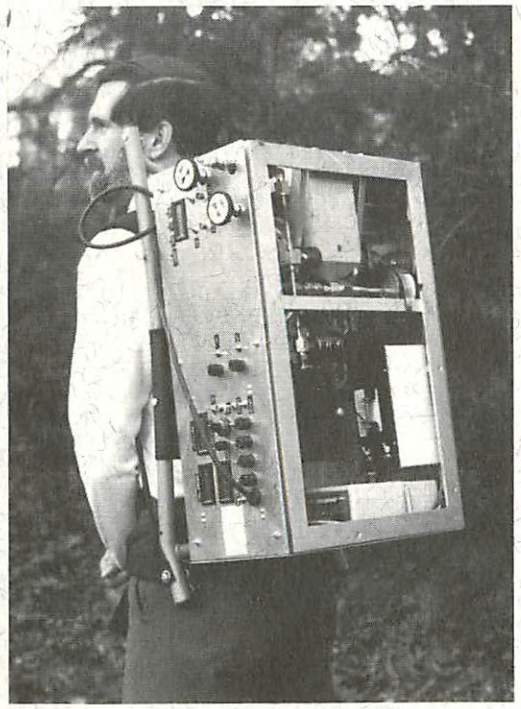

MIT Sea Grant College Program

Program Report

1994-1995

MIT Sea Grant College Program
Program Report 1994-1995

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A MESSAGE FROM THE DIRECTOR

America's coastal waters contain living resources, oil and gas, minerals and enormous recreational possibilities. However, overuse and misuse continue to result in polluted water, declining fish and shellfish populations and degraded coastlines. At the same time, insufficient knowledge about the shape of the sea floor, the dynamics of weather systems and the interplay of human and natural processes along our coastline is limiting both restoration and future use of resources.

In 1966, Congress created the national Sea Grant Program to engage professionals in the nation's universities to help capitalize on, protect and diversify the country's resources and long-term investments in the oceans.

The Sea Grant College Program at the Massachusetts Institute of Technology is one of 29 programs funded by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) to carry out Congress' mandate. MIT Sea Grant works cooperatively with institutions of higher learning throughout Massachusetts, mobilizing resources to solve the Commonwealth's marine-related problems. In addition to the Massachusetts Institute of Technology, partners and participants in MIT Sea Grant-sponsored programs include the various campuses of the University of Massachusetts, Massachusetts Maritime Academy, the Massachusetts Water Resources Authority, Brandeis University, Northeastern University and Harvard University. Collaborative activities with the Massachusetts Office of Coastal Zone Management, the New England Aquarium and the Massachusetts Bays Marine Studies Consortium, as well as across the Sea Grant network, magnify the program's impact.

MIT Sea Grant maintains a close collaboration with the Woods Hole Oceanographic Institution Sea Grant program. The two Massachusetts programs coordinate activities to prevent duplication and to best employ Sea Grant's resources.

While MIT supplements NOAA's financing, other government, industry, and research groups also contribute to the program. With funding from MIT Sea Grant, engineers and scientists from across disciplines and institutions are taking Sea Grant's mission into new areas, such as marine biotechnology and autonomous underwater vehicles. This report highlights some specific accomplishments in these and other areas.

continued on page 2

A MESSAGE FROM THE DIRECTOR *continued*

Although Sea Grant emphasizes basic and applied research, education and advisory services complete the MIT program. Education at MIT Sea Grant involves undergraduate as well as graduate students in marine research, providing them with training and experience for future careers. In addition, the program reaches out to elementary, junior high and high schools, as well as to the public. Finally, Advisory Services at Sea Grant help people in marine industries, consumers and the general public to appreciate and profit from the ocean's assets. The three elements of Sea Grant — Research, Education and Advisory Services — are interrelated and interdependent. Together they form a well-rounded management plan for the nation's marine resources.

Sea Grant will continue building on its strengths while following new opportunities for growth. The program will also continue cultivating close relationships with agencies at the state level and cooperating with these agencies in the management of marine resources.

In overall management, Sea Grant looks to future markets for its products and services. In coming years the program will continue to pursue industrial support. The program funds new projects, and, as the results become more applicable to industry needs, industrial beneficiaries are invited to jointly finance these efforts. Because of the ample success of past jointly funded projects, Sea Grant will be emphasizing the concept even more in the future.

Chryssostomos Chryssostomidis, Director
MIT Sea Grant College Program

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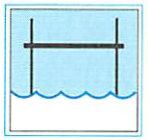

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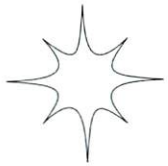

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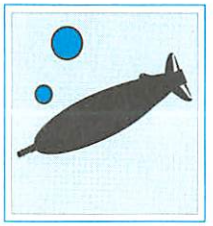


AUTONOMOUS MOBILE INSTRUMENTATION PLATFORMS

The primary objective of this research area is to develop unmanned autonomous underwater vehicle (AUV) technologies for efficient and effective means of gathering data and performing surveys in difficult underwater environments. Such environments include the deep ocean, the ice-covered Arctic and Antarctic, contaminated water bodies, sewers, and interior spaces of ships and power plants.

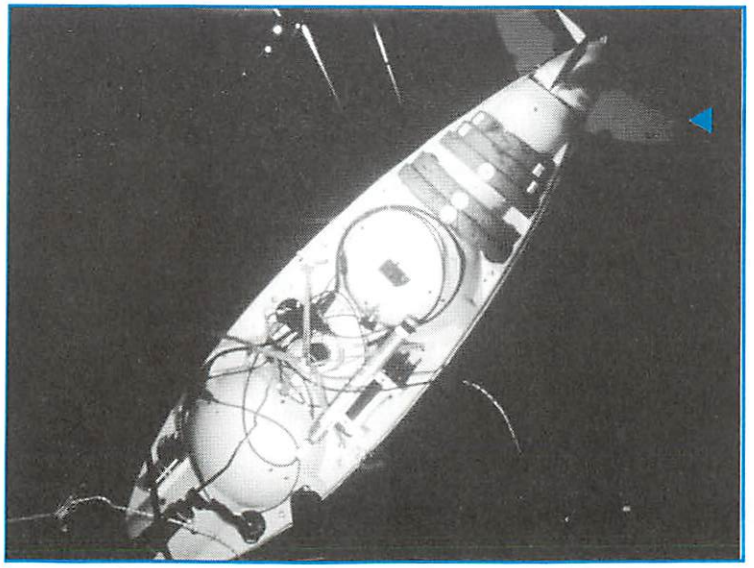
Initial emphasis has been on the design and construction of functioning testbed vehicles with complementary sensors capable of in situ *measurement of such parameters as temperature, conductivity, dissolved oxygen, pH, turbidity and trace metals. The research also focuses on developing and adapting the most recent advances in control theory, intelligent control, navigation and sensor processing strategies to underwater measurement systems.*

Areas of current interest include reliable localization approaches for navigation in multi-path ocean environments, compact vehicle state sensor systems and sensor strategies for use in small AUVs, and adaptation of advanced signal processing algorithms to the limited AUV computational environment.

Sensor-Based Control for Feature-Relative Navigation

Michael S. Triantafyllou
Department of Ocean Engineering, MIT
James G. Bellingham, John J. Leonard
MIT Sea Grant College Program

Many applications of AUVs require operations in close proximity to man-made objects or natural bottom topography. Experimental testing with the AUV Odyssey, equipped with a high-frequency mechanically-scanned sonar system and a low-resolution obstacle detection array, is expected to lead to improved navigation and control in AUV activities ranging from bottom sampling to rescue missions. The objectives of this project are to develop a generic capability to detect and track objects in the water column and on the bottom with sonar range sensing, and to use this capability to achieve feature-relative trajectory execution and obstacle avoidance with AUVs.



