Sea Grant College Program

The National Sea Grant College Program supports research, education, and outreach activities that address critical problems in human use of the sea. The MIT Sea Grant College Program focuses on developing scientific and technological systems that can provide ever-increasing accuracy and range in exploration, data gathering, analysis, and understanding of marine processes. Essential to this purpose is the transfer of knowledge to and within the program's broad constituency: industry, government agencies, public and private educational institutions, and the general public.

MIT Sea Grant's research and outreach efforts fall under four general headings—Autonomous Underwater Vehicle Laboratory, Design Laboratory, funded research projects, and education and advisory services—and are described below.

Autonomous Underwater Vehicle Laboratory

MIT Sea Grant is historically credited with creating and developing autonomous underwater vehicles (AUVs)—small, inexpensive, artificially intelligent robotic submarines for undersea exploration. Through spinoffs, and through having trained a number of leading engineers in the field, the MIT AUV Laboratory may be considered largely responsible for founding a multimillion-dollar industry.

Bluefin Robotics, a 1991 spinoff from the AUV Lab, has been developing a small, hovering AUV for the US Navy using technology developed in collaboration with MIT Sea Grant. In August 2012, the prototype HAUV-3 successfully completed government acceptance testing. The vessel is designed to autonomously perform ship hull inspection in the water, a demanding task typically performed by divers to ensure the safety of ports and harbors. Through its ongoing work with Bluefin, the AUV Lab continues to support local jobs and wages as well as businesses, vendors, and suppliers.

Figure 1: Small, hovering AUVs designed for inspecting ship hulls for explosives or contraband.

Sea Grant's own hybrid AUV/remotely operated vehicle, the *Reef Explorer* (*REX*), has evolved into a popular workhorse vehicle for use by researchers and educators. *REX* has been used to investigate *Didemnum vexillium* infestations in coastal Atlantic waters, to evaluate the health of eelgrass beds, for hull inspection of the R/V Discovery and the Around the Americas yacht Ocean Watch, and to study methane bubbles on the floor

of Mystic Lake in Winchester. The vehicle has been tele-operated in New Hampshire from a technology conference in Monaco and in the MIT Zesiger Center pool for video observation and intervention during the 2012 Sea Perch Institute Challenge. An early version of *REX* has had many successful deployments at the Hawaii Institute of Marine Biology, where it is used for observation and educational purposes on remote coral reefs.

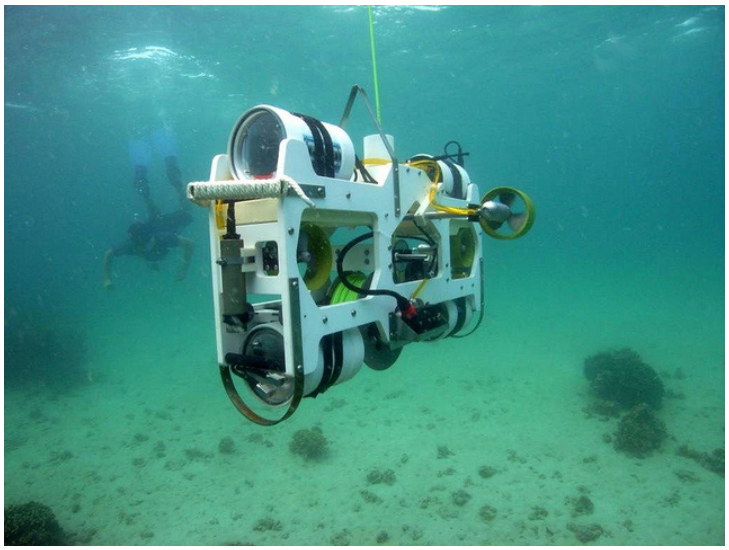

Figure 2: REX III *over corals, with divers.*

The popularity of *REX III* has inspired the AUV Lab engineers to produce *REX IV*, an even more robust and versatile version of *REX*—smaller, faster, more responsive, and with much greater video transmission capability. *REX IV* will allow us to reach out to more educational and research organizations and extend the public impact of the new technology incorporated into its systems.

