MIT SEA GRANT
Spring 1986

Quarterly Report

Josko Catipovic prepares to field-test DATS

Acoustical Communication through Reverberant, Underwater Environments

Routine maintenance tasks for the offshore industry include cleaning, inspecting and repairing parts of offshore platforms several hundred feet underwater. In those inky, frigid depths, divers depend on elaborate life support systems but are always aware that any slight error can mean quick death. Human efficiency is sharply limited by physical and psychological fatigue, and divers must spend several days after each work session in a decompression chamber to prevent the bends.

Ideally, people should remain safely on shore and send down unmanned submersibles to carry out the perilous deep-water chores. The submarine's versatility depends partially on how much information it can receive and transmit back to shore. However, communicating rapidly and efficiently with an underwater vehicle has always been a major problem. Usually an acoustic data link or else an electrical cable tether connects the surface station with the underwater instrument. While the tether carries information quickly and accurately, it is also heavy and awkward. An acoustical signal would free the vehicle from its cumbersome leash.

By incorporating current state-of-the-art technology, an experimental Digital Acoustic Telemetry System (DATS) can transmit data reliably without a tether at sufficiently rapid rates to be useful to a wide range of ocean exploration and development gear. Josko Catipovic, a PhD candidate in the joint MIT/Woods Hole Oceanographic Institution Program who helped develop DATS, says, "Most previous telemetry systems only operated in very unrealistic underwater situations, such as in deep water with nothing to reflect or scatter sound. The most important accomplishment of DATS was to operate over a very difficult channel. In fact, we designed a system for the worst channel we could think of: a marine harbor or marine worksite. I think that DATS is the first attempt at honestly evaluating the effects of a reverberant channel and trying to grapple with them in a telemetry system."

Catipovic considers the DATS an important experimental prototype which has specified crucial acoustical problems and showed clear ways of improving and simplifying a telemetry system's behavior. "We figured out what channel parameters are significant to the system, determined their effects, and measured them. This knowledge can be applied directly to a telemetry system inserted into a channel. From the information we can tell how a system will operate in the harbor. We've drawn out and performed a set of measurements that will define a harbor to an acoustic communications system."

A typical application for DATS would be to command a research submarine operating in a harbor, or to extract data from submerged oceanographic instruments without having to physically haul them up. Moorings for acoustic underwater tomography experiments, which measure slight changes across huge chunks of ocean, can stretch for thousands of meters and are very ungainly to deploy and retrieve. Currently the buoys have to be dredged up to the surface before the data can be scrutinized. With an underwater acoustic telemetry system, the buoys could be interrogated while still left in place, thereby saving days of expensive ship time.

Some systems need a clear path, or line of sight, between the speaker and the underwater listener. A line of sight path requires that all the echoes coming from different sides, such as the ocean bottom and surface, be suppressed. DATS, on the other hand, is capable of operating from the echoes of the received wave form, even if the transmitter is obscured by a ship or a dock. It will be able to operate from a principal echo coming in from another corner of the harbor since it can untangle secondary echoes coming at it from other directions and use them for a redundancy check, according to Catipovic.

In this issue

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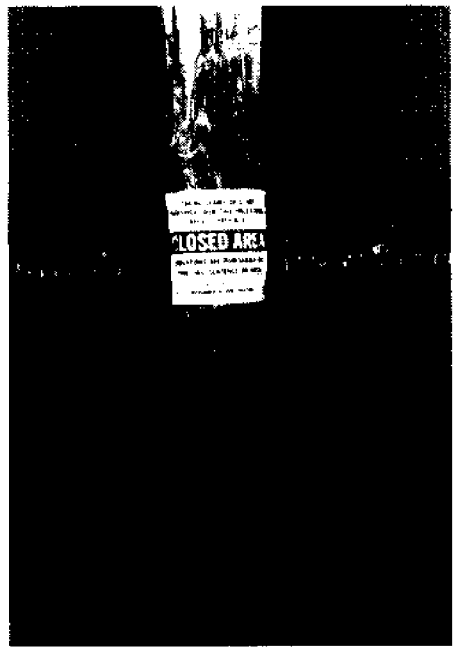
So far the system has been tested extensively in the Woods Hole (MA) harbor, under a frozen lake in New Hampshire, and in the marginal ice zone around northern Norway. Catipovic found that communicating in the marginal ice zone was quite different from communicating underneath a frozen lake. The former is a very lively environment that perturbs the signal dynamically with movements from icebergs, internal waves, and currents. Woods Hole Harbor is also a lively, dynamic place filled with noises and echoes from ships, heavy machinery in use, waves and docks. "DATS was well adapted to working in all these environments even though they are fundamentally different," he says.