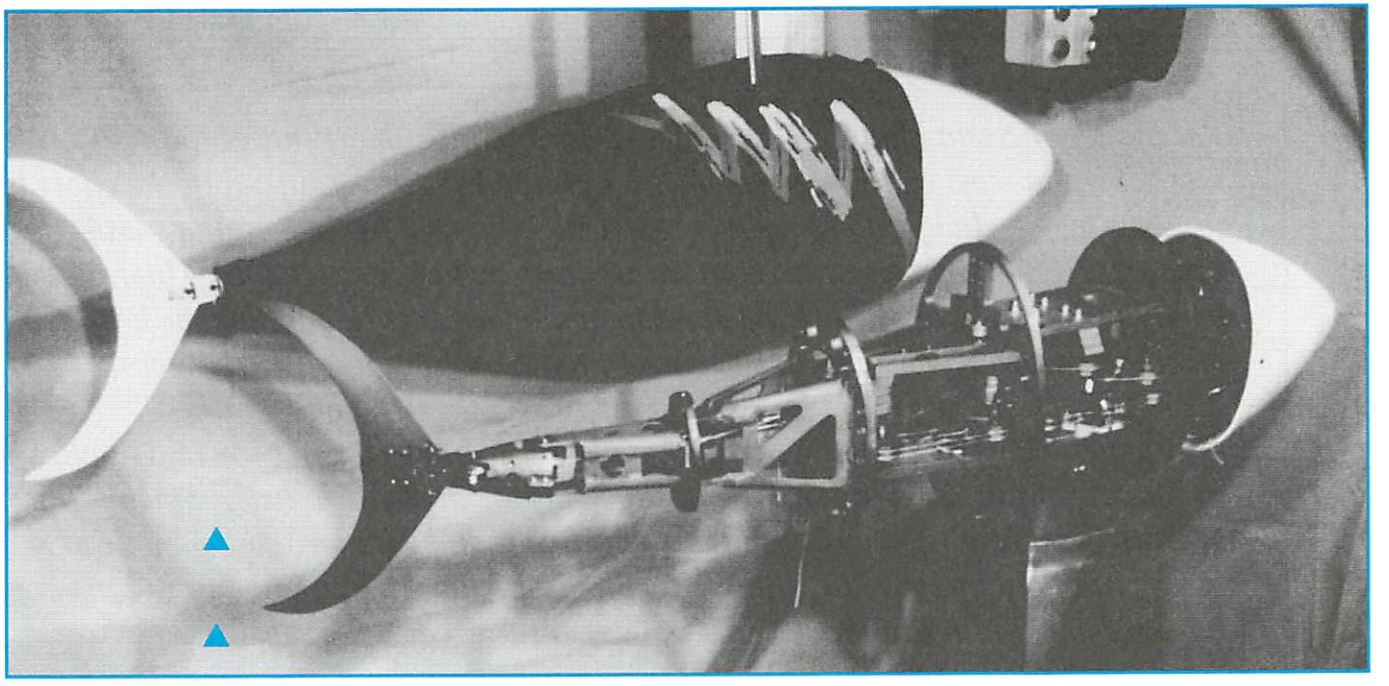
Rapid Response to Episodic Events in the Ocean

Chryssostomos Chryssostomidis, James G. Bellingham, Thomas R. Consi, James W. Bales
MIT Sea Grant College Program

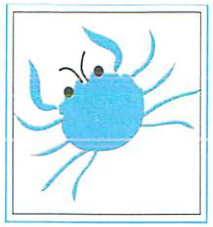
The objective of this study is to ensure that the new AUV technologies become a useful tool in the repertoire of oceanographers around the world by showing that a small, inexpensive, long range AUV such as *Odyssey* is sufficient to release an oceanographic vessel from the requirement of attending a deep-towed sled. This frees a support vessel, which now can be smaller, to carry out complementary data collection strategies, such as physical sampling of the water column. With this demonstration of an untethered survey vehicle capability, and the increase in reliability which comes from operational experience, the arena of applications will expand to shallow water. The capabilities to be demonstrated are directly relevant to a wide range of scientific and industrial applications in the deep ocean.

Rapid Maneuvering of Autonomous Underwater Vehicles through Vorticity Control

Michael S. Triantafyllou
Department of Ocean Engineering, MIT



The objectives of this research are to study the mechanisms of vorticity control that allow very fast starting and rapid maneuvering in fish, and to explore ways for technological developments leading to their use in an AUV. This will allow, for example, vehicle operation near complex boundaries and within the surf zone. By establishing ways to imitate the outstanding maneuvering performance of fish, it is anticipated that new marine vehicles will be developed with much faster transient performance than presently feasible. Also, AUVs could be developed capable of operating in environments which are hostile or change very rapidly. For example, operation near a high-temperature plume requires the capability for very fast motion, as the temperature gradients are very steep. Similarly, operation in the surf zone or in highly sheared flows will become feasible only if vehicles can accelerate very rapidly to respond to fast varying flows.



MARINE BIOTECHNOLOGY

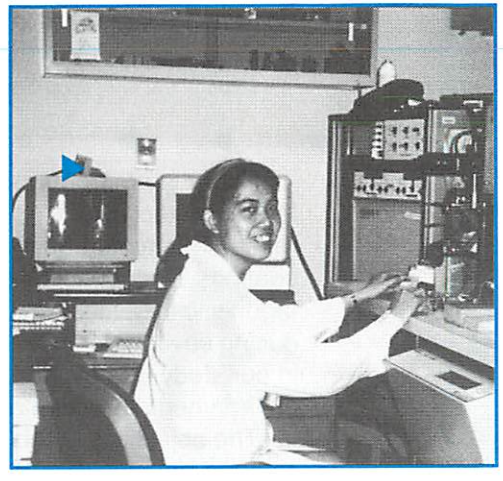
Recent advances in biotechnology have created many opportunities for designing more efficient, cost effective aquaculture techniques, which will aid in the effort to produce high-value food. Opportunities to develop new medicines and industrial products from living marine resources are now challenging us. Other biotechnology techniques may be applied to the development of sensors to monitor the health of marine and coastal systems or to control productivity of marine resources.

Our general objectives are to 1) develop marine biomaterials for use and application in industrial processes and in sensing systems for the marine environment and sensors for control systems in industrial settings and 2) using both genetic and biochemical engineering to improve productivity and utilization of living marine resources, including improvements in aquaculture.

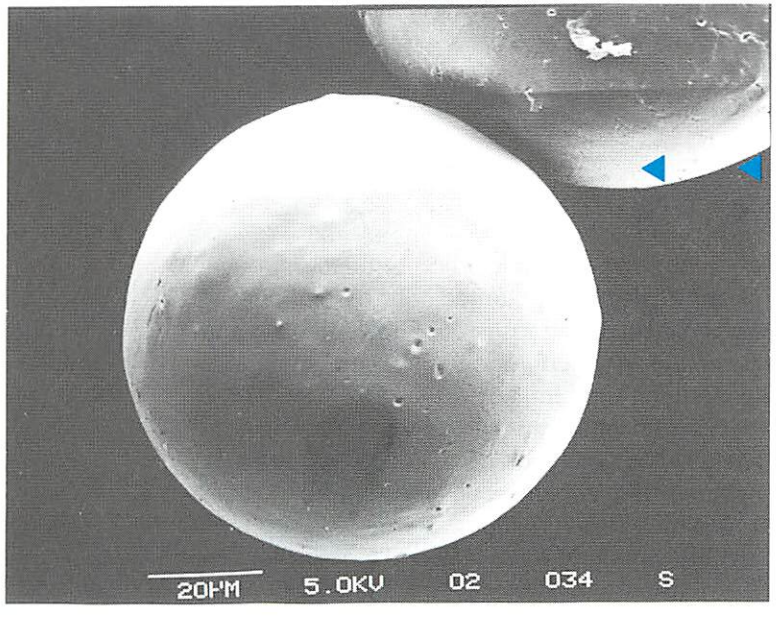
Specific areas of interest, which will provide the focus of activity in this theme area during the next two to three years are: to study and explore biotechnological applications of marine biopolymers — including controlled-release drugs — through medical applications and food additives, and to develop sensor and cell transplantation systems.