Technological developments in the AUV Lab include:

- A miniature attitude heading reference system in *REX* that allows the vehicle to be piloted without arcing off-course due to uneven hydrodynamic drag and ocean currents
- The addition of a downward-facing underwater camera system, GoPro Hero2, to *REX* to provide two- and three-dimensional photo and video imagery
- A high-resolution digital video camera mounted in a downward-facing configuration to allow streaming video of the sea floor in real time to the *REX* operator

Design Laboratory

Under the general heading of the Design Laboratory, MIT Sea Grant carries out advanced work in naval architecture and ship systems. Designs of ship components, power and propulsion systems, and the hydrodynamics of various vessel hull shapes are modeled and tested using complex numerical simulations. The Numerics in Computational Engineering group, with its expertise in multi-scale mathematics and high-performance computing, complements and supports the Design Lab's field tests of physical models of hulls, power systems, and propellers.

Electric Ship Research and Development Consortium

Since 2002, the Electric Ship Research and Development Consortium (ESRDC) has pursued its mission to design an all-electric vessel for the US Navy, with MIT Sea Grant director Chryssostomos Chryssostomidis leading the effort at MIT. Funded since 2008 by a five-year grant from the Office of Naval Research (ONR), the consortium successfully bid for a one-year extension for 2014 in the face of funding restrictions at ONR. MIT will play a more significant role as national leader of a key area: the development and validation of physics-based models.

MIT's function in the consortium, in addition to the current computational work, has been to create a new generation of design methodology that involves coordinating cross-disciplinary input from a large cadre of geographically dispersed experts. This collaborative method must be executed both in the cloud, where data and results are continually shared, and in the local offices of collaborators, where the heavy-duty computational work takes place. This allows for sharing vital information while keeping the greatest computational burden out of the cloud, which cannot sustain it. In addition, it allows researchers to adhere to ONR's security guidelines while not impeding necessary communications among the team members.

MIT's mandate under this new phase of funding is to continue development of the design methodology described above and also to tackle the management of the thermal load of the electric ship. This is a critical problem in any electric or electronic system: how to manage and minimize the heat generated by the operating equipment. Extensive mathematical modeling and computational analysis is needed to create a system that does not overheat at maximum function.

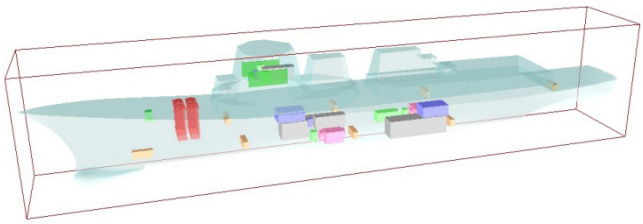

Figure 3: ESRDC ship displayed in 3D, populated with various pieces of equipment.

The consortium consists of members from a number of universities around the nation. The MIT group includes professor Michael Triantafyllou of the Department of Mechanical Engineering, professors Steve Leeb and James Kirtley of the Department of Electrical Engineering and Computer Science, and professor George Karniadakis of Brown University, who holds an appointment at MIT as a research scientist. The group is assisted by research scientist Julie Chalfant.

Funded Research Projects

As mandated by the National Oceanic and Atmospheric Administration, MIT Sea Grant conducts a yearly funding competition through the National Sea Grant office. Grants are available to any university-based investigator in the Commonwealth of Massachusetts.

Proposals are selected by peer review for scientific merit and to support the goals outlined in our strategic plan. Every $2 in federal grant money must be matched with $1 from nonfederal sources.

This year we selected three new core research projects and one new six-year, focused research Marine Center project. In addition, one proposal was rewritten with a more limited scope and funded at $25,000 as a seed project. We continued to support the four two-year core research projects that were initiated in February 2012 as well as two six-year Marine Center projects, one of which ended earlier this year. Also, we continued to provide partial support for the second and final years of two projects funded through the Northeast Regional Sea Grant Consortium.

New Projects

Investigators submitted proposals for comments by in-state stakeholders, for peer review by reviewers recruited from outside of Massachusetts, and a panel of technical experts chosen by the director. Five projects were approved for funding:

Michael Triantafyllou, MIT—Marine Center for Development of Biomimetic Underwater Sensors

Pierre Lermusiaux, MIT—High Productivity on a Coastal Bank: Physical and Biological Interactions

Cascade Sorte, University of Massachusetts, Boston—Are Blue Mussels Declining in the Gulf of Maine?: Population Trajectories, Connectivity, and Spatiotemporal Variation in Reproduction

Helen Poynton, University of Massachusetts, Boston—Development and Validation of the Coastal Biosensors for Endocrine Disruption (C-BED) Assay

