Sea Grant College Program

The National Sea Grant College Program of the National Oceanic and Atmospheric Administration (NOAA) supports research, education, and outreach activities that address critical problems in human use of the sea. At the MIT Sea Grant College Program, we focus on developing the scientific and technological systems that can provide an 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.

The Program can be loosely organized into three areas of endeavor:

- The Autonomous Underwater Vehicle (AUV) Laboratory
- Funded research projects
- Education and advisory services

Autonomous Underwater Vehicle Laboratory

The MIT Sea Grant College Program is historically credited with the creation and development of AUVs—small, inexpensive, artificially intelligent, robotic submarines for undersea exploration. In keeping with this tradition of innovation, the laboratory's current strategic plan revolves around these key elements:

- Building a strong field team capable of conducting critical ocean experiments
- Developing the next generations of AUVs
- Designing and implementing near-real-time, multi-user, underwater communications systems

Hovering AUVs—the Next Generation

The second hovering vehicle developed by the lab was a joint project with Bluefin Robotics Corporation, an early spinoff of the AUV Lab. They are already commercializing it. Our next hovering vehicle, *Odyssey IV*, is nearing completion.

Odyssey IV is currently outfitted for field deployment with sonar instruments provided by Edgetech, Inc. (formerly EG&G, founded by Doc Edgerton). This payload will allow us to help NOAA and the National Marine Fisheries Service track the extent and

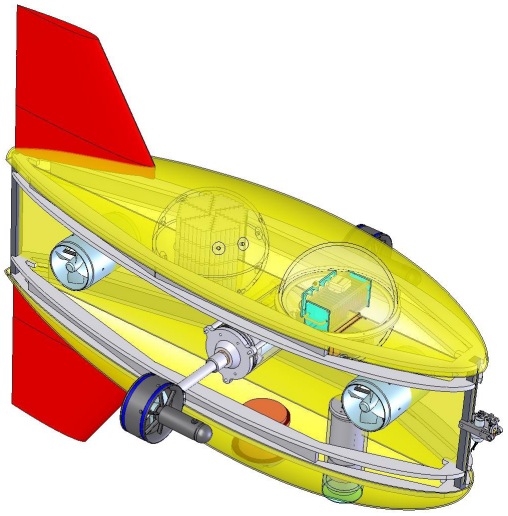

Figure 1. Odyssey IV: 2.1 meters long, 350kg in air, 2m/s top speed, 6000m depth rating.

spread of a recent infestation of *Didemnum sp.*, an invasive tunicate, on the seafloor at the important offshore fishing grounds of George's Bank.

This vehicle will serve as the basis for future prototypes now being considered by the Lab. These include vehicles capable of underwater manipulation, collecting physical samples, and intervention on deepwater installations.

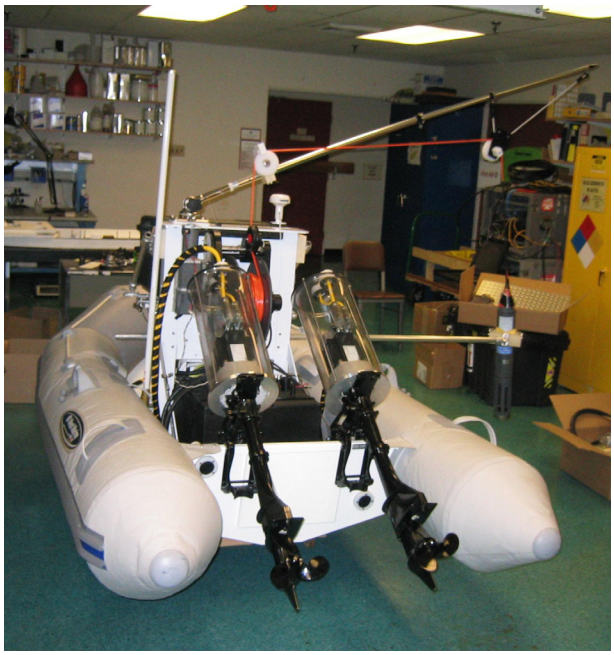

Figure 2. Katrina, an autonomous surface craft.

