

## **Sea Grant College Program**

The MIT Sea Grant College Program funds research, education, and technology-transfer projects directed to the wise use of marine resources. MIT has been a leading participant in the national program since 1969. In 1976 the Institute's program was designated a Sea Grant College Program, a status that offers the potential for greater funding and confers a responsibility to work with marine researchers throughout the Commonwealth of Massachusetts.

Funds are distributed among the 31 Sea Grant Programs in a competing grant process by the National Oceanic and Atmospheric Administration (NOAA) through its National Office of Sea Grant. Each program is required to match every two dollars of its federal grant with one from nonfederal sources, to ensure that Sea Grant universities are responsive to the needs of the public and industry.

In FY2004 the National Office of Sea Grant awarded MIT over \$2.5 million. Additionally, more than \$3.5 million was provided by MIT, industry partners, the Commonwealth of Massachusetts, and other federal agencies.

### **Education**

Sea Grant's mission includes educational services, and MIT Sea Grant consistently shines in this area, providing creative opportunities to students and teachers at all levels.

### **Graduate Student Research Assistants**

Support for graduate students is written into virtually every research project. We provided partial support for over 40 graduate students (27.5 FTE) at MIT alone, in the departments of Civil and Environmental Engineering, Chemical Engineering, Mechanical Engineering, and Ocean Engineering, and in the MIT-Woods Hole Oceanographic Institution Joint Program and the Harvard-MIT Division of Health Sciences and Technology. Students at UMASS/Amherst, UMASS/Boston, Boston University, Smith College, Tufts School of Medicine, Boston University School of Medicine, Massachusetts Maritime Academy, Worcester Polytechnic Institute, Gordon College, and Wheaton College also received funding.

### **Undergraduate Research Opportunities Program**

In addition, the program continues to provide major support for marine-related UROP projects. This year over a dozen MIT undergraduates did creative and innovative projects under Sea Grant guidance, including:

- Michael Jordan Stanway '06, ocean engineering, who received the Dean Horn Award for his work toward developing an artificial gill for human use. He designed a gill to supply oxygen to a microbial fuel cell that has potential as a source of renewable energy for small underwater vehicles.

- Rubi Rajbanshi and Melissa Wu, biology, who collaborated on a project tracking the development of colonies of marine bioinvaders in Boston Harbor, focusing on two exotic species of tunicates. Their paper “Analysis of the Growth and Sustenance of *Asciidiella aspersa* and *Ciona intestinalis*” adds to our knowledge of how invasive species occupy ecological niches, out-compete native organisms, and persist over long periods once established.
- Dan Walker, mechanical engineering, who is building an amphibious, quadrupedal robot, drawing 3-D solid models and then expertly machining the central pressure hull and the three-jointed legs, with all their component parts. He also designed the electronics, tether, software, and microcontroller to steer and coordinate the robot’s walking movements.

## **K-12 Education**

### ***Sea Perch***

MIT Sea Grant’s new Sea Perch program introduces precollege students to the wonders of underwater robotics. Part of the Office of Naval Research’s Recruiting the Next Generation of Naval Architects initiative, this program teaches students how to build an underwater robot (called a sea perch), how to build a propulsion system, how to develop a controller, and how to investigate weight and buoyancy. The Sea Perch program trains teachers and mentors to build the remotely operated vehicles (ROVs), which are made with PVC pipe. Boston’s Museum of Science, the Society of Naval Architects and Marine Engineers, and the National Shipbuilding Research Program are all involved in plans for expanding this popular program. Sea Perch programs have been initiated in Massachusetts, Rhode Island, Virginia, Maryland, and New Hampshire. More information is available at <http://web.mit.edu/seagrant/edu/seaperch/>.

### ***Adopt-a-Boat***

An initiative of Sea Grant’s Center for Fisheries Engineering Research, Adopt-a-Boat is now in its third year. The program links K-12 classrooms with commercial fishermen so that students can learn directly from “their” fisherman about his life and work—from equipping and maintaining the boat to the complexities of marine resource utilization and marine ecology. Over 50 partnerships are in place in New England, and organizations in New Jersey, South Carolina, and Louisiana have recently adopted this innovative approach to marine education. More information is available at <http://www.adoptaboat.org/>.

