MASSACHUSETTS
INSTITUTE
OF TECHNOLOGY
SEA GRANT
COLLEGE PROGRAM

"How fully and wisely the United States uses the sea in the decades ahead will affect profoundly its security, its economy, its ability to meet increasing demands for food and raw materials, its position and influence in the world community, and the quality of the environment in which its people live."

The Stratton Report
Our Nation and the Sea
January 1969

All quotations that appear throughout this publication are excerpts from The Stratton Report, *Our Nation and the Sea.*

A Report on the Massachusetts Institute of Technology Sea Grant College Program

1 July 1977 to 30 June 1978

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CONTENTS

"A new and potentially very important program in support of marine science and technology is that sponsored under the National Sea Grant College Program Act . . ."

LETTER FROM THE DIRECTOR

Almost a decade ago, the Stratton Commission reported to the President of the United States the results of an intensive review of the nation's marine resource development potential. In a four-volume study, *Our Nation and the Sea,* the Commission cited the Sea Grant College Program, then three years old, as a mechanism through which some of the objectives outlined in their report could be accomplished.

Today, as we review ten years of activity among Sea Grant researchers, educators, and advisory services, the National Program's achievements emerge to justify the Commission's confidence. Planning studies and computer models have helped to resolve conflicts and control unplanned growth in the coastal zone; Sea Grant research has contributed to cleaning some of the nation's polluted waters; new technology, developed with the Program's support, is adding to our knowledge of the oceans and to our abilities to recover valuable raw materials from them. In addition, Sea Grant by including students in its research activities, has trained and equipped many professionals for work in the expanding marine field.

MIT Sea Grant is one of 27 university-based programs; each carefully balances research, advisory services and education; each operates to serve both a local and national constituency; and each makes a unique contribution as it draws from the specific talents and the expertise of the university's faculty and students. All programs, funded through the National Oceanic and Atmospheric Administration in the U.S. Department of Commerce, share information and research with each other, creating a marine research network.

This annual report from the MIT Sea Grant College Program is a summary of one year's work in one university. It provides a glimpse into the larger reservoirs of knowledge and experience accessible through both the Massachusetts Institute of Technology and the entire National Sea Grant College Program. Our report has been framed against some of the recommendations made by the Stratton Commission to aid us in measuring our progress and achievements against national goals.

With this report on our projects and activities supported from July 1, 1977 through June 30, 1978, we invite scrutiny and encourage future participation of the American people in the MIT Sea Grant Program. Although we are proud of our accomplishments, we recognize that our contribution is necessarily small. The oceans are vast and complex, requiring the efforts of all the nation's citizens in the years to come if we are truly to achieve the wise and balanced uses of our marine resources.

Dean A. Horn
Director

RESEARCH

"The Nation's marine capability must be built upon an expanding base of knowledge and practical skills. Understanding the sea is the task of marine science. Improvement of operational skills, equipment, and methods is the responsibility of marine technology."

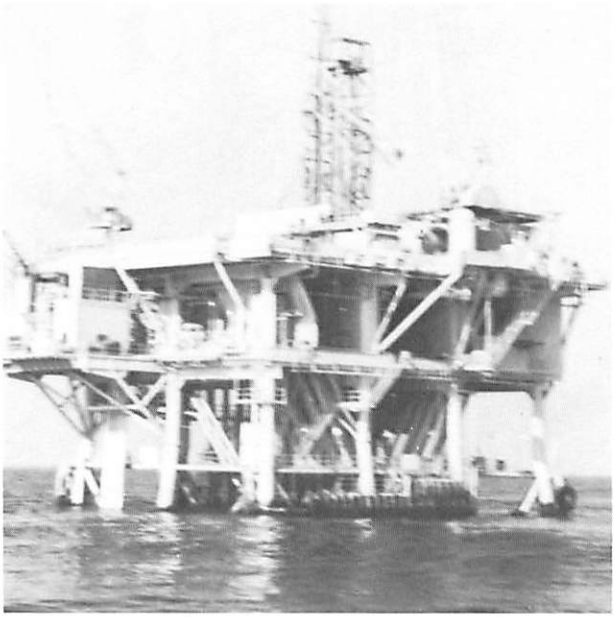
Although best known for contributions to technology development for land and space uses, the Institute has long been involved in applying fundamental engineering and scientific skills to ocean exploitation. Faculty and students first began creating a reservoir of knowledge and devising technology for use in marine development over eighty years ago, when MIT established the nation's first Department of Naval Architecture and Marine Engineering.

MIT's interest in joining the National Sea Grant College Program in 1970 stemmed from past experience in the ocean sciences and from faculty and student enthusiasm for sharing in the national effort to develop the ocean's potential and to redress past damage to the environment.

Within the Institute, Sea Grant serves as a focal point for applied marine research, identifying scientists who can help constituents solve problems or capitalize on opportunities. At present, as interest in exploiting offshore mineral resources grows, there is an urgent need for greater knowledge of the deep oceans. New materials are required to build, monitor, and maintain huge structures at sea. And the economic and environmental costs of oil spills from tankers and from operating oil wells, concern industry and coastal residents alike.

In the coastal zone itself, unplanned growth has placed serious strains on groundwater resources; lack of management has resulted in depleted fishery stocks; and unchecked construction onshore has caused serious erosion and deposition problems. Sea Grant's research program is designed to provide information and technology that enables business and industry to make development decisions that provide benefits to themselves and the nation for both current and future generations.

"The Commission urges that the proposed National Oceanic and Atmospheric Agency initiate a major program to stimulate the development of fundamental marine technology and engineering in order to expand the scope and to lower the costs of undersea operations."



OFFSHORE RESOURCE DEVELOPMENT

Undersea Telemanipulators

The challenge of communicating with, commanding, and controlling a remote vehicle first interested Professor Thomas B. Sheridan in the early 1960s when he was working to put men and monitoring equipment on the moon. Professor Sheridan and associates are adapting this aerospace technology to the hydrospace environment. Telemanipulator technology is being adapted to problems of inspection and repair of underwater structures. The telemanipulator is capable of responding to direct commands from an operator or using its own "intelligence" to make some of its own decisions and to carry out certain repetitive tasks.

Because sonar communications are slow and are of limited bandwidth, time delays are incurred between the time a signal is given and the time when the result of that signal is observed on the surface. During the time delay period, the teleoperator must be able to make its own decisions to avoid dangerous and damaging situations or to complete a sequence of tasks without awaiting complete instructions at each step.

Following a literature survey and consultation with industry experts, the researchers are analyzing the telemanipulator's abilities to perform a well-defined, specifically needed set of tasks under both direct manual and computer control.

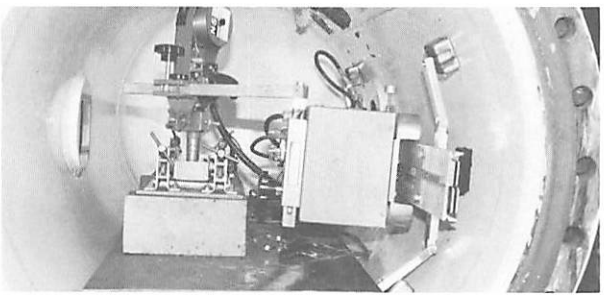
Because of high accident rates and high dollar costs for human divers and manned submersibles, such teleoperators, sharing and trading tasks with human operators located on the surface, promise the offshore industries safety and economic advantages.