Autonomous Surface Craft

This year the Lab has taken on the development of an autonomous surface craft called *Katrina*, which can be supervised from a distance of up to 10 miles. Currently the payload sensor package can measure conductivity, temperature, depth, turbidity, and pH, taken in vertical profiles while the boat is stationary. The boat was designed for use in lakes and enclosed bodies of water affected by natural disasters such as Hurricane Katrina.

An unexpected benefit of the *Katrina* boat is that it can also be used in data assimilation, a technique used to improve the predictive accuracy of major oceanographic computer codes. A joint project with Rutgers University has allowed us to determine the optimum location of ocean measurements for use with data assimilation for ocean circulation prediction. Such a capability has opened up a completely new line of investigation, which will allow the Laboratory to participate in cutting-edge research in physical oceanography. This capability has direct applications in defense, oil exploration and production, and global warming.

Underwater Acoustic Communication

Deploying AUVs in a network with other subsea devices requires a dramatic improvement in underwater signal processing capability, both to enable vehicle navigation and for data collection and transmission. This year, Dr. Milica Stojanovic helped to organize the First International Workshop on Underwater Networks, which took place in Los Angeles in September 2006. The workshop was well-attended—participants included world-renowned experts in both communications and acoustical oceanography who presented a valuable collection of research papers now available at http://wuwnet.engr.uconn.edu/register.htm.

The basic thrust of our in-house research in underwater communication this year ranged from increasing fundamental acoustic channel capacity to new modulation/detection methods that hold a promise of high-rate, low-complexity implementations. In addition to scientific and engineering work, the acoustics team did some outreach,

visiting a Boston public school for an all-day, hands-on demonstration of the AUV Lab's underwater robotic vehicles in their swimming pool. For more information see http://web.mit.edu/SEAGRANT/news/pressreleases/2006/AUVlabatJQS.html.

Funded Research

MIT Sea Grant conducts a yearly funding competition as mandated by NOAA through its National Sea Grant Office. Grants are available to researchers throughout the Commonwealth of Massachusetts. Proposals selected support the goals outlined in our strategic plan and are required to match every two dollars from our federal grant money with one from nonfederal sources. Next year we are supporting the following major research projects with grants that average $75,000 per year for two years:

New Projects, Beginning February 2007

- An Investigation of Transient Tidal Eddies in the Western Gulf of Maine
  Wendell Brown, UMass Dartmouth
- Development of a Radon/Nitrate Mapping System for a Large Scale Assessment of Submarine Groundwater Discharge and Non-Point Source Pollution to Coastal Waters
  Matthew Charette, Woods Hole Oceanographic Institution
- Versatile, High-Resolution, Low-Cost AUV 3-D Sensor
  Douglas Hart, MIT
- Adaptive Mapping of Complex 3-D Marine Environments
  John J. Leonard, MIT
- Acoustic Communication Networks for Distributed Autonomous Underwater Platforms (Six-Year Focused Research Project)
  Milica Stojanovic, MIT
- Development and Validation of In Vitro Bioassays for Pesticides in Coastal Waters
  Tim Verslycke, Woods Hole Oceanographic Institution

Continuing Projects, Begun February 2006

- Acoustic Height Control for Trawl Doors
  Cliff Goudey, MIT
- Design of New Hybrid Actuators for drag Reduction and Underwater Acoustic Communications
  George Karniadakis, MIT/Brown
- Touch-At-A-Distance: Pressure Microsensor Arrays for AUV Navigation (Six-Year Focused Research Project)
  Jeffrey Lang, MIT
- Development of a Management Model System for the New England Shelf,
  Changsheng Chen, UMass Dartmouth

- Classifying Hurricanes with Natural Underwater Sound
  Nicholas Makris, MIT
- Fate of Sedimentary Monomethyl Mercury in Boston Harbor
  Janina Benoit, Wheaton College
- Nantucket Sound Circulation—Observations, Analysis, and Model Development
  Richard Limeburner, Woods Hole Oceanographic Institution