### ***Blue Lobster Bowl 2004***

In close collaboration with the Woods Hole Oceanographic Institution (WHOI), Sea Grant conducted the Massachusetts regional competition of the National Ocean Sciences Bowl, which provides an educational forum and recognition for students who excel in math and science. The Blue Lobster Bowl follows a standard tournament model combining round robin and double elimination formats, with questions drawn from the scientific and technical disciplines used to study the oceans (physics, chemistry, geology,

atmospheric science, oceanography, biology, etc.) and from the relevant social sciences (economics, history, literature, etc.). Along with information about colleges and universities with undergraduate programs in ocean sciences, larger prizes, including scholarships and internships, are awarded.

### ***Women in Science and the Environment***

MIT Sea Grant is one of six higher education and nonprofit organizations working with Odyssey High School in South Boston to develop a hands-on, integrated curriculum around marine sciences and the environment. The focus of this activity, Women in Science and the Environment, funded by the Department of Education, is to develop after-school programs in which students receive a stipend to design and carry out their projects.

### ***Grants for Education in Marine Science***

Funds offered through this competitive program provide supplemental financing to Massachusetts students and educators. Each year five to eight schools receive funding to conduct a hands-on, technical classroom project. Each spring, MIT Sea Grant hosts a GEMS Symposium at MIT, providing an opportunity for students and teachers in the GEMS program to present their work, meet MIT staff, and tour the campus. This year schools representing Bedford, Worcester, Cohasset, Salem, Wareham, Ipswich, and Newburyport participated in the GEMS program.

### ***New Core Research Projects***

MIT Sea Grant funds core research projects that allow investigators to initiate marine studies in traditional theme areas. These projects are expected to be completed within two years.

### ***Coastal Management and Utilization***

“Development of a Rapid, *In Situ* Sensor System for Monitoring Bacteria in Coastal Waters,” Professor Julie Carruthers, University of Massachusetts, principal investigator. Professor Carruthers will be assisted by Professors Robert Chen and Michael Shiaris, also from the University of Massachusetts. The primary objective of this project is to develop an automated *in situ* system for measuring microbiological water quality in coastal waters. Designed for use on a buoy or pier, this system will use a modification of a well-established enzyme substrate method combined with recent advances in marine instrumentation to allow rapid, automated analysis of bacterial indicators of human health risks.

### ***Coastal Ocean Observation and Modeling***

“Retro-focusing Techniques for High Rate Acoustic Communications,” Dr. Milica Stojanovic, MIT Sea Grant Program, principal investigator. The objectives of this project are to design and demonstrate retro-focusing techniques for high-rate acoustic

underwater communications based on optimal solutions, adaptive retro-focusing algorithms, and using channel estimation and phase synchronization suitable for realistic time-varying conditions.

### **Technology Development**

“Data Fusion for Large-Scale Cooperative Autonomous Ocean Mapping,” Professor John Leonard, Ocean Engineering Department, principal investigator. This project will develop and experimentally validate new algorithms for cooperative ocean mapping using multiple autonomous underwater vehicles (AUVs). The proposed research will extend the framework of simultaneous localization and mapping (SLAM) for AUVs to accommodate fusion of data from multiple vehicles, mapping natural terrain features, and remapping dynamic environments at different snapshots in time. The advances in navigation and sensing for AUVs will enable the solution of critical problems faced by the scientific community, e.g. underwater search, mapping, inspection and repair, climate change assessment, and marine habitat monitoring. Perception and navigation are key issues in robotic research, and sonar is an intelligent avenue to travel in solving the problems.

“Basic Scaling Law in Fast-Starting and Rapidly Maneuvering Fish,” Professor Michael Triantafyllou, Ocean Engineering Department, principal investigator. The objectives of this project are to derive basic hydrodynamic scaling laws and control and actuation mechanisms of fast-starting and rapidly maneuvering fish. By mapping the basic mechanisms of fast-starting, from triggering the response to achieving an optimal wake structure, the project seeks to assess their impact on fish energetics and the implications for the control, sensing, and hydrodynamic procedures used in engineering applications.

“An Experimental Investigation of Lorentz Force Actuators for Control of Separated Flows and Associated Noise around Marine Vehicles,” Professor Hamid Johari, Mechanical Engineering Department, Worcester Polytechnic Institute, principal investigator. The aim of this project is to characterize the response of periodically driven electromagnetic actuators in the absence of external flow in order to assess their capability and efficiency over a wide range of input parameters such as current density, fluid conductivity, and forcing frequency. In the proposed research, harmonically varying Lorentz forces created by electromagnetic actuators would be investigated in a saltwater tank and water tunnel. The flow induced by a flat Lorentz force actuator will be measured using velocity profile measurements.