At Woods Hole, DATS was tested in shallow water (18 to 21 ft) amid interference from ships and docks. In a number of shorter range experiments the researchers communicated along the length of a dock, underneath a ship, and across the entire harbor. The object was to understand how strong echoes would affect the reception of the data signal. "If we communicate from underneath a ship there are very strong sound echoes off the dock pilings and the ship. We extended a model that assumed we would fine very strong echoes off of moving unknown scatterers, and we certainly did find such things in the water. In that sense we proved the validity of the model. Tests in the marginal ice zone showed very strong scatterers arising from completely different physical parameters, and we knew how to cope with this behavior. The theoretical techniques for grappling with those echoes were evaluated and I think we confirmed the theory," states Catipovic.

Catipovic expects DATS to be most useful in the ranges up to a mile or two, which would be far enough to communicate with many moored instruments or with a sub examining the legs of an offshore platform. The maximum range is limited by the sound frequencies because the higher frequencies attenuate (dissipate) faster. While a 1000 kHz wave would only travel perhaps 10 yards underwater, a 100 kHz will propagate about a mile before it is significantly attenuated, and a 10 kHz signal will propagate 10 or 20 miles. Scaled down yet another order of magnitude, sounds in the 1 kHz range emitted by whales are audible for several hundred miles.

DATS was developed with Sea Grant support under Professor Arthur B. Baggeroer at the MIT Department of Ocean Engineering. Bill Hanot, Dan Koelsch and Keith von der Heydt also participated in the research and development, and additional funding was supplied by the Gould Corporation. Baggeroer says that a second generation DATS which would perform at higher data rates and over greater ranges is being considered. ■



Health officials rely on accurate bacterial counts to detect coastal water pollution

Biologist Discovers Aquatic Pollution Detective

Every summer, public health departments regularly check the number of coliform bacteria in the water at ocean and lake beaches. When the number of bacteria rises too high, indicating that the water is contaminated by sewage or sludge discharges, the beaches must be closed and swimmers are drydocked.

"The microbiological assay for detecting and tabulating coliform is rather insensitive, laborious, and time-consuming," says Professor Renee Fitts of the MIT Department of Applied Biology. In contrast, recent advances in DNA probe technology make it possible to detect potentially any organism in water, sewage, or other biological samples. The probes are used in DNA hybridization assays and can reveal the presence of very minute quantities of the sought-for organism.

Similarly, the detection of other microbiological human health hazards in the ocean, such as the red tide organism (shellfish poisoning), the hepatitis A virus, and *V. parahaemolyticus* (which causes severe diarrhea), is so laborious and expensive that it is often simply not done. DNA probes and hybridization assays, on the other hand, provide an excellent, economically feasible tool for specifically identifying and quantifying microbes in complex environments, says Fitts. Fitts' work in this area has won her the 1986 Doherty Professorship at MIT, a two-year appointment to conduct her research under the aegis of the MIT Sea Grant Program.

Traditional methods for assaying bacterial populations in water samples include 1) counting under a microscope the number of organisms present; 2) allowing the bacteria to grow into colonies; or 3) measuring total DNA or ATP in the samples. None of these methods, though, specifically identifies the organisms present. With a carefully chosen probe, which may consist of chromosomal genes or plasmid-borne genes encoding toxins or virulence factors, a DNA hybridization assay allows the researcher to discern and count any particular organism.