Anna Michel, Woods Hole Oceanographic Institution (WHOI)—Laboratory Development of a Quantum Cascade Laser-Based Sensor System for Measurement of δ13C (CO2) in Seawater and Air (seed)

Continuing Projects

Matthew Charette, WHOI—Development of an Automated Seepage Meter for Quantifying Submarine Groundwater Discharge in the Coastal Zone

Changsheng Chen, University of Massachusetts, Dartmouth—Development of an Inundation Forecast System for Massachusetts Coastal Water

Philip Gschwend, MIT—Assessing the Bioactivity of Estrogens, Including Halogenated Derivatives, in Chlorinated Sewage Effluents and Coastal Seawater

Jennifer Bowen, University of Massachusetts, Boston—Microbial Community Composition of Permeable Reactive Barriers: Who Is Really Doing the Work?

Continuing Six-Year Focused Research Projects

Milica Stojanovic, MIT Sea Grant (begun 2007)—Acoustic Communication Networks for Distributed Autonomous Underwater Platforms

Franz Hover, MIT Department of Mechanical Engineering (begun 2008)—Autonomous Vehicle Exploration and Sampling of Deepwater Corals

Continuing Northeast Regional Social Science Research Projects

John Duff, University of Massachusetts, Boston—Governance Role of Local Authorities in Marine Spatial Planning: A Legal Assessment of Prospects and Problems

Robert Johnston, Clark University—Climate Change Adaptation and Ecosystem Service Resilience in Northeast Coastal Communities: Quantifying Economic Values and Tradeoffs for Regional Decision Support

Advisory, Education, and Outreach Program

MIT Sea Grant has an active advisory, education, and outreach program whose staff members have strong ties to the community. Their work ensures the transfer of research results and ocean science information to the appropriate constituents and also ensures that our research and programs address issues important to local, state, and regional government agencies; coastal municipalities; businesses; and citizen groups and organizations.

Boston Harbor Monitoring Internships

Sea Grant continues its decades-long involvement in protecting the Boston Harbor ecosystem by recruiting high school juniors and seniors for paid participation in a month-long ocean science internship program. These students are trained in proper scientific techniques to collect data from the beaches of the Boston Harbor Islands, data that will be used to track changes in water quality and the distribution and prevalence of native and exotic marine creatures. In July 2012, our interns became the first on record to identify the nonnative European rock shrimp as a new invasive species in the harbor.

Figure 4: A high school intern inspects a grid section used for species sampling on the Boston Harbor Islands.

Marine Invasive Species

MIT Sea Grant collaborates with other Sea Grant programs in the region to track the invasive sea squirt *Didemnum vexillium.* This year, as part of his internship for Leiden University, Serrano Pereira worked with Judith Pederson and Greg Booma to develop a method for calculating the percentage coverage of *Didemnum* and other benthic organisms on the Georges Bank sea floor, using images captured by a special optical camera mounted on *REX*. Polygons are drawn around species of interest and each polygon is annotated with the name of the species, sediment type, and other data. The information is stored in a web-accessible database so that an algorithm can calculate percentage coverage of the bottom by various marine benthic organisms.

Alternative Energy and Potential Space-Use Conflicts

Siting alternative energy facilities is a highly contentious issue in Massachusetts and elsewhere. In 2011 and 2012, MIT Sea Grant staff anthropologist Madeleine Hall-Arber collaborated with colleagues from the Urban Harbors Institute and the Oregon, California, and Virginia Sea Grant programs on a project designed to identify, avoid, and reduce space-use conflicts on the Outer Continental Shelf. The study, led by Industrial Economics Inc. and funded by the US Bureau of Energy Management, demonstrated that successful placement depends on consideration of sociocultural differences among affected interest groups and on a clear understanding of how different industries and groups use the ocean. Maps and images are useful but have inherent limitations in conveying the highly dynamic nature of space use at sea. The study recommended development of dynamic models to be more truly representative. The recommendations will be used by the Bureau of Energy Management in alternative energy development offshore.

Education

A key component of outreach is a comprehensive and varied educational program, mostly directed at K–12 students. One effective tool in our educational toolkit is the *Sea Perch*, a simple remotely operated vehicle that young people can build out of inexpensive, easily available materials. The original *Sea Perch* teacher training has evolved into a suite of programs and activities to exploit the outstanding success of this ongoing effort.