### **Ongoing Core Research Projects**

Two research projects begun in FY2003 belong to the Marine Biotechnology theme area. These two, as well as the others noted here, have a February 2005 completion date.

#### **Marine Biotechnology**

“Development of a Fish Tail System for Studying the Dynamics of Angiogenesis,” Dr. Tom Consi, principal investigator, with Professor Elazer Edelman, Harvard-MIT

Division of Health Sciences and Technology, associate investigator. This project is studying the factors influencing the formation and growth of blood vessels in humans and other animals with cardiovascular systems. Dr. Consi left MIT's Ocean Engineering Department this past year to become an associate scientist with the Great Lakes Water Institute, University of Wisconsin at Milwaukee. Professor Edelman now functions as the project's principal investigator with support from Dr. Consi.

"Tissue Engineering of Fish Skin," Professor Robert Langer, Department of Chemical Engineering, and Michael Triantafyllou, Department of Ocean Engineering, coprincipal investigators. The current project, begun in March 2003, follows a recently completed project of the same title, investigating the fabrication of artificial fish skin using tissue-engineering techniques. This project builds upon the success of the initial study and addresses the actual fabrication of skin suitable for the exterior of an aquatic robot.

### **Coastal Management and Utilization**

"Ecology and Management of Exploited Horseshoe Crab Populations: Stage-structured Models, Isotopic and Molecular Genetic Approaches," Professor Ivan Valiela, Boston University Marine Program, principal investigator. This study continues its investigation of horseshoe crab population dynamics, establishing geographical and ecological range information necessary for sustainable harvest.

"Assessing the Bioaccumulation of Toxic Organic Substances by Benthic Invertebrates from Contaminated Bed Sediments," Professor Philip Gschwend, Civil and Environmental Engineering Department, principal investigator. This project investigates the use of polyethylene strips inserted into sediment beds as passive samplers for measuring the concentrations of PAHs, PCBs, and PCDDs driving bioaccumulation in beds experiencing bioturbation and/or irrigation.

"Rates and Mechanisms of Mercury Methylation in Marine Coastal Sediments," Professor David Shull, Biology Department, Gordon College, and Professor Janina Benoit, Chemistry Department, Wheaton College, coprincipal investigators. This project investigates the influence of benthic organisms in stimulating the production of methyl mercury, a potent neurotoxin. The research is concentrated on Boston Harbor sediments. Professor Shull left Gordon College this past year to join the faculty at Western Washington College, where he continues to contribute to the project. The participation of Gordon College on this project is now the responsibility of Professor Dorothy Boorse, with Professor Benoit continuing as the principal investigator.

### **Coupled Ocean Observation and Modeling**

"System Integration and Advanced Capabilities for NEREUS, an Odyssey Compatible In-Situ Mass Spectrometer," Professor Harry Hemond, Civil and Environmental Engineering Department, principal investigator. This project seeks to develop and integrate the NEREUS (Novel, Efficient, Rapid Evaluation of Underwater Spectra) for application on the Odyssey-class AUV. The effort includes development and demonstration of necessary hardware and software, and appropriate system protocols to

increase the sensitivity of the NEREUS device to certain trace compounds, including nitrous oxide and hydrogen, possible DMS, carbon monoxide, low molecular weight fatty acids and alcohols.

“Small Hovering Autonomous Vehicle,” Dr. Franz Hover, Ocean Engineering Department, principal investigator. This project aims at developing a new autonomous vehicle for applications in close or energetic waters. A vehicle of this type would facilitate broad integrated sampling of marine waters, as well as survey, inspection, and mine countermeasures by the military.

### **Technology Development**

“Robotic Platform with Podded Propulsors,” Professor Michael Triantafyllou and Dr. Franz Hover, coprincipal investigators. This project investigates the suitability of podded propulsion technology for large vessels by constructing and testing an autonomous robotic model of a ship with electric (podded) propulsion—a concept supporting much more flexible maneuvering and, potentially, a more efficient use of energy.