The development of DNA probes for coliforms would be the first application of this technology to ocean pollution problems. Fitts says, "We have developed diagnostic assays for the presence of bacterial pathogens in foods, resulting in a commercially available test for the food industry which has shortened their testing procedure by several days. This Sea Grant project addresses similar problems in water resources, and might also lead to commercially available products for managing coastal waters."

To perform a DNA hybridization on a particular organism such as *E. coli* (the most prevalent coliform in sewage), the researcher carefully chooses a segment of that organism's DNA to use as a probe. The probe DNA must consist of a nucleotide sequence found in all isolates of *E. coli* but not in other organisms. Next, the researcher develops a method for handling the sample. For example, testing a water sample from a harbor into which sewage

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Abstracts

☐ The Design and Performance Analysis of a Digital Acoustic Underwater Telemetry System

J.A. Catipovic, A.B. Baggeroer
K. von der Heydt, D.E. Koelsch
MITSG 85-12 54pp $5

Because the deepwater environment is a dangerous one for humans, remote sensors and robots are required for working there. This report, based on five years of research, discusses the design and performance characteristics of a system for transmitting data between deepsea instruments and surface work stations. The system, Digital Acoustic Telemetry System (DATS), incorporates the current state-of-the-art technology and is capable of reliable data transmission at rates useful for a wide range of tasks.

DATS is designed to operate in very reverberant channels, a requirement for deepsea transmission. It adaptively monitors the time and frequency dispersion of the channel and uses the measurements to correct the demodulator and decoder. This yields a more complicated, but significantly more robust system which can operate in more places and with less care than other dispersion dependent systems. The design of DATS is based on a realistic model of the high-frequency channel generally accepted in the ocean acoustic literature. The report presents measurements of the channel used at frequencies centered at 50 kHz and at ranges of up to 1km in shallow water.

☐ Coastal Zone and Continental Shelf Conflict Resolution: Improving Ocean Use and Resource Dispute Management

J.D. Nyhart, ed.
MITSG 85-28 159pp $15

With advancing technology opening up greater opportunities for using the oceans, conflicts are arising over such differing uses as oil drilling and fishing or sewage disposal and recreation. Traditionally, remedies for such conflicts have been sought in the courts. But this route is costly both in terms of time and money, and often results in outcomes unsatisfactory to at least one of the parties. In response, non-adjudicatory processes have sprung up, including mediation and facilitation to settle cases out of court. An MIT Sea Grant conference focused on these alternative methods of dispute resolution as they applied to conflicts in the coastal zone and outer continental shelf. Papers presented at the conference are published in these proceedings.

☐ A Robust Design Method for Impedance Control of Constrained Dynamic Systems

Homayoon Kazerooni
MITSG 85-35TN 140pp $14

Remotely operated underwater vehicles must sometimes attach themselves to a structure to inspect, clean or repair it using a manipulator or other work tools. The interaction of classical control and constraining attachment systems can cause high forces and possibly destroy the equipment. This report complements MITSG 85-34 abstracted in the Winter 1986 QR. It provides considerable detail on the extension of impedance control to include constraints as a special kind of external load. The research reported shows that a controller can be built to work safely with systems having constraints or attachment mechanisms which severely limit motion.

☐ On the Rational Selection of Strengthening Criteria for Navigation in Ice

P.C. Xirouchakis
MITSG 85-32TN 127pp $7

Ice imposes severe limits on studying, exploring, and using Arctic resources. This report describes Sea Grant research to predict the maximum ice sheet pressure on walls of the side shell structure of vessels, such as ships, ice breakers, or mobile offshore platforms, which travel through ice. Structural idealizations, based on the theory of beams on elastic foundation, define stiffness criteria and numerical procedures define strengthening criteria for ice navigation. Elastic plastic frame buckling criteria use a generalized Shanley model and a numerical solution procedure. Stiffness criteria are important to interpret field test data so the imposed ice forces can be evaluated and the strengthening criteria defined. In the final chapter, the report recommends future research needs.

