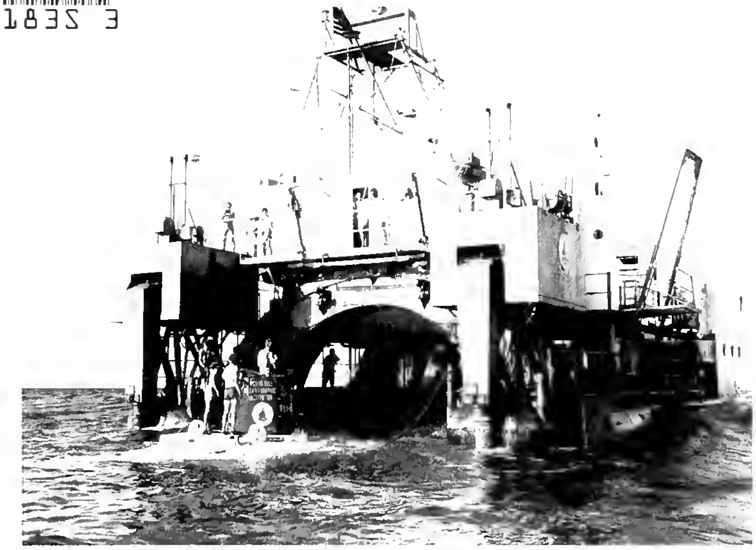
It also was our intention to avoid exposure to the pack ice as much as possible while making every effort to safely achieve science objectives. This proved difficult in the coastal regions of the Labrador sea. The end of every transect meant a close approach to pack ice in an effort to reach shallow water and complete data collection. We specifically planned to approach these regions at first light, do the best we could to work our way closer to the coast during daylight hours, and retreat before night fall.

Daylight hours are reduced that far north during winter. As a comparison, Mike McCartney's November/December cruise was more problematic in that regard than Scripps Scientist Lynne Talley's cruise that retraced the same track in May/June. Transit speeds along the southeast coast of Greenland were reduced for up to 14 hours a day in December due to darkness and concerns about ice in the area. In June, increased daylight allowed transit at full available speed for all but a few hours per day even though ice was still present.

Despite numerous obstacles, *Knorr* Voyage 147 is viewed as an unparalleled success. Preparation played a key role. The dedication and resourcefulness of the people aboard *Knorr* during those cruises put the voyage over the top. Their contributions were key to our success. ■

Arthur D. Colburn III is a second generation *Atlantis* captain. His father, Dick, was the last master of the first *Atlantis* and sailed on many other WHOI vessels during nearly 40 years with the Institution. A.D. graduated from Massachusetts Maritime Academy in 1978, having made part of his senior cruise as a cadet aboard *Knorr*. After working elsewhere in the maritime industry, he returned to WHOI as *Atlantis II* Third Mate in 1983, became the ship's master upon completing his master's license in 1995, and moved to *Knorr* when *Atlantis II* was retired in 1996.

Chain, 1958-1979



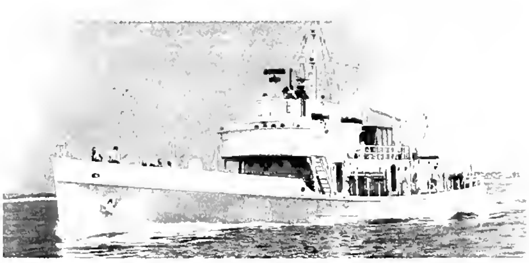
Lulu, 1965-1984

WHOI Pier, 1962

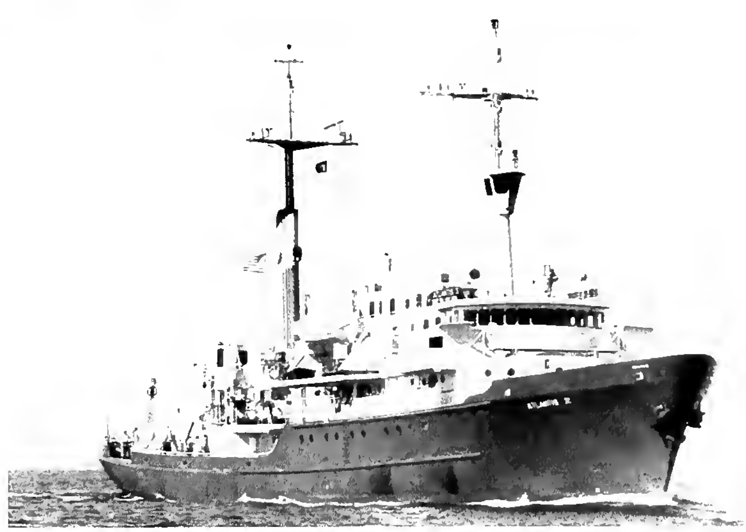
Asterias, 1931-1980

Gosnold, 1962-1973

Mytilus, 1913-1953



Crawford, 1956-1969



Atlantis II, 1963-1996

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