Advisory Services, Outreach, and Education

Part of MIT Sea Grant College Program's national and local mandate is to provide practical assistance to local communities, industries, educational institutions, coastal managers, fishermen, and the general public. The following is a sample of our advisory staff's current activities:

- Stretch-mesh catch controls—Design and testing of a trawl in Gloucester, MA, with a section of elastic netting, as a way to reduce catches of undersized groundfish.
- Whale-free buoy efficacy tests—Testing of a buoy designed to resist entanglement by marine mammals. This buoy has received a US patent.
- Selective gillnets for winter flounder—Evaluation of a new design of gillnet that targets winter flounder.
- Low-impact scallop dredge—Development of a habitat-sparing scallop dredge that does not scrape up the sea floor.
- Sand lance sampling gear development—Gear to aid in collection of sand lance, to evaluate their function in the food web of Stellwagen Bank.
- Passive acoustic detection of cod and haddock—Autonomous underwater listening stations are being designed to monitor vocalizations from spawning cod and haddock, for better decisions on protective closures of fisheries.
- Assessing Risk of Marine Introductions by Vessels in Small New England Ports: A Community Development Program—Researchers are working with small ports and harbors in Massachusetts to prevent or reduce invasions by aggressive introduced species such as the sea squirt.
- Marine Finfish Hatchery—MIT Sea Grant's hatchery is located at the Maritime Heritage Center in Gloucester and is an experiment in hatching marine finfish (fingerlings) to see if these species can be successfully aquacultured.

Regional Ocean Research Planning for the Gulf of Maine and Southern New England

The Gulf of Maine has been one of the most productive and diverse ecosystems in the nation, but today fish stocks are depleted and coastal areas suffer from overdevelopment, invasive species, and various forms of pollution. Policy makers and fisheries managers are faced daily with making decisions on resource extraction, zoning,

recreational boating and beach use, and maritime industry regulation, often without the data and information they need.

This project is a five-year effort to develop a "bottoms up" Regional Ocean Research (ROR) Plan that will provide a scientific basis to support policy decisions and management for the Gulf of Maine ecosystem. MIT Sea Grant was selected to lead this effort. In broad outline, we will:

- Appoint a regional Ocean Science Council
- Identify regional management and policy issues
- Prepare the ROR Plan, with budgets and timelines
- Design a process to ensure funding for regional councils and programs
- Implement the ROR Plan
- Create outreach materials for technology transfer and training

K–12 Education

MIT Sea Grant has always been active in K–12 education and we continue to create unique marine education programs that range from the very local to the national in scope.

The Sea Perch Program

Using the expertise of our AUV Lab, we have developed a groundbreaking educational initiative in underwater robotics. The program involves training high school teachers in the construction of a small, remotely operated vehicle called a Sea Perch, which is then deployed on some "mission" in a local body of water. This year, MIT Sea Grant staff traveled to Hawaii to do a training session that resulted in community college students introducing Sea Perch to high school students. Darren Okimoto of Hawaii Sea Grant is working with the state's Department of Education to align the Sea Perch curriculum with Hawaii teaching standards.

Reef Missions

The Exploring Remote Underwater Habitats with Autonomous Vehicles Collaboration in Hawaii will continue with an education project designed to allow students to remotely explore, map, sample, and observe an important coral reef ecosystem in Kane'ohe Bay off the Northwestern Islands. The AUV Lab's role will be to custom engineer a hovering vehicle, one that is compact in design and has shrouded propellers to prevent disruption

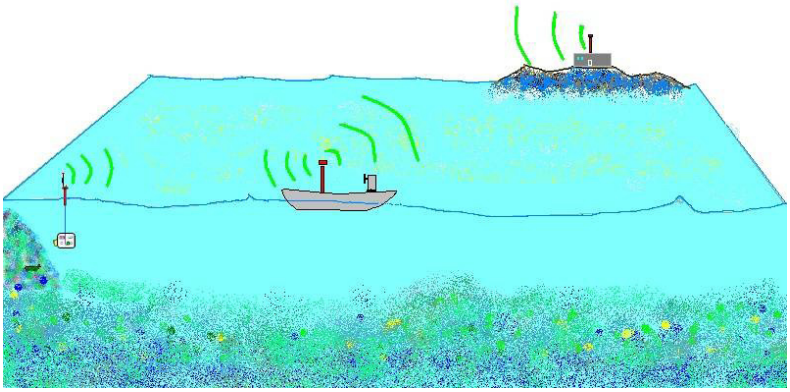

Figure 3. Drawing of the Hawaii Reef Project AUV in action.