The Ocean Engineering Experience 2012

The Ocean Engineering Experience—or "OEX"—is a one-week residential summer program at MIT that introduces high school students to ocean engineering as applied to marine vehicles and structures. Students from around the world are selected on the basis of their enthusiasm for engineering, academic achievements, and personal goals.

The July 2012 OEX project was to develop a remotely operated underwater vehicle to monitor effluent supposedly being flushed into the Charles River by an electric plant. Sixteen students formed teams to design and build different vehicles, mastering principles of mechanical structures and electrical systems as well as teamwork and the

basic science involved. In the design process, students played both administrative and technical roles, managed a budget, and finally presented their designs to peers, mentors, and parents at the MIT Museum.

Outside of project time, the group attended lectures by MIT professors and graduate students, practiced biological oceanography on the Boston Harbor Islands, and visited labs and other sites at MIT and elsewhere.

OEX is a distinctly popular and successful program; we are seeking funding to expand it geographically and to recruit participants from underserved and minority communities. We have arranged to partner with the MIT Minority Introduction to Engineering and Science program on some of the 2013 OEX activities.

Blue Lobster Bowl

This year's Blue Lobster Bowl, one of the 25 academic tournaments that make up the National Ocean Sciences Bowl, was delayed for a month by blizzard Nemo and took place on March 3, 2013. More than 100 students from 10 Massachusetts high schools competed in the daylong event, which ranged across nine classrooms staffed with over 70 volunteers. Competing teams answered questions on marine biology, chemistry, geology, physics, navigation and geography, ocean history, literature, and public policy. A guest speaker from the MIT Marine Robotics Club gave a presentation to all of the participants in the Kirsch Auditorium; marine microbe hands-on activities took place for those eliminated from the tournament, while campus tours were given to others. The winning team from Lexington High School went on to take second place in the National Ocean Sciences Bowl Finals in April in Milwaukee. All Blue Lobster Bowl participants were also eligible to apply for four summer internships.

Communications

The advisory group hosts seminars at which Sea Grant–funded scientists, staff, and students present their work. This year more than 200 people attended the seminars, which are open to all; themes emphasized climate change and the social science of communities' responses.

Sea Grant publications include technical reports, reprinted peer-reviewed journal articles, conference papers and presentations, and online videos and pamphlets providing marine science information for the general public. Among the 64 publications created and distributed during this reporting period, one of the highlights is *The Homeowner's Handbook to Prepare for Coastal Hazards*, coedited by MIT Sea Grant coastal ecologist Juliet Simpson and WHOI staff members. The booklet, inspired by post–Hurricane Sandy conditions, details how citizens can protect life and property from wind, rain, and flash flooding and provides a list of useful emergency supplies, general insurance information, and an overview of anticipated climate change impacts for Massachusetts.

An extensive collection of short videos on MIT Sea Grant's mission, people, and projects has been added to the Sea Grant YouTube channel. These videos include staff profiles and stories about Sea Grant initiatives and high-profile events. There have been more than 4,000 views of our videos since the project began in the fall of 2012.

Students Supported by MIT Sea Grant

MIT Sea Grant promotes and administers a number of programs and awards that directly support aspiring scholars who are pursuing studies and careers in marine research.

The 2013 Dean A. Horn Award for Undergraduate Study in Marine Research was presented to Andrei Ivanov, a freshman in mechanical engineering, for his extensive video work while he was an Undergraduate Research Opportunities Program (UROP) student at MIT Sea Grant.

The Dean John A. Knauss Marine Policy Fellowship places graduate students with host organizations in legislative or executive branches of government. Santhiska Pather, a marine biogeochemistry master's degree candidate from the University of Massachusetts, Dartmouth, was selected during this reporting year to serve as a fellow at the Environmental Protection Agency's Office of Water in Washington, DC.