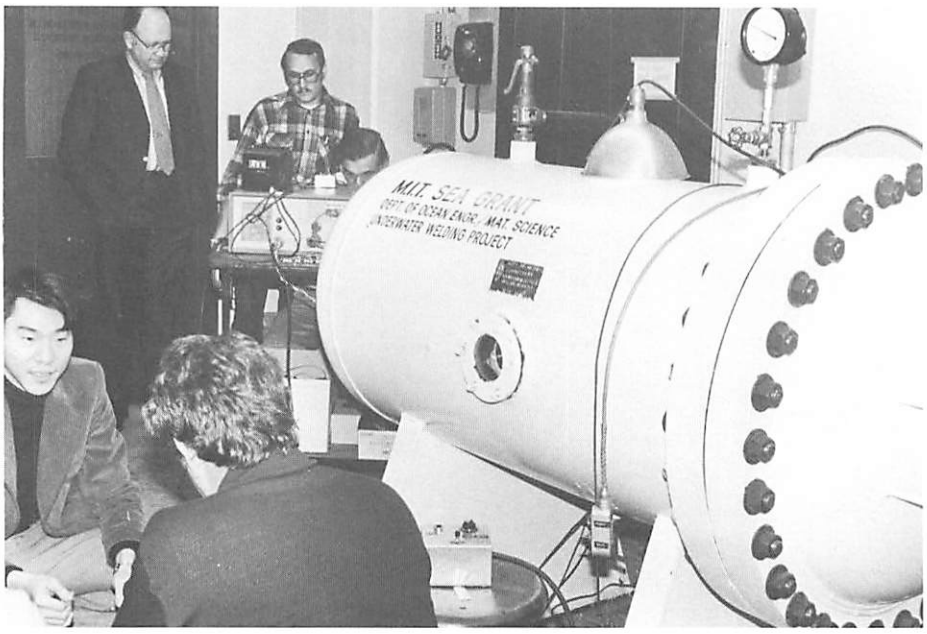
Navigation Systems Underwater

The successful development of a light-weight, lower power inertial rotation sensor for a compact navigation system will benefit deep sea operations, now dependent on magnetic compass devices where size, weight, or power preclude the use of expensive gyroscopic systems. Professor Shaoul Ezekiel of the Department of Aeronautics and Astronautics examined the feasibility of basing a new sensor concept on the use of a closed fiber-optic ring.

To make measurements of the pertinent parameters of the ring fiber, he and associated researchers designed a special helium-neon laser system. Work underway in the laboratory addresses the problems of obtaining an adequate signal-to-noise ratio in the system in order to obtain the required sensitivity.

Completion of the project in 1980 could prove the feasibility of such a device which could provide major benefits to industries working in the oceans as well as to recreational boaters who use the nation's waters for sport and pleasure. Essentially, this device will be equivalent to expensive inertial guidance systems and, like them, will be independent of local magnetic fields; hence no deviation or variation corrections will be required.





Deep Sea Construction And Repair Techniques

Underwater welding techniques developed by Sea Grant scientists at MIT will be a tremendous help to oil, shipping, and mineral industries as resource exploitation moves into deeper waters. Human divers limited by dangerous, deep ocean conditions, will be replaced by welding robots or remotely controlled deep sea vehicles which require simple, easy-to-use tools.

In an earlier Sea Grant project, Professor Koichi Masubuchi of the MIT Department of Ocean Engineering studied existing techniques and then adapted one, the flux shielded arc welding method, for underwater work. Underwater welding has generally resulted in brittle, unreliable welds because of the rapid cooling effect of seawater and the free hydrogen ions caused by the underwater arc. Professor Masubuchi is working on a technique that involves laying a flux-filled, water-tight plastic enclosure over the joint to be welded. The electrode is inserted through the plastic and the welding takes place in a flux-filled environment; the weld cools before the water displaces the flux.

Sea Grant research associates are testing this technique in a pressure tank designed and constructed to provide the pressurized equivalent of 700 foot depths. Observations analyzed in a computer program are being applied to creating welding tools that can be manufactured by industries for both construction and maintenance of oil rigs, pipelines, and off-shore porting facilities in deep water.

Soil Conditions and Structure Design

In order to design more efficient, safer offshore structures, engineers must be able to assess reliably the supporting capacity of ocean sediments. Since water pressure is reduced as a sample is brought from the bottom to the surface, such samples cannot be reliably analyzed in the laboratory to determine the sediment strength on the seafloor. As a consequence, industry engineers must overbuild structures because they are unable to predict accurately the supporting capacity of ocean sediments.

Professors Charles C. Ladd and Mohsen B. Baligh, geotechnical experts from MIT's Department of Civil Engineering, believe that *in situ* testing can provide engineers with consistent, reliable information on the underlying soil structure economically and simply. In cooperation with an industrial consulting firm, they have investigated the application of a penetration device, known as the Dutch cone, which was originally developed to design pile foundations.

They have observed and documented the performance of the instrument at three land sites, and will be able to correlate the data with information obtained from ocean tests conducted on a working platform exploring for oil off the coast of Venezuela. Information is obtained by measuring resistance of the tip of the cone itself and the friction created on a cylindrical sleeve behind the tip. By also measuring the water pressure as the cone is pushed through stratified sediments, then observing the rate at which pressure decreases when the cone is stopped, the Sea Grant scientists are further able to determine soil type, the presence of sand in cohesive deposits, and the soil strength. This new, more sophisticated instrumentation system provides valuable support to industry charged with developing marine resources.

Decisions Under Uncertainty

Georges Bank, located off the New England coast, supplies the United States with a substantial percentage of the fish caught and processed by Americans for domestic and foreign markets. Fishermen, food processors, and many boating and gear manufacturers are economically dependent on the continuing vitality of the area's stocks.

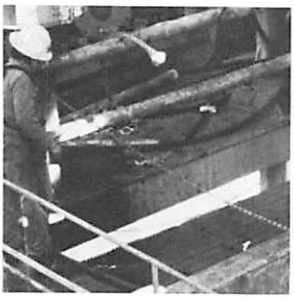
Recent geological surveys indicating that Georges Bank could also be a source of large oil and gas deposits have raised serious questions. How will oil recovery operations affect marine life? What risks are involved? How can these risks be quantified? Can they be eliminated or minimized?

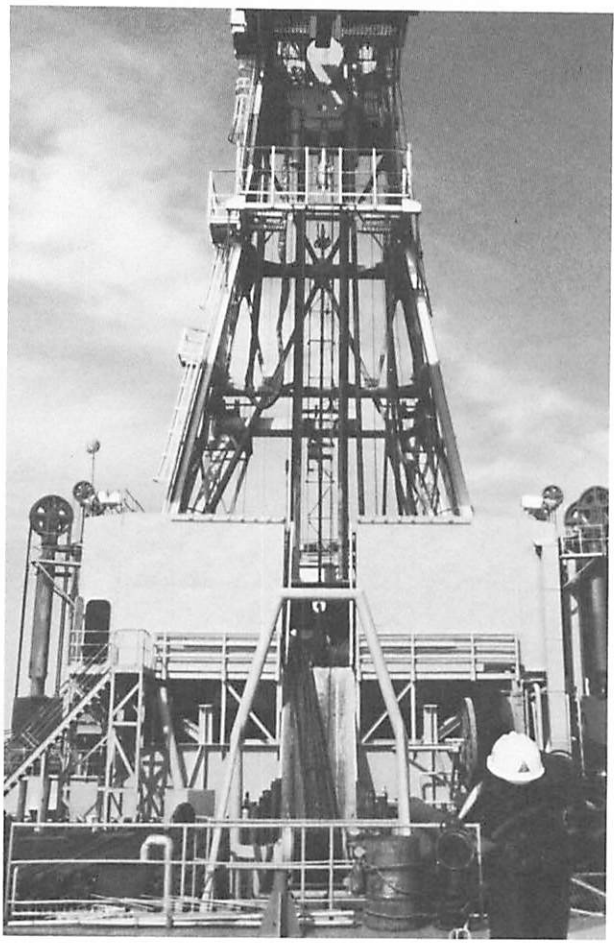
Over the years Sea Grant has supported a number of computer modeling projects in MIT's Department of Civil Engineering. The Department is known for its experience in risk assessment and decision analysis for onshore facilities. MIT Professor Gregory B. Baecher is now focusing his studies offshore. Professor Baecher points out that many unknowns are involved in working in the ocean at present, and that an assessment of the risks is essential to sound decision making.