Planktonic Size Spectra as Indicators of Trophic Status of Aquatic Ecosystems: Automated Analysis Using Flow Cytometry

Sallie W. Chisholm
Department of Civil and Environmental Engineering, MIT



Although planktonic size spectra represent a snapshot of the biotic health, trophic status and fish production potential of aquatic ecosystems, no simple or automated ways exist to measure them. The analysis generated in this research will eventually be applied to the Massachusetts Bay/Boston Harbor ecosystem to analyze the effects of the 1995 diversion of existing sewage outlets from the harbor to the bay. The objectives of this research are to modify a flow cytometer in order to analyze both large and small plankton particles on the same sample simultaneously and to develop analysis protocols to allow detection of and differentiation among organisms and detritus.



Development of New Methods for Efficient Vaccination of Farmed Fish: Controlled and Sustained Delivery of Vaccines

Robert S. Langer, Yonathan Zohar
Department of Chemical Engineering, MIT

Disease is a major problem in intensive aquaculture, resulting in substantial mortalities and significant economic losses. Vaccination is the only logical approach to overcome disease. However, for optimal vaccination, many presently available fish vaccines have to be repeatedly administered through individual injection, which is very labor intensive and stressful to the fish. This research is to develop a controlled-release formulation for fish vaccines that will be effective when administered by different routes and require only one application to induce intensive and long-term protection against disease.

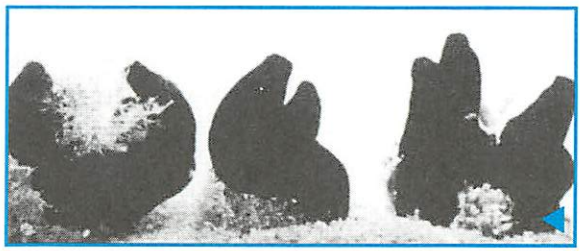
As a major objective, this research is to develop novel polymer-based, controlled-release delivery systems for fish vaccines. Two vaccines will be incorporated into polymer-based, biodegradable delivery systems administered to fish by different routes.

New Approaches to Control of Zebra Mussels by Targeted Microbial Products

Ralph Mitchell
Department of Applied Sciences, Harvard University

There is an urgent need to develop environmentally acceptable coatings to protect material surfaces against infestation by zebra mussels. Our research is aimed at providing information for the development of these coatings. Data describing the mechanism of action of microorganisms antagonistic to settlement of the mussels or microorganisms capable of producing environmentally acceptable antagonistic chemicals will be obtained in our study. We expect that this information will be used to develop novel environmentally acceptable coatings to protect against zebra mussels.

The objectives of this research are to isolate opportunistic microorganisms as potential biological control agents for zebra mussels, to isolate bacterial products for control and to test these chemicals in coatings.

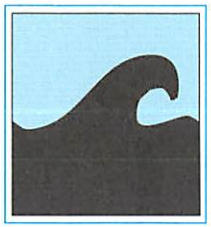


Relationship between Vanadium and Tunichrome in Sea Squirts

William E. Robinson
Department of Environmental Science
University of Massachusetts, Boston
Kenneth Kustin
Department of Chemistry, Brandeis University

The present lack of understanding of the *in vivo* function of tunichrome has inhibited research on the use of this molecule in biomedical and bioadhesive fields. This proposed research will fit critical data gaps in our knowledge of vanadium-tunichrome interactions *in vivo* and will encourage the subsequent investigation of tunichrome as a valuable natural product.

The objectives of this research are to characterize the vanadium environment within the various vacuoulated blood cell types in tunicates; to determine whether tunichrome is initially sythesized in a blood cell type that is known to contain vanadium; and to determine whether vanadium and tunichrome functions are related to self-suturing of the wounded tunic (a process related to the broader context of bioadhesion).



OCEAN AND COASTAL PROCESSES

The extensive use of coastal waters for various activities, including shipping, fishing, recreation and waste disposal, creates a pressing need for local, as well as regional, approaches to managing these competing uses. To develop such approaches, researchers need methods for estimating the impacts of various human actions on the coastal zone. Key physical, chemical or biological processes operating in coastal marine environments must be understood, including the effects of bottom morphology on coastal circulation, association of chemicals with particles or chelators, and rates of biotransformations of pollutants. Field measurements are encouraged in addition to laboratory studies, and new methods or instrumentation for studying coastal processes are welcome if the applications for the resulting data is clear.

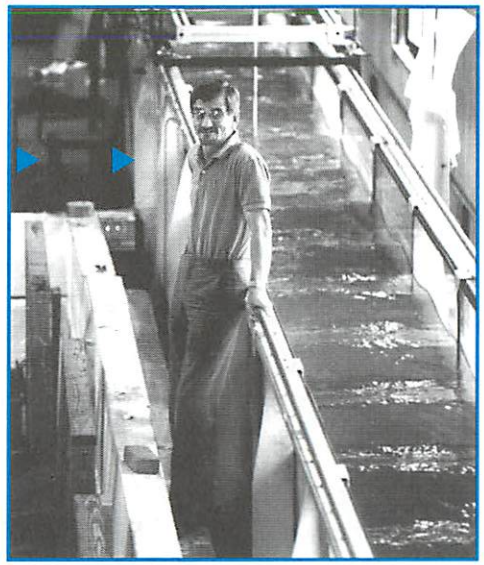
MIT Sea Grant's study area is the Boston Harbor/Massachusetts Bay/Gulf of Maine region, to facilitate the acquisition of information useful to other New England coastal programs.

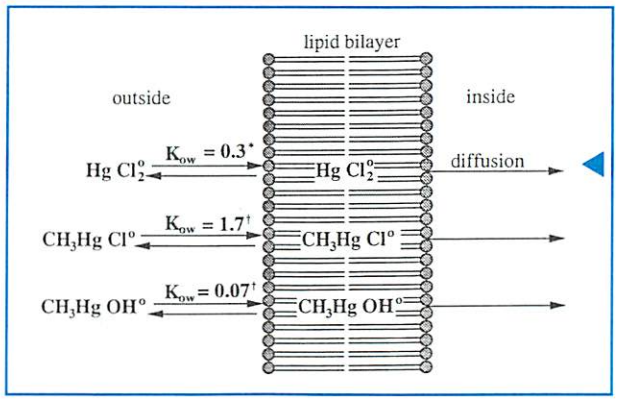
In addition to coastal processes, the program is interested in research that addresses continental shelf and deep-ocean processes. Efforts involving these open-ocean processes are of interest only if these processes influence coastal environmental behavior.

Effects of Seawalls on Coastal Sediment Transport

Ole S. Madsen, Eng S. Chan
Department of Civil and Environmental Engineering, MIT

This research project is aimed at clarifying whether or not seawalls lead to increased coastal erosion. The results obtained from the study will aid coastal engineers in assessing coastal processes as well as coastal regulatory agencies in formulating sound coastal protection regulations. Its objectives are to design, construct and develop an automated beach profiling system to analyze beach profile changes obtained in a newly constructed wave basin. Erosion patterns will be compared for laboratory experiments in which periodic and spectral waves of both normally and oblique incidence impinge on a beach with and without a seawall.



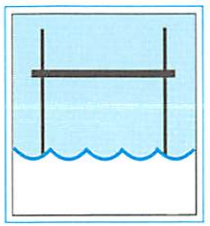


The Cycling of Silver and Mercury in Boston Harbor and Massachusetts Bay

Francois M.M. Morel
Department of Civil and Environmental Engineering, MIT

Both silver and mercury are toxic to aquatic biota and to humans at very low levels, yet we have absolutely no information regarding their occurrence in Boston Harbor and Massachusetts Bay. Concentrations of mercury in fish and shellfish sometimes approach or exceed the FDA standard (1 ppm), and it is thus important to understand how such concentrations are (or are not) controlled by local pollution. The investigators believe that silver will provide a convenient tracer for the Massachusetts Water Resources Authority (MWRA) effluent, allowing the MWRA to quantify the concentration and distribution of metal waste inputs in the bay before and after completion of the new outfall. Such a tracer will also prove invaluable as a complement to the MWRA's program of phytoplankton measurements in the area.