☐ **Strength-Deformation Properties of Arctic Silt**

C.C. Ladd, J.S. Weaver
J.T. Germaine, D.P. Sauls
MITSG 85-22J 11pp no charge

The offshore industry is developing mobile gravity structures to operate in deep Arctic waters. Foundation design depends on complex soil conditions requiring more comprehensive evaluation of strength deformation properties than has been needed for pile supported platforms. Lack of experience in in situ behavior of silts complicates the problem further. This paper summarizes classification and related properties of Arctic silts in Harrison Bay, Alaska and discusses the effect of temperatures on consolidation test results. The main focus is on undrained stress-strain-strength anisotropy of normal consolidated Arctic silt. Reprinted from Arctic '85 ASCE, San Francisco, CA, March, 1985.

☐ **Test Results from the New England Trawl Net Training Courses**

Clifford A. Goudey
Center for Fisheries Engineering Research
Report No. 11
MITSG 85-33 15pp no charge

Over the last two years the Fisheries Engineering Center at MIT has helped to organize and run a series of net tests at the David Taylor Naval Ship R&D Center in Bethesda, Maryland. This publication includes reprints of articles written by Goudey for *Commercial Fisheries News* on model test results from the New England Trawl Net Training Courses which were held from March through September 1985.

☐ **Tow Tank Results of Bulbous Bow Retrofits on New England Trawler Hulls**

Angelos D. Heliotis
Clifford A. Goudey
Center for Fisheries Engineering Research
Report No. 9
MITSG 85-7 45pp no charge

Most large ships are designed with blunt bulbous projections on their bows to increase the efficiency of driving a hull through the water. Research in this report applies the rounded, bulbous concept of bow design to New England trawlers 76' and 119' in overall length. (MITSG 85-15 reported on tests applied to 50 meter freshfish stern trawler, QR, Fall 1985). Calm water resistance tests were done with 4.5' models. Bare hull results were compared with data gathered when the models were retrofitted with a series of 12 cylindrical bulbous bows. The researchers concluded that simple bulb shapes can effectively reduce hull resistance at steaming speeds typical for the trawler hulls studied and thereby reduce horsepower requirements.

☐ **MIT Sea Grant Thesis List 1980-1983**

Susan Stolz Goldie
MITSG 83-8 30pp no charge

The MIT Sea Grant Information Center has made available a list of theses and reports from Undergraduate Research Opportunity (UROP) projects sponsored in 1980-83. The papers are organized in the same subject categories as MIT Sea Grant's two research report directories (MITSG 84-16 and MITSG 78-6). Each citation lists the thesis title, author, supervising faculty, and MIT department. The 1984-85 list is being compiled.

You may order one copy of these reports free of charge.

Please check off those publications you would like to order, and return this entire page – or a copy of it – to the Sea Grant Program, Massachusetts Institute of Technology, Building E38-302, Cambridge, MA 02139.