His Sea Grant model is based on probability analysis, a modeling technique employed when available data and experience are inadequate or unsupported. The method allows him to draw conclusions based on the laws of physics and experience under similar but different conditions, and it enables the researcher to incorporate identified uncertainties.

Professor Baecher is analyzing the risks of building on various kinds of soils under shifting, settling, and breaking conditions induced by either natural or structural forces. Because a number of current geotechnical studies are underway at MIT, Professor Baecher is incorporating new, increasingly reliable data on *in situ* sampling, subsurface geometry, and mechanical structural behavior.

The research will be of great value to government officials responsible for making the decisions required for all offshore development projects. Engineers and industry will be able to make cost and design decisions employing the model to study the sequence, consequence, and magnitude of potential structural failures. Long-range benefits will redound to all citizens when resources are recovered with methodical, careful considerations for all coastal and ocean resources.





Detecting Structural Failure

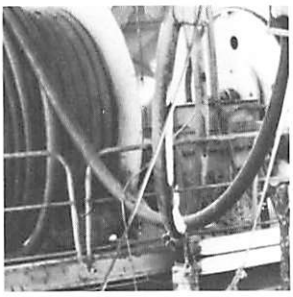
Offshore structures, subjected to severe natural stresses from ocean waves, shifting sediments, high winds, and strong currents, may weaken and fail. Defects must be identified before they become serious enough to cause human or environmental accidents or force costly closings of large and productive oil and gas rigs.

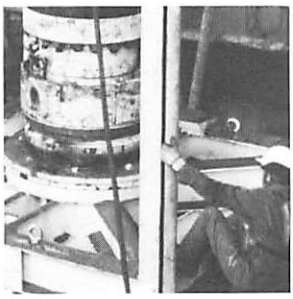
For several years, civil engineers have measured the natural frequencies of buildings with sensitive devices, known as accelerometers, before and after earthquakes to locate possible structural damage. A detected shift in the vibration response between successive measurements indicates a change in the structure. Such a change implies failure in either the structure itself or its supporting bottom conditions.

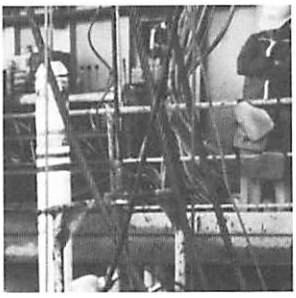
Professor J. Kim Vandiver of MIT's Department of Ocean Engineering proposed to extend this technique to offshore structures. In 1974, experiments on and computer studies of a manned U.S. Coast Guard tower near the Massachusetts coast showed the technique had potential in ocean applications. By combining vibration measurements and a computer model, a standard is obtained against which future vibration measurements can be compared to determine if structural changes have taken place. Though not applicable to all the more than 2,000 offshore structures in use today, measurements of vibration response may prove useful for many existing and future structures in monitoring structural integrity.

In a separate study, Professor Vandiver developed a new technique for estimating the vibration response of a structure to random ocean waves. The new techniques allow upper bound response estimates to be made without requiring the details of the structural configuration or the explicit calculation of wave forces.

In a parallel Sea Grant project, Professor Vandiver and research associates are investigating technology that would allow engineers to supress the vibration response of a structure and the resulting cyclical stresses by careful configuration and placement of the oil and water storage tanks located on the deck. Preliminary field tests and analysis by Professor Vandiver reveal that the shape of the storage units can be altered to tune the structures to minimize deck response. Future collaboration with industry will allow researchers to develop hardware and conduct field tests to implement this novel design in future deepwater structures.







Modifying Existing Materials for Ocean Uses

Cost and durability are of prime importance to industries building and working in the seas. At present, many materials that have survived the stresses of land use degrade rapidly in the marine environment and must be replaced. Fibers currently used to insulate electrical cables in aids to navigation and underwater work and survey equipment are one example of materials that have limited life at sea.

In the Department of Chemical Engineering, Sea Grant Professors Richard G. Donnelly and Robert E. Cohen are conducting simultaneous experiments on three methods for modifying polyethylene, a common, inexpensively manufactured polymer, to increase its resistance to degradation in seawater. To date the most extensive tests have been completed using a surface active agent to trigger a sequence of reactions to form a resistant protective coating around the polymer. However, radiation grafting and cross linking with activated gasses are also being seriously considered as methods for altering the materials to make them more durable in seawater.

In the future, low cost, versatile polymers could have applications in the manufacture of many primary construction materials required for recovering minerals and energy from the oceans.

Energy from the Oceans

There seems to be little question that other sources of energy are needed to supplement reserves of oil, gas, and coal. No one energy source appears to provide a simple, technologically, and economically feasible answer.

To plan ahead, scientists, supported by government and industry, are studying the sun, biomass grown on land and in the ocean, and the seas themselves – tides, currents, and temperature variations.

At MIT Sea Grant, during the past two years Professor C.C. Mei of the Civil Engineering Department and Professor A.D. Carmichael of Ocean Engineering have been investigating the efficiency and practicability of employing a teardrop-shaped cylinder as a potential small power source for at-sea use.

"Today, man's damage to the environment too often is ignored because of immediate economic advantage. To maximize the present economy at the

Named after its British inventor, the Salter Cam is a device that rotates on a central axis, rocking back and forth with the waves and absorbing energy by driving a generating device such as an hydraulic pump. Uncertain about its behavior under the random condition of ocean waves, Professor Mei conducted a theoretical hydrodynamic computer analysis with promising results. Professor Carmichael comprehensively tested the Cam's efficiency in MIT's wave and towing tanks to assess the effects of changing the operating conditions and giving it varying degrees of freedom to rock. The results indicate the device operates efficiently as an energy absorber, but the cost of a mooring system may prohibit its widespread application. Future economic and design considerations will be discussed in early 1979 when Professors Mei and Carmichael present their findings to government and industry representatives at an MIT Marine Industry Collegium meeting.

Policy for Deep Ocean Mining

New technology has made it possible to recover significant deposits of mineral-rich manganese nodules from seabeds in international waters. Professor J.D. Nyhart and research assistants have created a computer cost model that is being used by the U.S. government as a tool for creating an ocean mining policy which considers both the rights of American investors and the international community. The model calculates capital and operating costs of a "typical" deep-sea mining company. It allows users to estimate changes in tax laws, market conditions and delays in using existing technology on return on investment to the company. Congressional committees and government agencies, seeking to establish a stable investment climate for U.S. industry and to assure fair profit-sharing arrangements with other nations, are benefiting from the detailed economic information available through this model.