Undergraduate Research Opportunities Program

This year the following students conducted UROP projects, supervised by Sea Grant staff in the lab or in the field:

Sydney Beasley, junior (Civil and Environmental Engineering UROP): Social Impacts of Herring Management in the Northeast Region of the United States (with Madeleine Hall-Arber, fall 2012)

Andrei Ivanov, freshman (Sea Grant): joint video and research work for MIT Sea Grant projects including Socioeconomic Impact of Federal and Interstate Management of Herring in the Northeast United States (with Lillie Paquette and Madeleine Hall-Arber, fall 2012)

James Slonaker, sophomore (Mechanical Engineering UROP): Solar Boats for Indigenous Amazon Peoples (with the Sea Grant Autonomous Underwater Vehicle Lab, fall 2012)

Mateo Pena Doll, junior (Mechanical Engineering, Sea Grant UROP): Solar Boats for Indigenous Amazon Peoples (with Sea Grant Autonomous Underwater Vehicle Lab, fall 2012)

Jennifer Astrachan, sophomore (Electrical Engineering and Computer Science, Sea Grant UROP): Survey of Eelgrass Beds (with Judy Pederson, fall 2012)

Rachel Aptowitz, sophomore (Mechanical Engineering UROP): Survey of Eelgrass Beds (with Judy Pederson, spring 2013)

Darcy Thompson, freshman (Sea Grant UROP): Seeking Invaders: Putting a Mitten on Crab Beds (with Judy Pederson, spring 2013)

Nathasha Rodriguez, junior (Sloan School of Management, Sea Grant UROP): Social Impacts of Herring Management in the Northeast Region of the United States (with Madeleine Hall-Arber, summer 2013)

Kira Schott, sophomore (Mechanical Engineering, Sea Grant UROP): Construction of a Model Wooden DDG Destroyer for the Classroom (with Chrys Chryssostomidis, summer 2013)

Internships and Volunteers

Husayn Karimi, a high school junior at Buckingham Browne and Nichols in Cambridge, MA, continues to make remarkable contributions at Sea Grant as a paid intern. This year he closed out his water temperature sensor project and was asked to develop a system to control and steer a small object, ostensibly a model plane. Husayn used the existing control algorithms from the Roomba vacuum cleaner, available at the Robot Operating System website, to make a seemingly aware mobile robot that is able to perceive and navigate its environment. He will next try to make this work in an aquatic environment.

Stephen Rodan (Mechanical Engineering) and Madeline Parry (Olin College) had paid internships helping to organize and run the 2012 Ocean Engineering Experience residential summer camp.

Blue Lobster Bowl participants hired as paid interns were Isabelle Holt of Watertown (home schooled), Jeffrey Ho of Sudbury High School, Pavlina Karafillis of the Winsor School, and Carolann Schack of Glastonbury High School in Connecticut. Their project focused on the intertidal ecology of the Boston Harbor Islands. It was these students who discovered a new invasive species, the European rock shrimp, in local waters in July 2012.

Staffing and Oversight

MIT Sea Grant is overseen by a joint advisory committee consisting of faculty members from MIT and other Massachusetts colleges and universities, leaders of Massachusetts marine-related industries, and representatives of state government and key nongovernmental organizations.

The program's management team previously consisted of a director (Chryssostomos Chryssostomidis) and a principal researcher (E. Eric Adams). Professor Chryssostomidis was responsible for overall program management, and Professor Adams focused on coastal processes. Our current research direction requires in-depth expertise in computational fluid dynamics and has led to the appointment of Dr. Stefano Brizzolara as the program's assistant director for research. Dr. Brizzolara brings a sophisticated understanding of the science and math of fluid dynamics that is essential to our ability to address a number of practical problems and solutions relevant to our research goals. The management team is jointly responsible for planning the program's strategic direction.

MIT Sea Grant's administrative staff consists of assistant director Timothy Downes (supported by two administrative staff members), program coordinator Katharine de Zengotita, and information technology professional Ben Bray. Judith Pederson leads the program's advisory group. The advisory, education, and outreach program currently has five professional staff members, including Pederson, who provide expertise in climate change mitigation, coastal ecosystems, invasive species, educational programming, fisheries anthropology, and data and communications. The advisory group has one administrative support staff member. In addition, Sea Grant employed six research engineers and two research scientists in the AUV Lab and in the Design Lab, working in support of externally funded projects.

Lillie Paquette joined the program as a communications specialist in September 2012.

Special Awards and Funding

Each year MIT Sea Grant awards the Doherty Career Development Chair for Ocean Utilization, a two-year appointment at $25,000 per year for a young professor working on a marine-related research topic. The 2013 winner is assistant professor Jonathan Runstadler (Department of Biological Engineering and Division of Comparative Medicine) for his project Influenza Ecology in the Ocean Environment: Environmental Persistence, Viral Adaptation, and Transmission between Seabirds and Marine Mammals.

Chryssostomos Chryssostomidis
Director
Henry L. and Grace Doherty Professor in Ocean Science and Engineering