### **Focused Research/Marine Center Projects**

The objective of the Focused Research/Marine Center concept is to plan and conduct research programs in collaboration with, and jointly sponsored by, industry and government agencies in order to attack major problems of broad interest to the marine community, and to foster industrial competitiveness by transferring the resulting technology to users. Focused research projects have a six-year duration with the initial years heavily supported by Sea Grant Program funds. By the end of these multi-year projects the funding is expected to come entirely from non-Sea Grant sources.

As a consequence of the success of the focused research programs that addressed AUV technologies and applications, the Sea Grant Program at MIT has been successful in capturing additional funding. This illustrates the intent of our focused research theme area and further demonstrates how early funding of well-thought-out research areas can establish the soundness of more specific research and development objectives.

“Poseidon: A Coastal Zone Management System via the World Wide Web,” a project begun in March 1998, is currently nearing completion. The project is a consequence of the high availability of raw ocean data, the various modeling approaches that can be applied to large, multi-parameter data sets, and the extensive applications such data-derived knowledge makes possible (weather forecasting, fisheries management, environmental impacts, etc.). This focused research project was completed in February of 2004.

In 1999 we again included the opportunity for new focused research proposals in our program solicitation for new research and educational proposals. We received one such proposal, “Distributed Observatories for the Coastal Environment.” With the departure of Jim Bellingham, Professor Henrik Schmidt of the Ocean Engineering Department had

served temporarily as principal investigator. During the past year Dr. Milica Stojanovic, principal research scientist with the MIT Sea Grant Program, has taken on the role of principal investigator for this focused research project. This project is now in its sixth and final year with a completion date of February 2005.

A more recent focused research project, “Biomimetic Rigid-Hull Vehicle with Flapping Foils for Enhanced Agility in the Surf Zone and Cluttered Environments”, was submitted by Professor Michael Triantafyllou and Professor Dick Yue, Ocean Engineering Department, as coprincipal investigators. The long-term goal of this research is to develop a new class of rigid-hull autonomous underwater vehicles, best adapted to environments that require continuous maneuvering. This project, begun in March of 2001, is now in its fourth year and will be completed in February 2007.

In our Omnibus Proposal of November 2004, we included the most recent focused research project, “Autonomous Multi-Scale Digital Imaging of Ocean Species.” This proposal was submitted as a collaborative effort by Dr. Cabell Davis, senior scientist at WHOI, Professor Jerome Milgram, Ocean Engineering Department, and Professor George Barbastanthis, Mechanical Engineering Department. The proposed study will assemble a team of experts in plankton and micronekton/nekton biology, video plankton imaging and image analysis, digital holographic imaging, volume holographic imaging, range-gated laser imaging, adaptive optics, in-situ DNA analysis, and autonomous underwater vehicle (AUV) technology. This team will develop a modular multi-scale imaging system and incorporate it into an AUV for autonomous quantification of distributional patterns of plankton, micronekton, and nekton species.

### **Advisory Services**

The MIT Sea Grant Marine Advisory Program (MAP) conducts research on numerous scientific, technological, environmental, social, and educational issues. MAP also provides outreach and information to agencies, industry, advocacy groups, and the general public.

### **Center for Fisheries Engineering Research**

Under the direction of Cliff Goudey, the Center for Fisheries Engineering Research (CFER) works to improve the economic viability and environmental sustainability of the fishing and aquaculture industries by providing technical information and advice and by conducting and collaborating on research to develop improved methods and technology:

- **Whale-Free Buoy.** CFER continues to advocate rational approaches to support commercial fishing while recognizing the need to protect endangered marine animals. The Whale-Free Buoy has been developed and was awarded a US patent. The innovative buoy will reduce the risks of whale entanglement in passive fishing gear such as is used in lobstering.
- **Autonomous Underwater Listening Station.** A low-cost Autonomous Underwater Listening Station (AULS) has been developed for deployment in

cooperative research with commercial fishermen. The AULS devices use consumer-grade MP3 recorders providing 60 hours of recording time. They have been used in research to locate spawning aggregations of cod and haddock to help in the development of protective management measures. CFER has built AULS for each of the fourteen NOAA sanctuaries for use in their public education on the role of sanctuaries in the ocean ecosystem.

- **Marine Finfish Hatchery.** This facility has been moved from the Charlestown Navy Yard to the Gloucester Maritime Heritage Center, where the location and additional space allows extensive public interpretation on aquaculture and marine ecology.