The principle objectives of this project are to quantify the present extent of pollution by silver and mercury in Boston Harbor/Massachusetts Bay, and to elucidate the processes responsible for the transformations of these elements and their transfers between aquatic and biotic compartments.



OCEAN ENGINEERING

All the processes that influence the design, construction and safe operation of ocean systems are in the domain of ocean engineering. Thus, wave forces and the amplitude spectrum of waves are of interest, as are their effects on ships, submarines and/or oil drilling platforms.

Development of methodologies and instrumentation for the measurement of physical, chemical and biological properties of the three-dimensional ocean are of interest. The effort may include intelligent instruments and sensors, autonomous vehicles and acoustic mapping methods, as well as large-scale coordinated measurements to assist data assimilation.

Hydrodynamic research on both the relatively small scale (vehicle propulsion) to the very large scale (ocean circulation and vorticity) has been supported. Because energy efficiency is so important in small ocean vehicles, the design and testing of energy efficient propulsion systems is also important.

Vibration Suppression and Drag Coefficient Reduction for Marine Cables

J. Kim Vandiver
Department of Ocean Engineering, MIT

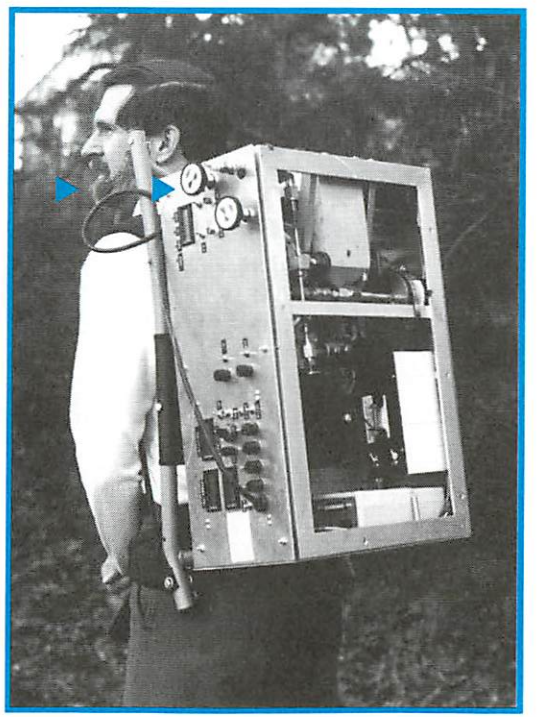
The objective of this research is to reduce to practice an invention that suppresses flow-induced vibration of oceanographic moorings, vehicle tethers and cables. Reduced vibration translates into longer fatigue life and significant reductions in mean drag coefficient. Although the invention is based on sound and accepted principles of vibration theory, it has yet to be demonstrated in the laboratory or tested at sea. The project will also provide opportunities for undergraduate students at MIT to engage in real engineering problem solving.

Membrane Inlet Mass Spectrometry: A Universal Chemical Sensor for *in-situ* and Autonomous Underwater Vehicle Applications

Herold F. Hemond
Department of Civil and Environmental Engineering, MIT

The development of this concept will provide a highly versatile chemical sensor for use aboard a small AUV. The principle advantages of the membrane inlet mass spectrometer are its universal response to volatile chemicals, its ability to operate in a continuous flow mode, its suitability for control by computer, and its adaptability to low-power operation.

The objectives of this proposed work are to complete our engineering/design model that predicts flow rates of individual components of a multi-component vapor in a membrane inlet system, thereby replacing the present "cut and try" approach by a rational design process; to evaluate alternative spectrum separation algorithms for the membrane-inlet mass spectrometer; and to design a membrane-inlet mass spectrometer within the constraints of a small AUV.

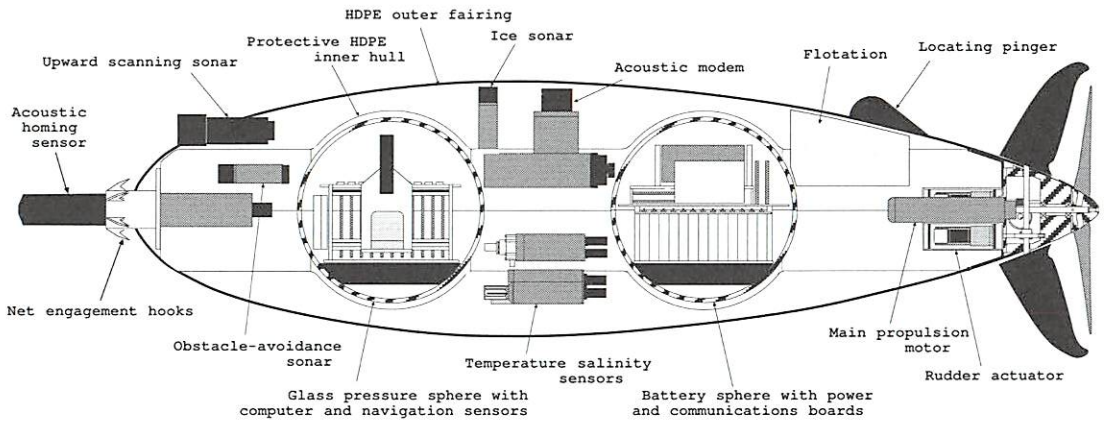


MIT Sea Grant Autonomous Underwater Vehicles Laboratory

Dedicated to the development of fully autonomous underwater vehicles (AUVs), the MIT Sea Grant Autonomous Underwater Vehicles Laboratory is the nation's leading developer of small, inexpensive, high-performance, unmanned underwater robots. Because our vehicles are capable of accomplishing missions without tethers, cables or remote control, they will have diverse applications in oceanography, environmental monitoring and underwater resource studies. In addition, the laboratory is a stimulating training ground for graduate and undergraduate students and visiting engineers and scientists from around the world.

ODYSSEY II - ARCTIC CONFIGURATION

AN UNDERWATER ROBOT FOR EXPLORING THE DEEP OCEAN



CHARACTERISTICS

	Arctic Configuration	Ridge Mapping Configuration
Displacement	140 kg (309 lbs)	160 kg (353 lbs)
Thruster	1 electric (brushless); 6 kg (13 lbs) max. thrust	1 electric (brushless); 6 kg (13 lbs) max. thrust
Depth rating	50 m (55 yds)	3,000 m (1.9 miles)
Sensors	CTD, mechanically scanned sonar	CTD, still-electronic imaging
Navigation	ultra-short-baseline, long-baseline	long-baseline
Onboard computer	68030-based computer	68030-based computer

Endurance of 6 to 12 hours using 2 kW-hrs of silver-zinc batteries at 0°C is typical with the vehicle configurations above. A 40-hour endurance at 5 km/hr can be realized if battery capacity is maximized at 50 kg.

Current Research Activities of the Underwater Vehicles Laboratory

Intelligent Control: Intelligent control of AUVs is a research area rich with challenges and potential rewards. Our research has focused on software approaches designed for fully autonomous underwater vehicles (AUVs) engaged in complex survey missions in unmapped environments. Our initial work focused on a fully autonomous survey vehicle which, once launched, remains out of communication until retrieved. We have developed new control architectures to take advantage of intermittent low-bandwidth communication to achieve expanded capabilities and high reliability. Tools that would allow non-researchers to use the vehicle are currently in development.