ONSHORE/OFFSHORE POLLUTION

Oil at Sea

The chances that large oil spills will occur multiply as offshore oil recovery expands, and tanker capacity and oil transport increase. At present the world produces 3 billion metric tons of oil every year. And 70 percent of this is transported across the oceans.

Even the most spohisticated technology cannot eliminate accidents; neither machines nor people are flawless. Therefore, it is necessary, indeed essential, to anticipate spills and make plans to minimize the damage they can cause.

Present strategies and equipment for cleaning up oil seem to be effective in the nearshore environment, but offshore efficiency is limited. At sea a number of processes affect the dispersion of oil, making it difficult to determine how much evaporates and how much is entrained in the sea; or to know in what direction and at what speed the residual oil will travel. Without this information, responsible government agencies such as the Coast Guard are unable to specify equipment design or logistical requirements that will ensure the oil is cleaned up at sea before it either washes ashore or is embedded in ocean sediments.

expense of the future is to perpetuate the pattern of previous generations, whose sins against the planet we have inherited."

For several years, Professor Jerome H. Milgram has studied the behavior of oil in an effort to develop reliable, effective oil pollution control technology. In his most recent Sea Grant work, he and students in the Department of Ocean Engineering studied four crude oils to analyze what properties caused each to break up and spread at differing rates and in different amounts. Identification of the individual components and observations of how they interact will be helpful in developing a reliable theory for predicting how commonly transported oils will spread in turbulent ocean waters. Scientists and engineers will then have more accurate information to be used in developing methods for oil spill pollution control.

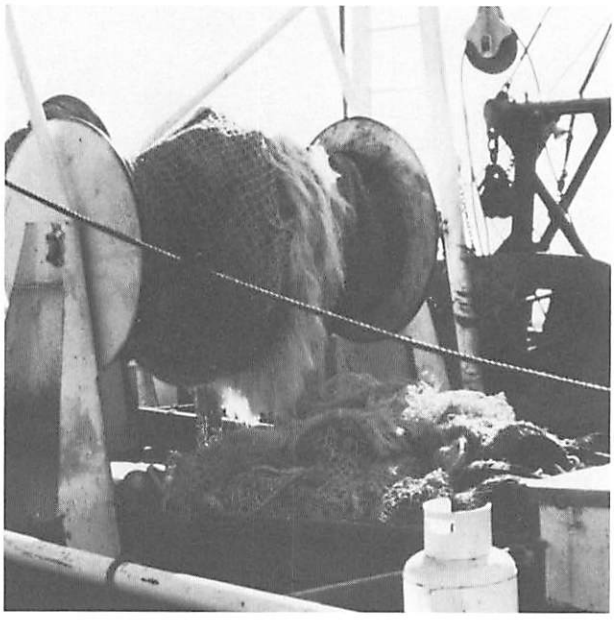
A related aspect of the oil pollution problem is being addressed by Professor Richard G. Donnelly of MIT's Department of Chemical Engineering who is investigating what chemical characteristics of the marine environment itself make oils spread differently. Why, for instance, when Platform Charlie in Louisiana caught fire in 1970, spilling 3 million gallons of crude oil into the ocean, did the natural processes disperse and degrade a large proportion, leaving only a small amount to wash ashore; while the oil spilled from the TORREY CANYON and from an offshore well in Santa Barbara remained intact, covering the beaches in an oily mass?

The MIT researcher belives that the composition of oil changes with time as it evaporates, loses active surface agents, and is affected by sediments and pollutants in the water. Confirmation of these assumptions supported by quantitative data could lead to pollution prevention by improving the predictive capabilities of scientists. It may also be possible to use the information to help devise chemical controls when spills occur.

As a member of a national research team that includes scientists from several government agencies and from the Texas A&M Sea Grant College Program, Professor Keith D. Stolzenbach is helping to study the environmental impact of disposing of a highly saline brine in the Gulf of Mexico.

Large caverns created onshore—near seaports and major oil distribution lines—are being used to store reserves of oil in the event of another crippling oil embargo. To make room for the oil, the brine must be removed and is discharged some distance offshore by a high velocity jet diffuser system designed to mix the brine with seawater. Concerned that the brine, which is denser and saltier than natural seawater, will have an adverse affect on marine life, the Department of Energy asked Sea Grant to help monitor the effects of the waste disposal operation on the shrimp stocks in the heavily fished Gulf.

"Expansion of world fisheries production is a matter of advancing on several fronts at once—improving the technical efficiency of harvesting known stocks, locating and defining new stocks, recasting the institutional setting for fisheries management, developing new end products from presently unused or underutilized species . . ."



Professor Stolzenbach of MIT's Ralph M. Parsons Laboratory has created a model to determine the dispersal of the dense substance in the water at various distances from the jet diffusing system. To date, the information has been utilized in the design of diffuser systems at a number of sites and has guided the conduct of preoperational environmental surveys.

In the future the MIT Sea Grant scientist believes the work he is doing will be useful in evaluating the operational performance of jet diffusion for not only brine disposal but for dredge spoils, sewage sludge, and deep ocean mining effluent disposal as well.

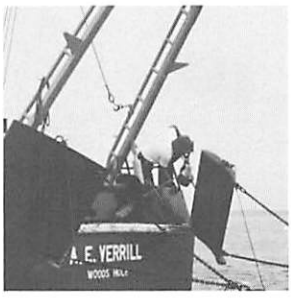
LIVING RESOURCE DEVELOPMENT

Technology for Marketing Underutilized Fish

Professor David Gordon Wilson in the Department of Mechanical Engineering is completing a final prototype design for mechanically skinning the spiny dogfish shark following extensive consultation with representatives of the New England fishing industry.

Originally, the Overall Economic Development Committee for Cape Ann asked Sea Grant to create a machine that would help fishermen exploit marketing opportunities for a fish that had long been a nuisance to them. In England dogfish shark is commonly used in fish and chips and in Germany parts are smoked and sold as an expensive delicacy. Demand for the shark in France, Belgium, and several Scandanavian countries cannot be met by American fisheries because existing skinning machines are unable to remove the shark's extremely tough skin. Hand methods are too slow and expensive to provide a satisfactory solution.

Following a detailed analysis of the shark's physical properties and a survey of available technology, the researchers developed a concept for the machine that follows the steps used by European hand skinners. In the spring of 1978, processors, fishermen, machinery manufacturers, and the National Marine Fisheries Service met with Sea Grant to suggest changes and refinements from an industry perspective. It was decided that a final prototype, incorporating recommendations put forth at the meeting, should be completed by March 1979. When manufactured, the machinery will help establish a new U.S. fishery tapping an abundant underutilized species. This will relieve pressure from current, depleted stocks and provide profitable alternatives for small boat owners when fishery management quotas must be imposed. Sea Grant will also continue to promote the growth of American markets by encouraging consumers to take advantage of delicious, low cost sources of protein—like the spiny dogfish shark.



Improved Trawl Doors

MIT Sea Grant researchers are designing gear for the U.S. fishing fleet that is more energy efficient and easier to maintain. Improved technology helps fishermen to capitalize on new economic opportunities opened to them by the passage of the 200-mile limit.