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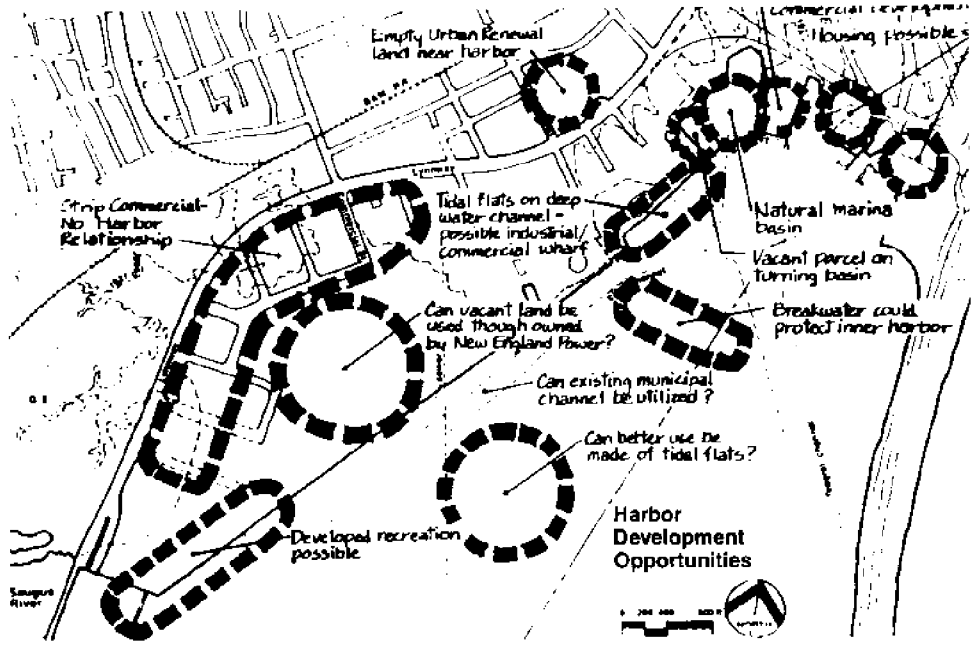
has been released can involve collecting the bacteria in the sample onto a membrane filter.

The DNA in the bacteria which are stuck to the filter is released from the bacteria by adding a simple reagent. Then the DNA is denatured into single DNA strands and permanently stuck to the filter, so it will not wash away when the filters are soaked in a hybridization mixture containing probe DNA. The probe molecule seeks out complementary sequences in the target DNA on the filter and base-pairs with it to form a hybrid duplex. Since the probe molecule is always labeled in some way, usually with a radioisotope, the amount of *E. coli* in the water sample is calculated by simply measuring radioactivity on the hybridized filter.

Isolating a DNA probe specific for *E. coli*, and additional probes for other organisms which are health hazards, would make it possible to locate and count these organisms throughout Massachusetts Bay and the New England coastline. These techniques would be extremely useful to public health laboratories, environmental protection workers, researchers interested in aquatic microbial populations, and some commercial fishing ventures. In addition, DNA probes and hybridization assays are especially amenable to automation and are attractive for further development as products for biotechnology companies.

Fitts and colleagues plan to study several thousand water samples from the New England coastline using their *E. coli* specific probe and presumptive coliform-specific probe in hybridization assays. In parallel, they will perform standard microbiological assays for the presence of coliforms to determine the relative efficiencies of the different methods and evaluate any possible discrepancies. "The only really time-consuming part of the study will be the microbiology, since the hybridizations can be done in batches very easily in a short time," says Fitts. "The advantages of hybridization assays will become clear at this point, because of the ease of handling samples and the tremendous savings in time and effort."

"The major benefit of a DNA hybridization for the presence of coliforms in coastal waters is a major time saving and cost saving in the performance of coliform counts, mainly by public health laboratories," remarks Fitts. "Since these assays are done to evaluate health and environmental hazards, the end result of a faster, better test is better management of water resources from both commercial and recreational standpoints." ■



Conflicts arising over competing coastal uses can be resolved cooperatively

How to Avoid Litigation in Coastal Zone Conflicts

There is a story of two people who fought over an orange, one needed to use the peel but the other wanted the fruit for juice. Finally the rivals settled by splitting the orange in half, having lost sight in the heat of the argument that each could have had all that they wanted.

This scenario, says Donald B. Straus, President of the Research Institute of the American Arbitration Association and then MIT assistant professor of Behavioral and Policy Sciences Max Bazerman, is typical of the traditional approach to settling disputes through litigation, where conflicting parties focus on "How much of the orange can I get?" instead of "What is the best way in which this orange can be divided?" This win-lose mentality overlooks so-called "integrative agreements," where all parties come out winners: one person takes the whole peel, leaving the other all the juice.