Acoustic Navigation in Complex Environments: Navigation continues to be a challenging problem for vehicles in the underwater environment. The most common method is navigation within a net of acoustic beacons. The accuracy of acoustic navigation is greatly degraded by multipath, a phenomena that occurs in acoustically complex environments. We have conducted field tests in the Arctic with a novel acoustic navigation system that will uniquely exploit mulitpath effects to adaptively estimate environmental conditions and derive improved estimates of vehicle position. Research is underway to explore how this type of system could be extended to work in shallow waters.

Non-Traditional Navigation: For potential large area-of-coverage missions we are developing navigation algorithms based on the interrogation of maps of geophysical properties. Typical candidate quantities are the intensities of the earth's magnetic and gravitational fields and sonar altimetry measurements of bottom topography. With this approach, the AUV makes measurements of simple geophysical properties using vehicle-mounted sensors and determines its location by matching these observed properties with electronic maps of these physical quantities.

Acoustic Communication: Establishing a bi-directional communication channel between an AUV and an operator provides a means by which mission level decisions, normally made by the mission planning software on the vehicle, can be made by a human operator. A commercial acoustic modem is undergoing field tests in Odyssey II. This capability opens many new avenues of research in supervisory control.

Three-Dimensional Scene Reconstruction: For now, finding and identifying rigid objects in the deep ocean is an expensive, labor-intensive process. The laboratory is developing a geometric approach to underwater scene reconstruction using sonar range sensing. The goal is to recover explicit geometric surface descriptions for synthetic objects by fusing the geometric constraints of multiple sonar returns obtained by a moving AUV.

Autonomous Ocean Sampling Networks: In the long term, the most exciting operational scheme is afforded by the Autonomous Ocean Sampling Network (AOSN) concept, in which moored buoys supply power and communication nodes to provide a long-term, multiple vehicle presence in the ocean. The objective is to provide an economically feasible capability for repeated synoptic characterization of large scale oceanographic phenomenas such as meso-scale eddies or ocean fronts. The key to such a system is a small, low-cost autonomous vehicle that can be operated reliably over extended unattended deployments at sea. Present work is focusing on deploying a prototype AOSN in Massachusetts Bay.

Odyssey II: Scientific Missions

Arctic: In the spring of 1994, Odyssey II was deployed from an ice-camp in the Beaufort Sea in support of a mission to understand Arctic sea-ice mechanics. All operations were carried out in a 15' x 15' tent, enclosing a hydrohole through five feet of ice. While at the ice camp, Odyssey II performed a series of "out-and-back" missions, demonstrating its ability to home into the recovery net. Acoustic communication was demonstrated from the AUV to receivers as far as 7 km away. Tests were cut short after nine days when the ice flow began to break up, forcing the evacuation of the camp. These tests set the groundwork for providing a unique capability for responding to transient events in the ice.

Antarctic: The history of seafloor spreading at ridges can be deduced from observations of the magnetization of the seafloor. The seafloor under the permanent Antarctic ice has not been mapped, and its spreading history is not known. This work is intended to confirm or preclude the existence of a hypothesized, undetected tectonic plate and, if it exists, to measure the spreading history via magnetization measurements. This will require traveling up to 100 km under the permanent Antarctic ice. AUVs represent the only safe, economical method to obtain these unique results.

Juan de Fuca: Episodic volcanic events on spreading ridges, such as the Juan de Fuca Ridge, are important in terms of the geophysics and geology of the seafloor, the biological communities of the seafloor, hydrothermal vents and the lower water column, and the heat and chemical balance of the ocean. There is considerable interest in the scientific community to study the aftermath of such events, and, if at all possible, to study an event while in progress. Small, long-range AUVs, deployed from a vessel of opportunity, are uniquely suited to meet this need to rapidly respond to a remotely detected episodic event.

East Pacific Rise: A very similar use of Odyssey II to that described for Juan de Fuca will occur on the East Pacific Rise, which is also an active spreading ridge. The scientific interest is the same, although in this case the observations are focused on observing the post-eruption recovery of a region from an event that occurred several years ago. However, the operational rationale is focused on employing the AUV as a compliment to an existing oceanographic asset — the manned Alvin vehicle. This type of operation has two important benefits. First, Odyssey II can make use of the night period of the surface support vessel, the Atlantis II, which is often otherwise unused. Second, Odyssey II can cruise faster than Alvin, and therefore can be used for larger ranging excursions on the sea floor, providing survey results for better planning of Alvin dives.

Current Education Activities

MIT is first and foremost an educational institution. We have found that the level of complexity and the small size of our vehicles make them ideal research projects for both graduate and undergraduate education. Many subsystems have been designed and built for the test-bed vehicle by undergraduates and graduate students. The students are forced from the beginning to consider the integration of their subsystems into the vehicle as a whole. Because the subsystems are interactive, the students learn the teamwork needed to ensure compatibility between the various parts of the vehicle and the need to define and maintain standards of design, construction and maintenance. Over the last six years, 12 graduate and over 50 undergraduate students have worked in the program, leading to two Engineer theses, six M.S. theses and three B.S. theses.

MIT

AUV LAB

Personnel

Chryssostomos Chryssostomidis, MIT Sea Grant College Program Director; Henrik Schmidt, MIT Sea Grant College Program Associate Director for Research; James G. Bellingham, MIT Sea Grant Underwater Vehicles Laboratory Manager; Thomas R. Consi, MIT Sea Grant Underwater Vehicles Laboratory Research Engineer; Clifford A. Goudey, MIT Sea Grant Fisheries Engineer; James W. Bales, Postdoctoral Research Fellow; John J. Leonard, Postdoctoral Research Fellow; Donald K. Atwood, Postdoctoral Research Fellow; Jérôme Vaganay, Postdoctoral Research Fellow; Brad A. Moran, Postdoctoral Research Fellow; Seamus T. Tuohy, Postdoctoral Research Fellow; Thomas Altshuler, Postdoctoral Research Fellow

Vehicles and Instrumentation

AUV Sea Squirt

35 kg, 1 m long autonomous underwater vehicle; test-bed for software and instrumentation

AUV Odyssey II

2.15 m long, 0.59 m diameter autonomous underwater vehicle capable of operation at 6,000 m (3.7 miles)

R/V Penelope

22-foot research support vessel, capable of carrying underwater vehicles and a crew of six

Other equipment and facilities: long-baseline acoustic array and calibration equipment, experimental ultra-short baseline system, electronics test and fabrication facility, fairing fabrication facility, vehicle software simulation facility, experimental autonomous surface craft, field site at Charlestown Navy Yard

Current Sponsors and Industrial Supporters

MIT Sea Grant College Program; MIT Office of the Provost; MIT Chair of Teaching Innovation; MIT Department of Ocean Engineering; Henry L. and Grace Doherty Charitable Foundation, Inc.; Office of Naval Research Arctic Sciences Program, Manufacturing Science Program; National Science Foundation, Ocean Engineering Program, Computer and Information Science and Engineering Program; Analog Devices Inc.; Benthos, Inc.; Intel Corp.; Motorola, Inc., Semiconductor Product Section

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Ocean Engineering Test Tank Facility, MIT
Underwater Acoustics Laboratory, MIT
Biomedical Engineering Laboratory, MIT
Ralph M. Parsons Laboratory, MIT
Edgerton Center, MIT
Chemosensory Biology Laboratory, Boston University Marine Program
Woods Hole Oceanographic Institution (WHOI)
French Institute for Research and Sea Exploitation (IFREMER)
Underwater Research Laboratory, Simon Fraser University, B.C., Canada
Florida Atlantic University
National Oceanographic and Atmospheric Administration
Pacific Marine Environmental Laboratory
Naval Undersea Warfare Center
Naval Research and Development Center

FOCUSED RESEARCH

MIT Sea Grant initiated its Focused Research Program to foster close relationships among industry, government and academia. Such relationships allow faculty to contribute directly to industrial development and to meet evolving societal needs, in turn strengthening educational programs by keeping academic researchers attuned to those needs. The real contribution of such relationships, however, is not just the solution of specific problems and the improvement of education, but the familiarization of faculty with industrial and societal problems. This knowledge allows researchers to steer their long-term research to benefit industry and government agencies.