Arthur B. Clifton, Sea Grant's Marine Liaison Officer, directed a project to design new steel trawl doors using hydrodynamic principles. Shaped like a hydrofoil, the doors were tested first in MIT's laboratory water tunnel and then at sea by New England fishermen cooperating with Sea Grant engineers.

The trawling technique is considered one of the most efficient methods for harvesting evenly distributed bottom dwelling fish such as flounder, cod, and haddock. The trawl net, shaped like a funnel, is able to filter large amounts of water as it is towed by the vessel over New England's fishing grounds. Kept open vertically by floats and weights, and horizontally by the trawl doors, the net scoops up the fish in its path.

Trawl doors used by fishermen at present are made with steel-banded wood, and though they satisfactorily spread the mouth of the net by "ruddering," the towing vessel wastes fuel to compensate for substantial drag. With the new shape, the doors spread the net using hydrodynamic lift and a low angle of attack with approximately 20 to 40 percent less drag than the conventional flat doors. Fishermen save fuel costs or are able to use larger nets for the same fuel required to operate the present doors. Subsidiary savings are realized in maintenance because of the durable steel construction.

Development of new fishery technology has enabled Sea Grant to serve the needs of two industry clients—fishermen who will realize cost benefits from the improvements and the manufacturer of the doors who will derive direct benefits from the research when the doors are offered for sale in late 1978.

New England Red Tides

New England's red tides, though common in Maine and eastern Canada for many years, did not affect Massachusetts until 1972. Since then, however, shellfishermen and food processors have suffered annual economic losses when toxic outbreaks of *Gonyaulax tamarensis,* a dinoflagellate alga, have forced the closure of some shellfish beds to prevent potential outbreaks of paralytic shellfish poisoning (PSP).

Sea Grant researchers from MIT's Department of Civil Engineering believe that *G. tamarensis* was introduced to the Commonwealth's waters during a massive coastal bloom that extended from Maine to Cape Cod following a hurricane six years ago. Once present in the local waters, the dinoflagellate formed thick-walled dormant cells (cysts) that settled to the sediments as seed populations for future blooms. In locations where conditions were favorable, the cysts were revived by the warming of the water in the spring. A second bloom sometimes occurs in these same areas in the fall when the water temperatures drop.

Francois M.M. Morel, the third Henry L. Doherty Professor of Ocean Utilization, concludes that the location, timing, and spreading of *G. tamarensis* can be linked directly to this cyst stage. He and research associates believe that the coastal sediments in New England should be surveyed to locate existing cyst seed populations. The information can then be used by shellfish wardens and scientists to further study chemical and biological factors that lead to the toxic blooms. Scientists are now beginning to monitor the mechanisms by which the cysts are transported and accumulated. At present the researchers speculate that both human activity and natural processes may be responsible for movement from one location to another.

The Sea Grant scientists are also investigating the role of natural levels of copper in seawater in inhibiting the growth of *G. tamarensis.* The results of this work may help to predict and control dangerous and costly outbreaks of red tide in the future.

Chitin:
Waste to Raw Material

Like other shellfish processing companies, the Hunt Crabmeal Company in Hampton, Virginia faces a disposal problem because environmental regulations prohibit them from dumping shellfish wastes into coastal waters. The firm is hoping, however, that with the assistance of university researchers like Benjamin Averbach, they will be able to turn a problem waste into a valuable raw material.

Crustacean shells are a source of chitin, the natural polysaccharide related to cellulose, which has a diverse number of promising applications in medicine, papermaking, adhesives, natural and synthetic fibers, and waste treatment.

In MIT's Department of Materials Science and Engineering, Professor Averbach has completed extensive research to cast films from chitosan for use as a tool in removing pollutants from water. One of chitosans many attributes is its ability to trap contaminants, including radioactive heavy elements and chemical substances like DDT, PCBs, and Kepone. Because of the variability of chitosan itself, however, it has been difficult to produce a raw material that could be used to make consistently strong, clear, and flexible films. With the aid of Hunt, the Sea Grant researchers have sought to refine the processing methods. The experiments have produced good results and research is now aimed at precisely measuring effectiveness and improving the durability of the films.

In June 1978, MIT Sea Grant published the Proceedings of the First International Conference on Chitin/Chitosan to promote research that will turn this abundant substance into a valuable raw material. As scientists succeed, companies like the Hunt Crabmeal Company can organize and operate regional chitin and chitosan production plants, turning waste to beneficial use.

"A management system for the coastal zone provides only a framework within which development may take place. The full potential of the coastal zone will be realized only when science and technology are coupled with imagination and sound management to make existing uses more efficient and to introduce new beneficial uses."

MANAGING THE COASTAL ZONE

Groundwater Management

Sea Grant research supplies communities with information that helps them to make difficult, frequently complex choices. Professor John L. Wilson is creating a computer model of the groundwater resources (aquifers) of Martha's Vineyard that will allow residents of that island and other islands and peninsulas to assess the impact of population increase and industrial development on underground freshwater supplies.

Underground seawater contamination has long plagued coastal communities, and though models exist for mainland freshwater assessments, they cannot be applied to the unusual underground geometry of islands and peninsulas. Martha's Vineyard itself, though continuously growing, has not yet been affected by saltwater intrusion, but predictions that the island will experience an increase in permanent population of up to 60 percent makes it essential for the community to start planning for further demands on its resources.

Professor Wilson's model draws upon data collected by the U.S. Geological Survey and enables the community to "look at" the current behavior of the natural aquifers, or natural storage units, beneath the island. Then, through calculations that locate the water table and the boundary between the salt- and freshwater coexisting in the aquifer, the model can be used to show what effect future freshwater extractions will have.

According to Professor Wilson, the boundary is maintained by the continuous flow of freshwater moving from higher elevations to sea level. If too much of the freshwater is removed, the flow can be slowed, allowing the seawater to move upwards.

Engineers and planners using this model will be able to predict the effect of development on pond levels and tidal water supplies for an entire area, not just site by site. Residents of Martha's Vineyard and other islands and peninsulas can then estimate how much growth they can absorb without endangering their groundwater resources.

Structures and Shoreline

Recreation areas are lost, homes endangered, barrier beaches destroyed, and harbor openings threatened as the shoreline shifts and changes with the transport of sand from place to place.

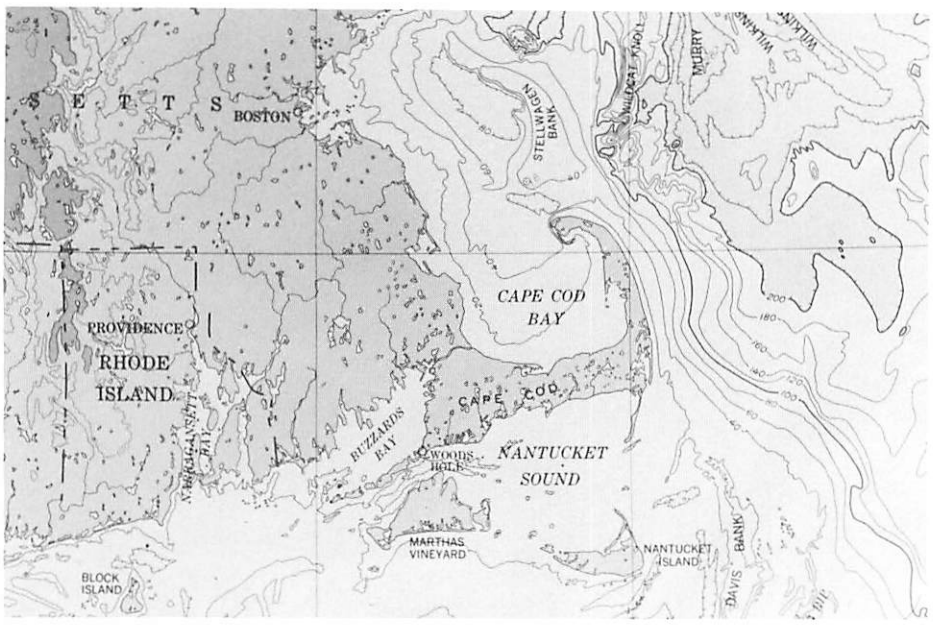
Sea Grant is concerned with helping coastal communities predict the effects of structures—such as groins and jetties, sewage plants, or port facilities—on the existing shoreline before development plans are carried to fruition. Professor Ole S. Madsen, of MIT's Civil Engineering Department and the Third Henry L. Doherty Professor in Ocean Utilization, is organizing a simple model that estimates the rate of sediment transport parallel to the shoreline as a function of the angle and height of waves, the slope of beach, the speed of currents, and the grain size of sand. This new tool will help government and industry to locate and design structures that will conform to the natural environment, not change it.