### **Center for Marine Social Sciences**

The principal goal of the Center for Marine Social Sciences (CMSS), under the leadership of Dr. Madeleine Hall-Arber, is to apply advances in the social sciences to marine-related issues and contribute to policy development, in particular helping the New England fisheries to become sustainable through improved management. This year two projects in which CMSS partnered with local fishing industry organizations, including the Gloucester Fishermen's Wives Development Program and Massachusetts Fishermen's Partnership, neared completion:

- **New England Fishing Communities' Panels Project.** The objective is to develop a community-based process for gathering and assessing social science data relevant to the fishing industry. Six community-based panels review, add to, and create socioeconomic profiles for their communities. This provides managers with information that will enable them to more accurately anticipate social impacts of policy changes.
- **Community Audit Project.** Funded by the Department of Labor, this project entailed a strategic planning effort to obtain information useful to policy makers, workforce and economic development practitioners, and educators in fifteen communities of the North Shore region of Massachusetts. A specific goal of the project was to focus on local fishing communities to determine if we can match needs and services, identify new opportunities for employment, and create a plan to assist employers and potential employees in finding a good fit.

### **Center for Coastal Resources**

Under the direction of Dr. Judy Pederson, the Center for Coastal Resources (CCR) makes scientific and technical information accessible to coastal stakeholders and the public, with the long-term goal of providing an understanding of the human impact on marine ecosystems. The CCR works in three general areas:

- **Effects of Contaminants and Pollutants on Marine Ecosystems.** The CCR spearheaded a scientific advisory committee to investigate dry-weather beach closures in South Boston. The committee identified broken sewer lines and illegal hookups of sewer pipes to storm water pipes as the primary causes. In wet weather, storm water and combined sewer overflows were primary sources. A



plan has been adopted by the state and the City of Boston to build a large, underground storage tank to treat and redirect the flows away from the beaches. This solution will be both cost-effective and protective of human health.

- **Marine Bioinvasions.** Invasive species are economically and ecologically damaging. This year the CCR section of MIT Sea Grant has:
  - made information from scientists who monitor invasive species available online (<http://massbay.mit.edu/ExoticSpecies/exoticmaps/index.html>) in geographic information system (GIS) format.
  - produced a new field key, Hitchhiker’s Guide to Invasive Species.
  - funded a study of non-ballast water vectors by Weigle, Smith, Carlton, and Pederson that will be published in *Conservation Biology*.
  - organized a regional ballast water-management approach that will minimize ballast water releases in New England and Canadian ports.
- **Regional Ecosystems and Habitats.** CCR is currently focused on facilitating public participation in the identification of marine protected areas with the creation of an interactive geographic information system that uses sound scientific data to identify potential protected areas, but also allows the public to weight the data layers in terms of importance. This study focused on the Stellwagen Bank National Marine Sanctuary: <http://dogfish.mit.edu/eSite/>.

## Outreach and Communications

The Marine Communications/Information Service (MC/IS) develops guides, technical reports, proceedings, and reprints as the most in-depth means by which our research is communicated. Other publications and activities, such as those below, target groups such as fishermen, children, and the general public:

- Our newsletter, *Two If by Sea*, is published jointly by the MIT and WHOI Sea Grant Programs.
- In the past year, MC/IS collaborated with the New England Aquarium and Nature and Environmental Writers/College and University Educators (NEW-CUE), a nonprofit environmental education group, in a series of conferences. Andrea Cohen, MIT Sea Grant communications manager, was a featured speaker at the NEW-CUE Third Writers’ Conference and Workshop held this past June.
- In outreach, MC/IS partnered with several local organizations to plan a clean-up along the Charles River that drew over 1,000 volunteers.
- MC/IS created the Sea Perch website, an online searchable database for Adopt-a-Boat partnerships, and public displays for the Gloucester Hatchery.

## **Program Management**

The program director is Professor Chryssostomos Chryssostomidis of the Department of Ocean Engineering. The associate director for research is Dr. Milica Stojanovic, principal research scientist with the Sea Grant College Program. Richard Morris continues to serve as executive officer for the program, and Timothy Downes continues as the program's administrative officer. Cliff Goudey is the marine advisory leader for the MIT Sea Grant College Program.

**Chryssostomos Chryssostomidis**

**Director**

**Henry L. and Grace Doherty Professor in Ocean Science and Engineering**

*More information about the Sea Grant College Program can be found online at <http://web.mit.edu/seagrant/>.*