Projects are planned to have a lifetime of about six years and are designed to integrate multi-agency sponsorship under Sea Grant leadership. While under the direct management of the program director, each project has a project director, and an active advisory panel helps oversee the project. For example, the coastal advisory panel, assembled for the Coastal Water Quality project, includes members from the Urban Harbor Institute of the University of Massachusetts at Boston, the U.S. Environmental Protection Agency, the Army Corps of Engineers and the Massachusetts Coastal Zone Management office, as well as MIT and MIT Sea Grant.

In addition, the MIT Sea Grant Program's investment is matched by equal (or greater) industry funding. Preliminary funding of most initial studies comes from the MIT Sea Grant Core Research Program, with support from other government funding sources, but initial funding may be enhanced several fold.

Focused Research I: Coastal Water Quality

E.E. Adams, F.M.M. Morel
Department of Civil and Environmental Engineering, MIT

The fate of contaminated sediments and the response of algae to nutrients and trace metals are the two most important aspects of coastal pollution identified by the scientific advisory group assembled for this Focused Research project. In addition to being nearby, Boston Harbor/Massachusetts Bay is heavily polluted, providing an excellent opportunity for study. By focusing on a collection of related projects, we improve the likelihood that our project will provide sufficient understanding to affect coastal zone management decisions.

The specific objectives of this research area are: 1) to measure rates of initial particle deposition; 2) to measure sediment resistance to resuspension; 3) to measure and model sediment-water exchange of toxics; 4) to quantify rates of contaminated sediment transport between harbor and bay; 5) to determine if phytochelatins can be used to measure algal stress in response to trace metals; and 6) to explore innovative treatment technologies to remove nutrients and prevent eutrophication.

Focused Research II: Autonomous Underwater Vehicles: Basic Technologies

H. Schmidt
Department of Ocean Engineering, MIT
J. Bellingham, T. Consi
MIT Sea Grant College Program

AUVs are the next logical step in the evolutionary ladder of underwater vehicles. For many applications, maximum efficiency can be achieved by having unmanned untethered vehicles with at least partial, and preferably total, autonomous capability. From our experiences with Odyssey and Sea Squirt, we estimate that it is possible to produce full ocean rated AUVs with ranges in excess of 100 km for under $70,000 for each base vehicle, without missions sensors. Thus, autonomous underwater vehicles offer the potential for vastly increasing human presence in the ocean in an economical manner.

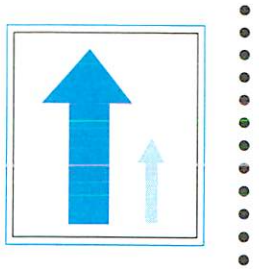
The specific objectives of this research area are to form a multi-disciplinary center for the development of AUV technology; to develop a general software architecture for the intelligent control of AUVs; and to design and build a series of intelligent underwater robots with increasingly sophisticated capabilities, including: exploring their environment, operating without human supervision, locating themselves and communicating their findings to their human masters.

Focused Research III — Autonomous Underwater Vehicles: Scientific and Industrial Applications

H. Schmidt
Department of Ocean Engineering, MIT
J. Bellingham, T. Consi, J. Bales
MIT Sea Grant College Program

AUVs can vastly increase human presence in the ocean in an economical manner. Realizing this potential requires demonstrating the utility and economy of AUVs in specific applications. It also requires including potential users in science and industry in all stages of AUV development and technology transfer, giving them first-hand experience with the new technology and allowing them to interact personally with the developers of AUVs. Our AUV operations will address a series of scientific and industrial applications, initially in deep-water. With the increase in reliability that comes from operational experience, we expect the arena of applications to expand to shallow water.

The specific objectives of this research area are to begin the process of transferring newly developed AUV technologies into the field for scientific and industrial applications, and to demonstrate that AUVs can provide economic access to the ocean by employing an existing AUV to carry out well-defined missions. The first mission is the rapid response to episodic events on the Juan de Fuca Ridge. In addition, the research is to show that a small, inexpensive, long range AUV such as MIT's Odyssey can operate without an oceanographic vessel in constant attendance, in contrast to the situation with a deep-towed sled. Thus the support vessel can be smaller and can be free to carry out complementary operations.



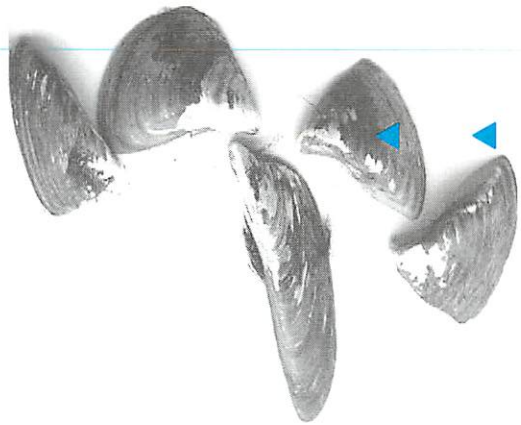
ADVISORY SERVICES

The MIT Sea Grant Advisory Services are specifically charged with transferring the knowledge derived from Sea Grant research to the public, to other researchers, to industry and to government agencies — audiences defined broadly as all those interested in marine and coastal issues. MIT Sea Grant's advisory program reflects MIT's traditionally strong ties to local, state and national government agencies, as well as to industry and public corporations. As such, the advisory service serves a broad range of constituents — reaching into varied communities to solve marine problems, bringing them to the attention of Massachusetts researchers as appropriate. Thus, advisory staff members bring the users in need of information to its sources and into the research process. Advisory staff members also make certain that the results of Sea Grant's projects are widely broadcast throughout the marine community. In these activities MIT Sea Grant cooperates with the Sea Grant Program at Woods Hole Oceanographic Institution — formally by membership on one another's advisory boards, and informally by pursuing common overlapping interests.

Projects

Marine Industry Collegium
(617) 253-4434
Richard Morris, Manager

The Collegium introduces member businesses and agencies to marine research with profitable prospects and provides a forum for exchange among businesses, encouraging members to identify research needs and participate in university-based marine research. The manager also interacts with environmental and coastal organizations in Massachusetts to help Sea Grant focus research and service to most benefit the Commonwealth.

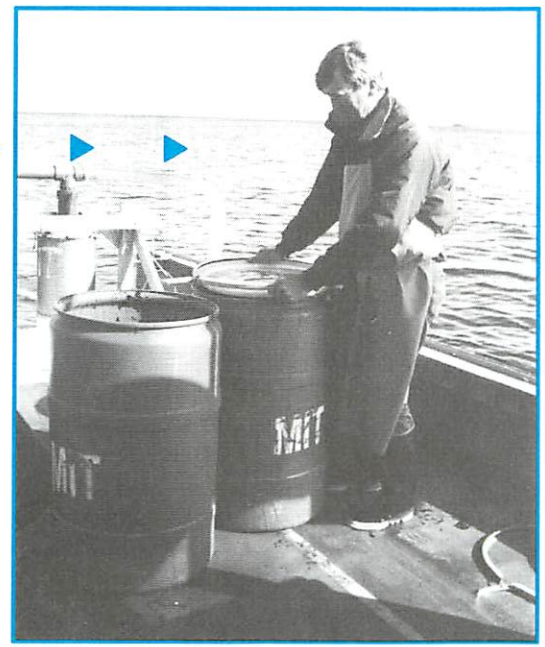


Massachusetts Marine Liaison Service
(617) 253-9308
Madeleine Hall-Arber, marine agent

The Liaison Service disseminates information, particularly Sea Grant research results, to the marine community, furnishing expert advice according to staff specialties and forwards community needs to appropriate Sea Grant investigators for research consideration or assistance. Current projects include assessing the impact of limited access on fishing communities, serving as a zebra mussel information center and coastal zone management.