A new instrument system is being developed to measure velocity and surface elevation in the surf zone, which will enable engineers to make decisions on quantitative information. By contributing fundamental knowledge about the marine environment, this Sea Grant project ensures that more careful, considered judgments can be made in developing U.S. coastal resources in future years.


EROSION
CONTROL
AREA
KEEP OUT

ADVISORY SERVICES

"A time of decision is here. Multiple pressures force the Nation to turn to the sea, and multiple opportunities await the seaward turning. The time of decision is not for the Federal government alone, although Federal leadership is essential. State and local governments, industry, academic institutions and the American people must share in decision and action."



Throughout its history, America has depended on the optimism, confidence and initiative of private enterprise to develop the country's abundant resources on land. And again, as the nation turns to its last frontier, the oceans, the burdens and the opportunities for recovering minerals and food from the seas have fallen, in large measure, on the shoulders of business and industry. At the same time, the oceans are commonly owned, with few boundaries and no fences to stake out individual territory for private use. Sea Grant is charged by the government to help resolve the conflicts of multiple demands placed on limited resources, while promoting the growth and vitality of ocean-related businesses.

In meeting its obligations, MIT Sea Grant Program must be keenly aware of what problems or conflicts require resolution. And when solutions have been found, the answers must be disseminated in a timely fashion to the people who can apply them. This information exchange is the function of the advisory services component of Sea Grant.

It is one of the Program's unique and strengthening features that we ask our constituents, the final users of Sea Grant research, to participate and contribute expertise and experience throughout every stage of a project, from initiation to application. This special partnership assures that the research is targeted at real problems and facilitates the dissemination of the results.

Many decisions that will help the nation as a whole to profit from long-term ocean and coastal resource management are made politically, at local, state and federal levels. Sea Grant's advisory services provide the mechanism for promoting the public's interest and involvement in the process. Technical reports, conferences, articles in trade and public media are just a few of the methods used as advisory services continuously publish, publicize and look for new ways to encourage the interest of all American citizens in marine resource development.

"Although land-based activities will continue to dominate the economy for many years to come, new and expanded ocean industries offer some of the Nation's most inviting opportunities for economic growth."

"The Commission recommends that the National Oceanic and Atmospheric Administration establish a strong scientific and technical information and extension program to meet industry and other civil needs."

MIT/MARINE INDUSTRY COLLEGIUM

Through the MIT/Marine Industry Collegium, companies of national and international stature share in and profit from Sea Grant's marine research and ocean-oriented activities. The Collegium, established in 1975, has just completed its third year of promoting commercial development and application of new marine technologies.

In 1977-78 over 90 member organizations participated, blending the practical perspective of business, the broad overview of government, and the special scientific concerns of researchers. They met four times to discuss well-documented surveys prepared by the Collegium staff. The surveys, known as Opportunity Briefs, review research that could lead to new markets, new products, or could solve existing design, construction, or regulatory problems.

January 1978 was the first time a research project completed by a Collegium member was the focus of a workshop. Under the Department of Energy, the Dynatech Research and Development Corporation led a study team of scientists from four Sea Grant schools in assessing the technical and economic potential of growing algae biomass as a future energy source.

Three other workshops addressed a range of problems of interest and concern to the marine industry. "Deep Ocean Mineral Mining: A Computer Model for Investigating Costs, Rates of Return, and Economic Implications of Some Policy Options," brought representatives from the U.S. Department of State and Department of Commerce together with Collegium members to discuss government regulations and treaty agreements that will affect companies recovering manganese nodules from international waters. A collaborative research effort of faculty and students from MIT, the University of Michigan, and the University of Colorado was the topic of the May meeting on "Computer-Aided Preliminary Design of Ships."

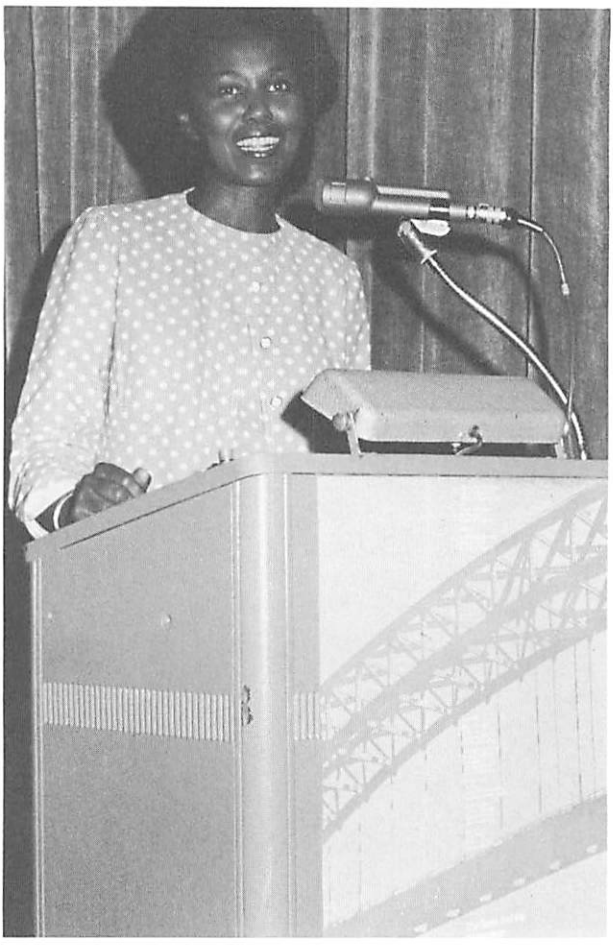
Members involved in constructing, monitoring, and maintaining offshore facilities joined Professor J. Kim Vandiver to discuss his research on "Vibration Response and the Structural Integrity of Deepwater Structures." Professor Vandiver, who holds one of the Henry L. Doherty Professorships in Ocean Utilization, awarded each year by Sea Grant to encourage talented, imaginative junior faculty members, gained access to valuable, proprietary industry information during the Collegium meeting. By encouraging this kind of interaction, we hope to advance research that will benefit industry and the nation.

EXTENSION SEA GRANT ADVISORY PROGRAM

Many decisions in resource management are made at a local level in communities and towns along the coast of Massachusetts. Sea Grant serves these citizens through the Extension Sea Grant Advisory Program (ESGAP), a joint project that utilizes the resources of MIT and the University of Massachusetts.