Straus and Bazerman spoke at an MIT Sea Grant conference on Coastal Zone and Continental Shelf Conflict Resolution, at which alternatives to litigation were explored for solving disputes over the uses and management of coastal resources. (See *Abstracts* insert in this *Quarterly Report* for information about ordering a copy of the conference proceedings.) Bazerman and Straus contend that most negotiators operate on a "fixed-pie" assumption learned in society through, for example, athletic competitions, academic admissions, and job ladders. "Unfortunately, individuals tend to overgeneralize this lesson learned in fixed-pie contexts to many other domains in which an expandable pie exists," the speakers maintain.

The need for conflict resolution techniques in the coastal zone has arisen as new technologies open up greater opportunities for using ocean resources. J.D. Nyhart, MIT Professor of management and ocean engineering, says that adversarial confrontations are erupting among industry, recreation groups, environmentalists and governments over offshore oil and gas exploration and exploitation, offshore dumping, effluent piping, boundary determination, and environmental preservation. In the U.S. differences arising over these issues are usually litigated through the court system. Often, however, the result of litigation is that neither party is satisfied and frequently one party is totally unsatisfied.

Lawrence Susskind, MIT professor of Urban Studies and Planning and Executive Director of the Harvard Law School Program on Negotiation defines a "good" outcome in negotiation as one that

- satisfies the interests of all parties
- produces a solution in which all possible joint gains are secured
- produces definitive results that are implementable
- is legitimate in all eyes
- deals wisely with uncertainty
- is reached as quickly as possible and
- improves relationships

Unfortunately, Susskind says, traditional approaches to conflict resolution fail to achieve a satisfactory outcome. When emotions heat up, the dispute degenerates into tests of will rather than focusing on

problem-solving. In addition traditional dispute resolution mechanisms frequently produce decisions that are unenforceable or that require still further legal action to implement. In some instances they undermine relationships or encourage an escalation of adversarial behavior.

On the other hand less adversarial, non-adjudicatory forms of dispute resolution recognize the legitimate claims of both sides and explore potential joint gains. These consensual approaches are often quite appropriate in the multi-party, multi-issue disputes typical of OCS and CZM decisionmaking. Susskind describes five alternative approaches to dispute resolution, several of which have been used successfully in marine-related disputes:

Unassisted Negotiation. Disputing parties are encouraged to talk through their differences and to search for win-win outcomes. If the parties are trained negotiators, they may be able to transform confrontation into side-by-side problem solving.

Facilitation. From the start of negotiations or when disputing parties have reached an impasse, trained, non-partisan facilitators can transform incipient conflicts into joint problem-solving opportunities.

Mediation. A non-partisan outsider selected by mutual agreement can reestablish broken-down communications by serving as a go-between or by helping bring about a reconciliation. Mediators with substantive knowledge of the issues involved can sometimes come up with ingenious solutions acceptable to all parties.

Mini-Trials. Prior to incurring the costs and delays of going to court, parties to a dispute may find that mock trials in front of a panel of experts, or "rented judges" can give a more realistic appraisal of the chances of winning in court and thus lead to negotiated settlements. The method is a popular way of settling business cases.

Non-Binding Arbitration. This approach serves many of the same purposes as a mini-trial, but tends to yield more definitive outcomes.

The use of models, or Computer-Aided Negotiation (CAN) is also a widely-touted technique in coastal and OCS conflicts involving complex scientific processes and multiple interest groups. MIT Associate Professor of Marine Systems Harilaos Psaraftis defines a model as "an abstraction of reality whose purpose is to represent well-defined real-world processes." In addition to providing insights into the workings of the processes it represents and organizing highly complex realities into workable scales, models can help negotiators to test various alternative solutions to problems.

According to Nyhart, the time for alternative negotiating techniques has come. There is now, he says, an accumulated body of experience in ocean-related negotiation. Federal agencies, the oil and fishing industries and environmental groups concerned with offshore oil and gas lease sales appear serious about finding better ways to resolve their differences. Finally, besides oil and gas drilling, other proposed uses of the ocean – incineration at sea, waste disposal, and tidal power, for example – threaten to cause conflicts that are by nature susceptible to alternative resolution approaches. ■

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