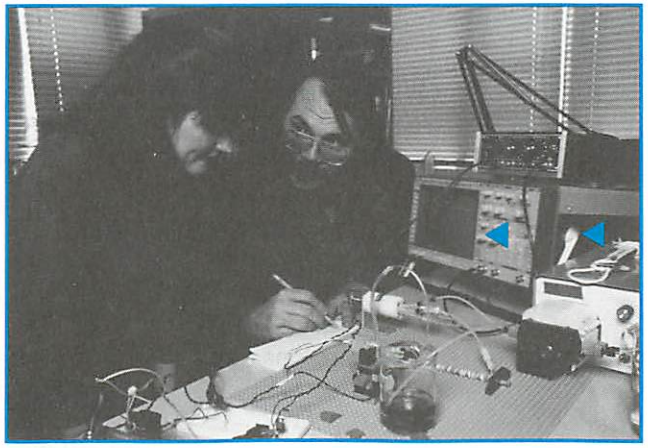
Center for Fisheries Engineering Research
(617) 253-7079
Clifford A. Goudey, fisheries engineer

The Center provides the New England fishing industry with information and technical expertise on gear and vessel design. The Center conducts and assists in projects to improve net selectivity and harvesting of non-traditional species. Courses for fishermen are taught at trawl-testing facilities at the David Taylor Model Basin in Bethesda, Md. A towed video camera system developed by the Center is used to make field observations of working gear. Students regularly participate in fisheries research projects, exposing them to career opportunities in a field that needs practicing engineers.



Communications/Information Service
(617) 253-7041/5944
Carolyn Levi, communications manager
Andrea Cohen, editor
Margaret Weigel, publications assistant, graphic designer
Kathy de Zengotita, information specialist

The Service disseminates Sea Grant research results and publicizes activities to a broad audience through research reports, news releases, exhibits, the *Quarterly Report* newsletter, *Nor'easter* (a regional Sea Grant magazine), and a new interactive report on the Internet's World Wide Web server. Database search capabilities help the information specialist respond to the marine information needs of staff, researchers and the public.



Faculty/Graduate Student
Marine Advisory Service
(617) 253-7042
Madeleine Hall-Arber, marine agent
Judith Pederson, manager Commonwealth relations and coastal processes

The Service maintains flexibility in Sea Grant's advisory program by allowing it to respond to more technically challenging, advisory-oriented problems, enabling its advisory program to respond to increasingly sophisticated problem-solving opportunities, and introduces graduate students to applications of their research, as well as allowing part-time use of professional specialists in the execution of advisory projects.

Implementation Impacts of Amendment Five to the Multispecies Plan, New England Region

Madeleine Hall-Arber, marine agent

Tracking actual socio-economic impacts of new fisheries management schemes will identify and analyze the consequences of changes in management, so that negative impacts may be avoided or mitigated in the future. An early awareness of impacts could be used to attract aid programs, such as job training services to help communities cope with change.

Continuation of the collection of basic baseline information is a significant contribution, since the state of knowledge about the complex groundfisheries in New England is quite limited. Increased awareness of the values and attitudes of fishermen could help facilitate communication between the regulators and the regulated. Aspects of this work will apply to fisheries and other natural resources management at the state and federal level, locally and nationally. Those engaged in developing plans for Marine Mammal Protection might find it particularly helpful.

Specific objectives are to investigate impacts of recent changes in the management of the groundfisheries in New England, refine survey instruments used for collection of social and economic data required to analyze management alternatives, facilitate the communication between industry participants and fishery managers and provide information about the impacts of the changes to the industry, managers, environmental organizations and interested citizens.

Zebra Mussel Outreach

Madeleine Hall-Arber, marine agent

Judging from the devastation that has occurred in the Great Lakes region due to zebra mussel infestation, proactive steps to slow or prevent their movement into Massachusetts are valuable undertakings. Minimizing the spread of zebra mussels by raising boaters' awareness of both the devastation associated with infestation of zebra mussels and the simple techniques that can limit their movement are the primary anticipated benefits of this project.

Specific objectives are to develop and implement a proactive public outreach program to respond to the potential infestation of zebra mussels in the Northeast region, to draw on the expertise of MIT Sea Grant Communications and Information specialists (MIT will serve as a repository of information about zebra mussels pertinent to Massachusetts), and to maintain a network of researchers and other specialists outside of MIT for additional information and extension of outreach efforts.

EDUCATION

At MIT Sea Grant, education is intertwined with research and advisory activities. Sea Grant's research programs are excellent training vehicles for young scientists and engineers, and Sea Grant's public education — for children as well as adults — brings a taste of the sea of marine knowledge to nonspecialists. While the major education activity under MIT Sea Grant is support of graduate students in the research projects, the program supports a Sea Grant Undergraduate Research Opportunities Program (UROP), offers a public lecture series and produces computer-based exhibits, as well as other educational materials. In addition, MIT Sea Grant supports marine safety training at the Massachusetts Maritime Academy.

Projects

Museum Collaborations

Carolyn Levi, communications manager

MIT Sea Grant is developing new modes of public education using new technologies, and working cooperatively with other public education institutions.

A new, two-part exhibit designed expressly for the New England Aquarium was installed and is receiving enthusiastic support. It uses animation, sound and text in interactive computer-based stations. The first explains the Boston metropolitan sewage system, the changes it is going through, and the Boston Harbor cleanup. The second teaches what people can do to protect the Harbor.

SEA GRANT LECTURE

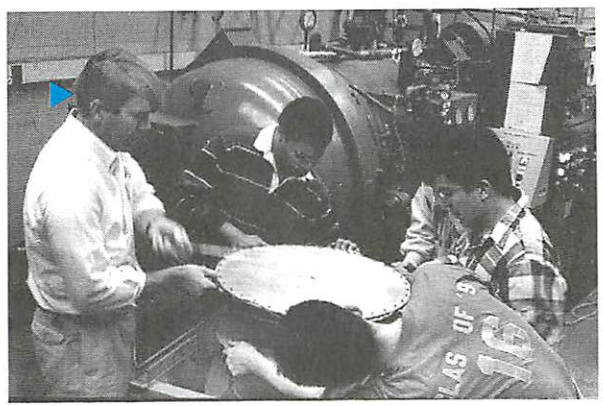
Every other year, Sea Grant offers a public lecture. In 1994, the program worked with Sea Grant director in his role as chairman of the Behavior of Off Shore Structures (BOSS 94) Conference and published keynote lectures as the Sea Grant lecture.

Undergraduate Research Opportunities Program

Norman Doelling, executive officer & assistant director for education and advisory services

The Undergraduate Research Opportunities Program (UROP), more than any other single program, defines the unique undergraduate program at MIT. UROP allows students to work on research projects early in their careers. The Sea Grant approach especially stresses team work — reflecting the multidisciplinary, team-oriented world these engineers are soon to enter. MIT Sea Grant has been proud to be a major sponsor of UROP and has benefited by attracting some of MIT's best young minds and talents to work in marine-related areas.

Sea Grant supported twenty-two UROPs for Summer 1993, nine for the Fall 1993 term, six for IAP/Spring 1994 and 11 for Summer 1994. Undergraduates from Aeronautics and Astronautics, Civil and Environmental Engineering, Ocean Engineering, Mechanical Engineering, Chemical Engineering, and Electrical Engineering, Physics, Economics, Mathematics and Computer Science were represented.



Projects

MIT Sea Grant/MMA Joint Program in Marine Safety and Environmental Training

John J. Callahan, Massachusetts Maritime Academy

MIT Sea Grant/MMA Joint Program in Marine Safety and Environmental Training is focused on outreach to local commercial and sports fishermen, operators of whale watching boats, operators of launches for hire, and others who make their living from or concentrate their recreational activity on, a boat.