Close liaison with state and town governments, with community colleges, and with the many businesses keeps Sea Grant attuned to the needs of Massachusetts residents. Workshops and conferences, organized in conjunction with state governmental agencies and with other Sea Grant programs, have promoted the application of research results to serious state-wide and regional problems.

During this past year, ESGAP sponsored meetings that allowed our New England constituents to consult with business and research experts on some of the region's critical concerns. "Northeast Clam Industries: Management for the Future" brought together representatives from three groups, the shellfish industry, governmental regulatory agencies, and university researchers, to forge a plan, that would be mutually acceptable for



managing one of the region's most important fisheries. New research and information sources were introduced at the "Barrier Beach Management Workshop" and the "Waterfront Development Conference." Marina owners, who suffered financial losses from ice damage during the severe 1976-1977 winter, discussed preventive design considerations and technology with researchers from the University of Wisconsin Sea Grant Program, the Cold Regions Research and Engineering Laboratory, as well as engineers and product experts from private industry at a November, 1977 meeting.

One of the most substantial concerns of Massachusetts's coastal residents is erosion which threatens many homes and recreational areas. In 1977-1978, MIT Sea Grant's coastal engineer presented a slide-tape show describing various effective, economical control systems to homeowners and conservation commissions.

One erosion control technique, created by researchers for application in the Chesapeake Bay, is being tried in several locations on Cape Cod, under MIT Sea Grant surveillance. The method, which uses plastic bags, called sill bags, to raise or perch the beach as sand builds up behind and in front of the bags, may not be adequate in the active, exposed environment of the Massachusetts coastline. A final assessment will not be made, however, until a thorough monitoring program has been completed, and the results evaluated in late 1979.

The Sea Grant Advisory Service staff facilitates the interaction between MIT researchers and Massachusetts constituents. In the past year they played a critical role in the development of the dogfish skinning machine and the testing of a new trawl door for the fishing industry. Planning tools – for assessing the effect of population growth on the groundwater resources of Martha's Vineyard, and for revitalizing the Hyannis waterfront –will be completed and the results disseminated with the assistance of ESGAP agents.

SEA GRANT LECTURE

The Annual Sea Grant Lecture is sponsored each year to highlight major issues that demand the attention and study of, not only the scientific community, but all citizens. Technology is only one part of resource development. Decisions that have far-reaching consequences are made by voters in local, state, and national elections, by owners of private property and business, and by regulatory agencies in the federal governments.

In the 1977 Lecture, Congresswoman Yvonne B. Burke of California, in her lecture, "The Seas and Waterways – The New Frontier," discussed several issues of national and international concern: ratification of the Panama Canal Treaties, "flag-of-convenience" ship registry, and safety standards required to prevent oil pollution in the oceans. An expert panel responding to Congresswoman Burke and the audience included Mr. Erling D. Naess, Chairman, International Association of Independent Tanker Owners; Paul E. Atkinson, President, Sun Shipbuilding and Dry Dock Company; A. Douglas Carmichael, Professor of Power Engineering, MIT Department of Ocean Engineering; and John P. Sheffey, Colonel (ret.), Executive Vice President of the National Association for Uniformed Services.

COMMUNICATIONS/ INFORMATION SERVICES

A complement to the Marine Industry Advisory Services and the Extension Sea Grant Advisory Program, the Communications and Information staff publishes reports describing the results of MIT Sea Grant research and translates technical information into forms more easily useable by Sea Grant's constituents.

The Marine Resource Information Center in the Sea Grant offices maintains a collection of reports and publications from MIT, and all other Sea Grant programs. Journals and newsletters covering current marine issues are available. And in addition, topic files, indexes, abstracts, and bibliographies on oceanography, land-use planning, ports, fisheries, water quality control, coastal processes, and environmental regulations are useful reference sources available through the Center.

As the opportunity and need arise, the Communications/Information staff prepares, publishes and distributes guides to information sources, proceedings of important conferences, and reports on program activities. The annual MIT Marine-Related Research Directory guides constituents to the current work at the Institute; a directory to MIT Sea Grant's publications from 1970-1977 reports on the body of information available through the Program.

Communications/Information helps to fulfill the Congressional mandate and the Stratton Commission recommendation that Sea Grant maintain and encourage a continuous flow of information between the Program and all groups involved in ocean and coastal resource development.

RESEARCH VESSEL EDGERTON

MIT's Research Vessel EDGERTON, maintained under the direction of the Sea Grant advisory service Marine Liaison Officer, is available through charter to researchers from the Institute, industry, and other universities who need to gather data or to test equipment at sea. Compact by research vessel standards, the 65-foot, 90-ton ship is designed for small groups who require an economical and flexible oceangoing work platform. The EDGERTON, outfitted and maintain by the Institute, is used for oceanographic and ocean engineering research along the New England coast and in deeper waters on the continental shelf.

EDUCATION

"The primary need in Government support of education and training is to assist in acquiring necessary facilities; initiating new curricula for midcareer training; and meeting specialized manpower needs in marine engineering, technician training, and the social sciences."

The world is becoming increasingly aware that water is a substance not only indispensable for all of life's activities, but also of extraordinary complexity, requiring the greatest understanding and respect. Both Congress, in establishing the National Sea Grant College Program, and the Stratton Commission, in setting forth a marine resource development plan, wisely recommended that new programs be inaugurated for educating and training professionals to work in the marine field. MIT Sea Grant has continuously expanded and refined educational courses for students at the Institute. In recent years, we have also created educational curricula for professionals outside MIT.

In 1977-78, with the encouragement and support of Congress, we extended the reach of our educational component even further, to encompass students in other universities and in elementary and secondary schools. As the nation and the world have turned seaward, it has become apparent that critical decisions will have to be made. By educating people of all ages to appreciate the power and fragility of water, we hope to promote the wise and balanced uses of both fresh and oceanic marine resources.

OCEAN ENGINEERING

MIT's educational philosophy rests on the premise that the most effective method for teaching science and engineering is to involve students in research and technology development. Therefore, students are asked to work side by side with faculty researchers in all Sea Grant research. In addition, Sea Grant support to the Institute keeps the ocean engineering curriculum current, reflecting the constantly changing and evolving advances in this relatively new discipline. Information and research from Sea Grant projects are incorporated into MIT's ocean engineering curriculum, and the Institute, in return, introduces new subjects relevant to identified Sea Grant concerns. This partnership produces scientists, engineers, and teachers qualified to assume the responsibilities for future planning and development of the ocean's living, mineral and coastal resources.

Undergraduates participate in the Ocean Engineering Project Laboratory to gain firsthand "at sea" experience, creating and adapting technology for work in the seas. The R/V EDGERTON allows them to test equipment under actual ocean conditions. Sea Grant supports the development of a course to train specialists to site, build, monitor, and maintain the complex structures required for offshore resource recovery. Data which are being collected at present by Professor Erik H. Vanmarcke of the Department of Civil Engineering will be incorporated into an integrated textbook on structural forms, the effects of loading on platform design under wave, wind, and seismic strains, considerations in marine soil exploration, material and design problems, and the development of analysis techniques. Courses in these areas, taught in the Department of Civil Engineering, help give the faculty experience in developing the long-term courses and textbooks needed for future generations of students.