of the reef's delicate ecosystem. The submersible's missions can be programmed beforehand or remotely operated in real time, with data transmitted back to students in the classroom, at first wirelessly and then over the web.

Adopt-a-Boat

In this program, commercial fishermen from Maine to Massachusetts, from seasonal lobstermen to captains of offshore trawlers, are partnered with classrooms. Activities include visits, fieldtrips, and information exchanges directly from the boat to the class. Fishermen help educate students about marine ecology, the complexities of marine resource utilization, and the daily work of the commercial fisheries.

Aquaculture in the Classroom

This activity is an extension of our Gloucester Marine Finfish Hatchery and outfits several Commonwealth schools with recirculating aquaculture systems for student participation and study. The Eelgrass Project described below is an extension of this program.

Figure 4. Young students transplanting eelgrass.

Developing a Classroom Eelgrass Cultivation Program for Massachusetts

Eelgrass is one of the most ecologically valuable marine and estuarine habitats in North American coastal waters, and is very common in Massachusetts. In this project, students learn to cultivate eelgrass as part of a polyculture recirculating aquaculture system. The goal of this two-year project is to develop a pilot program in which Massachusetts schools will grow eelgrass from seed and then participate in a statewide eelgrass restoration initiative by replanting their seedlings in local Massachusetts waters. Our objectives are to:

• Determine appropriate growing techniques and polyculture recirculating systems for eelgrass cultivation in the classroom

• Develop a year-round program in schools where students study the life history, biology, ecology, and cultivation of eelgrass

- Produce a "How-To" manual on growing eelgrass as part of a polyculture recirculating aquaculture system Foster a relationship with the Massachusetts Office of Coastal Zone Management seagrass program, particularly the Eelgrass Habitat Suitability Project

Faculty, Staff, and Oversight Committees

MIT Sea Grant College Program's management team consists of director Professor Chryssostomos Chryssostomidis, associate director Dr. Milica Stojanovic, and associate director for research utilization Dr. E. Eric Adams. Dr. Adams's research portfolio is in coastal processes, and Dr. Stojanovic's portfolio is in underwater communications. Professor Chryssostomidis is responsible for overall program management, including planning for the future.

MIT Sea Grant is under the oversight of a presidential committee consisting of faculty members from MIT Sloan School of Management and seven departments from the Schools of Science and Engineering. One of the principal tasks of the committee is to advise the MIT Sea Grant management team as to research directions and opportunities. Four members can rotate out of the committee each year. The MIT Sea Grant Committee is supported and complemented by the State-Industry Committee. This external committee includes leaders of local industry, faculty members from neighboring universities, and representatives of state government and key nongovernment organizations. The breadth, flexibility, and dedication of these two committees are key ingredients in the success of the MIT Sea Grant College Program.

The director is assisted by Richard Morris, executive officer; Timothy Downes, administrative officer; Clifford Goudey, marine advisory leader; Kathy de Zengotita, assistant to the director; and three administrative staff (two full-time employees). In addition, MIT Sea Grant employs eight research engineers to support our research activities, which include research in AUVs and our other externally-funded research. Our Advisory, Education, and Communications Program is executed by our advisory staff, whose activities include anthropological research in fisheries, control of nonindigenous species, public education, and communications.

MIT Sea Grant funds research in various departments. In addition, it is home base for four undergraduates doing in-house research, three visiting students, and two graduate students. We also support young MIT faculty by awarding the Doherty Career Development Chair for Ocean Utilization. The current holder is Professor Vladimir Stojanovic of Electrical Engineering and Computer Science, in the area of communications.

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 at http://web.mit.edu/seagrant/.