The Knauss Fellowship Program

The Dean John A. Knauss Marine Policy Fellowship program selects highly qualified graduate students for a one-year, paid fellowship in the legislative or executive branch. MIT Sea Grant has sent five such fellows to Washington from Massachusetts. MIT Sea Grant's 1993 fellow was Shane Merz, a graduate student in Ocean Engineering. Merz participated actively in the office of Senator Akaka of Hawaii.

The Dean A. Horn Award

The Dean A. Horn Award was established in 1982 in honor of the contributions of a former Sea Grant director. The award is given to the marine-related UROP project that best reflects Mr. Horn's high regard for significant innovative marine research projects carried out with competence and reported with clarity. In September 1993, the award was given to Civil and Environmental Engineering student Amy B. Chan for her summer UROP at the MWRA, estimating contaminant loading in Boston Harbor and Massachusetts Bay.

Outreach to Schools

Carolyn Levi, communications manager

MIT Sea Grant has two initiatives aimed at K-12 education. The first is *The Boston Harbor Sewage Stack*, a computer program covering the much same subject as the New England Aquarium (see p. 23) exhibit, but in greater depth. This program is distributed as a computer diskette to educators nationwide. Teachers and informal educators integrate it into their programs.

The second is a children's book of marine questions and answers. Based on inquiries the program has received from children, this fact-packed and cleverly illustrated book was published in early 1995.

PROJECT MANAGEMENT

The MIT Sea Grant College Program provides a focal point for marine-related activity at MIT and strives to strengthen and coordinate Sea Grant interests throughout the Commonwealth. MIT Sea Grant is responsible for Sea Grant's activities in Massachusetts, working as the senior partner in collaboration with the Sea Grant Institutional Program at Woods Hole Oceanographic Institution. Program management objectives are to support the goals of the National Sea Grant College Program and those of MIT by deploying financial and human resources in appropriate endeavors throughout the Commonwealth.

MIT Sea Grant's basic management tenets are:

(1) research is the driving force for MIT Sea Grant;

(2) education is integral with and an adjunct to research and to effective technology transfer; and

(3) advisory service has as its three-fold function, helping to solve problems, translation and dissemination of research results, and the feedback of ideas, needs and opportunities from the local and national user communities to the academic community.

Program Administration
(617) 253-7131
Prof. Chryssostomos Chryssostomidis, director
Norman Doelling, executive officer and assistant director for education and advisory services
Rere Quinn, administrative assistant

Associate Directors for Research
Professor Henrik Schmidt,
Department of Ocean Engineering, MIT
E. Eric Adams
Department of Civil Engineering, MIT
Marcia McNutt
Department of Earth, Atmospheric and Planetary Sciences, MIT

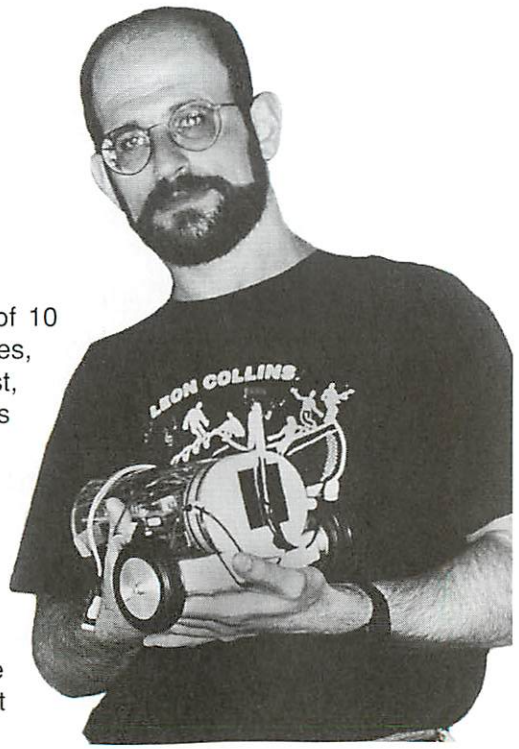
Overall management of the research program is carried out by the director, with the assistance of the associate directors for research. Together, they organize the proposal review and selection process, update research theme areas, monitor research progress, and help review and select "seed" and "quick response" projects. The executive officer, is responsible for the MIT Sea Grant advisory and communications programs. The director is responsible for overview of all education projects.

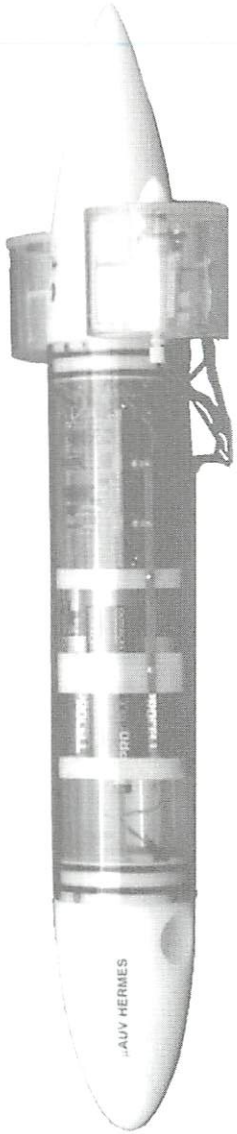
Financial Management
(617) 253-7138
Timothy Downes, administrative officer
Janice Ahern, administrative assistant

Faculty Committee
Professor Robert S. Langer, chairman
Department of Chemical Engineering, MIT

MIT Sea Grant's Faculty Committee consists of 10 faculty members who provide advice on policy issues, program goals and program evaluation to the Provost, and provide guidance and advice on program goals and objectives to the Director.

The Sea Grant Faculty Committee also reviews the preliminary proposals and assists the Sea Grant Director in selecting a limited number of proposals for full write-up. In addition, the Committee is responsible for relations between Sea Grant and departments within the Institute. Its major activities are related to identification and development of theme areas and evaluation of peer reviewed Sea Grant proposals.





State-Industry Advisory Council
Professor Robert D. Collier, chairman
Department of Mechanical Engineering, Tufts University

Because MIT Sea Grant does not receive omnibus funding from the Commonwealth of Massachusetts, its program management recognizes the need to develop strong ties with the Commonwealth in order to fulfill Sea Grant objectives. The State-Industry Advisory Council reflects MIT Sea Grant's special concern for working closely with marine-related agencies in the Commonwealth, with public interest groups, and with private and corporate citizens. MIT Sea Grant's overall organization and its special emphasis on service to industry responds to its special need for non-government sources of matching funds.

The Council is headed by a faculty member from Tufts University to assure an academic perspective that extends beyond MIT's campus. Representatives of the Commonwealth include the director of Massachusetts Coastal Zone Management Office, a previous associate commissioner for education for the commonwealth, a representative of the Massachusetts Water Resources Authority, the director of the Division of Marine Fisheries, the director of the Urban Harbor Institute at the University of Massachusetts/Boston, representatives from the General Court of the Commonwealth (state legislature) as well as representatives of the Massachusetts Maritime Academy and the Director of the Woods Hole Oceanographic Institution.

The State Industry Advisory Council membership also includes a representative of the Woods Hole Northeast Fisheries Regional Office for the National Marine Fisheries Service. Seven members come from industrial companies. An environmentalist, a lawyer, a banker and two members of the MIT Corporation round out a diligent, concerned and active State-Industry Advisory Council.

The most important activity of the Council is reviewing the preliminary proposals obtained in response to our annual call for proposals.

Other functions of the Council are:

- to help identify and define marine-related problems;
- to provide diverse public perspectives on issues;
- to evaluate MIT Sea Grant program objective and themes;
- to provide advice on priorities for program efforts;
- to identify methods for rapid and effective transfer of technical information and program results to users; and
- to identify institutions and organizations where cooperative and coordinated project efforts will be most productive.

Photo Credits

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Don Atwood/MIT Sea Grant
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