INTERDISCIPLINARY DESIGN COURSE

Students from many disciplines, such as engineering, economics, management, political science, law, and architecture, are encouraged to participate in the Sea Grant Interdisciplinary Systems Design Subject. The course not only gives undergraduate and graduate students an opportunity to apply classroom knowledge to real world problems, but also teaches them to integrate many conflicting considerations into the solution of a broad, complex problem.

Each year, Professor William Seifert identifies a coastal community in New England seeking Sea Grant student assistance in analyzing and devising various planning options, which would provide economic and aesthetic benefits to its residents. Completed studies of Gloucester, the Boston South Shore, and Lynn are being followed by an assessment of many of the urban problems in Hyannis, Massachusetts. Data gathered during 1978 will be used by the students in the Spring 1979 course to create a set of recommendations that will help citizens of this Cape Cod community to make optimum use of its resources.

PRE-UNIVERSITY MARINE STUDIES

A disused army camp by the ocean has been used for the past ten years by the New Bedford school system as a summer Sea Lab for teaching students history, oceanography, meteorology, physics, chemistry, and biology in the classroom, in laboratories, on the beach, and in the water. Started with limited funds, but great community and teacher support, the Summer Lab gained in popularity, with increasing numbers of students eager to participate each year.

In 1977, the administrators of the Sea Lab turned to MIT Sea Grant for assistance to strengthen their educational materials and to expand the goals of the program. During this past year, New Bedford teachers and Sea Grant staff have developed a series of teaching modules created around basic questions on the "world of water." During the 1978 summer course, students learned scientific methods and improved analytical skills by observing, analyzing, and reporting natural marine phenomena.

The educators are developing the curriculum material by building, grade by grade, new concepts and skills. A fourth grader learns about navigational aids and lighthouses and then, in the sixth grade, studies how to use a sextant for celestial navigation. By the ninth grade the student is able to carry out sophisticated water quality studies employing a number of techniques and instruments that he or she learned to use during previous summers at the Sea Lab. To date, the New Bedford and Sea Grant educators believe the experimental modules have been successful as learning tools, and at the same time have infused new vitality into the teaching process at the Lab. When a full series of modules has been carefully tested and evaluated, the materials will be made available for use in classrooms throughout the country.

INTERCOLLEGIATE MARINE EDUCATION COURSE

In December 1977, MIT Sea Grant began an investigation to see if it would be possible and useful to develop an interdisciplinary, intercollegiate marine studies program in the Boston area. The city houses a great many academic institutions, with an array of courses and faculty expertise that, if coordinated, could offer students an exciting, unique, marine-oriented educational opportunity.

An *ad hoc* committee and several volunteer subcommittees, selected by 50 representatives from 27 Boston-area colleges and universities, reported interest and enthusiasm for creating a consortium to offer a one-semester, three-credit undergraduate course that would discuss the role of the marine and aquatic environments in our lives. Because the complexity of water defies traditional disciplines, studies of politics, economics, music, art, literature and the marine sciences will all be incorporated into the innovative course. A major theme will be the impossibility of understanding the world of water without a multiple perspective, like the one offered by this course. Team teaching will be used to integrate the many facets of marine studies when the course begins in the spring of 1980.

CONTINUING EDUCATION FOR FISHERMEN

If the United States is to derive the maximum economic benefits from its fisheries, it must have a modern fleet, run by men and women with skills in using new technology and up-to-date management methods. At the Massachusetts Maritime Academy, Sea Grant helped to establish elective courses in fishery science, gear design and use, and fishing vessel operations designed to motivate students to enter the U.S. commercial fishing industry as professionals.

Last year, the program was expanded to give active fishermen the opportunity to improve and develop new skills through classes on piloting, aids to navigation, equipment maintenance, safety, and business management. The program was strengthened in June of 1978 when Governor Michael Dukakis signed a bill committing the state's financial support for the training center. This growing educational program will result in improving the effectiveness of New England's fishing fleet in managing the ocean's living resources.

SUMMER PROGRAMS FOR PROFESSIONALS

Information on technical progress in the marine field is available to professional engineers and scientists from industry, government, and universities through courses sponsored by Sea Grant during MIT's Special Summer Program. Short, intensive classes on scientific, technical, and management topics attract people from around the United States and abroad during July and August.

In 1977 well-attended courses dealt with Transportation Systems Management and Analysis; Air Transportation; Port Planning and Development; Urban Transportation, Issues and Techniques; Freight Transportation; Forecasting Transportation Demand; Design and Construction of Offshore Facilities; and New Frontiers in Welding Technology.

Fiscal Year 1978
Institutional
Program
Summary

For year beginning
1 July 1977

PROGRAM MANAGEMENT		
Sea Grant Program	Mr. D.A. Horn	Continued project
Project Development Opportunities	Mr. Horn	Continued project
EDUCATION AND TRAINING		
Education and Training: Development, Operation and Management	Mr. E.R. Pariser	New project
Interdisciplinary Systems Design Subject	Professor W.W. Seifert	Continued project
Ocean Engineering Project Laboratory	Dr. I. Dyer	Continued project
Development of a Commercial Fisheries Training Program	Mr. A.B. Clifton Mr. D.M. Kan	Continued project
State-Industry Sea Grant Internship	Mr. Horn Dr. Dyer	Continued project
Development of an Integrated Course on Offshore Structures	Professor E.H. Vanmarcke	New project
Development of Teaching Materials for Pre-University Marine Education	Mr. Pariser	New project
ADVISORY SERVICES		
Advisory Services: Development, Operation and Management	Mr. Pariser	Continued project
MITSG/CES Marine Extension Service	Mr. Pariser Dr. J. Noyes	Continued project
Marine Industry Advisory Service	Mr. N. Doelling	Continued project
Sea Grant Communications/Information Service	Ms. E. Harding	Continued project
Annual Sea Grant Lecture	Dr. A.A.H. Keil	Continued project
Public Education and Training Short Courses	Professor J.M. Austin	Continued project
Computer Program Dissemination	Professor J. Connor	Continued project
Sea Grant Independent Activities	Mr. Clifton	New project
Development of a Guide to Information Sources in the Field of Offshore Engineering	Ms. M. Chryssostomidis	Continued project

RESEARCH		
The Hydrodynamic and Engineering Evaluation of an Ocean Wave Energy System	Professor C.C. Mei and A.D. Carmichael	Continued and completed project; report will be published
Development of Joining and Cutting Techniques for Deep Sea Applications	Professor K. Masubuchi	Continued project
Application of Teleoperators	Professor T.B. Sheridan	Continued project
Exploration and Evaluation of Engineering Properties of Marine Soils for Foundation Design of Offshore Structures	Professors M.M. Baligh and C.C. Ladd	Continued and completed project; report will be published
Enhancement of the of Common Polymeric Materials against Undersea Degradation	Professors R.G. Donnelly and R.E. Cohen	Continued project
Dynamic Analysis of Offshore Structures	Professor J.K. Vandiver	Continued and completed project; report will be published
Offshore Geotechnical Risk Analysis	Professor G.B. Baecher	New project
Laser Inertial Rotation Sensor for a Portable Navigation System	Professor S. Ezekiel	New and completed project; report will be published
Oil Slick Control in the Offshore Environment	Professor J.H. Milgram	Continued and completed project; report will be published
Study of a Cost Model of Deep Ocean Mining	Professor J.D. Nyhart	Continued and completed project; additional report will be published
The Effect of Oil Composition and Physical Properties and the Ambient Water on Oil Slick Dispersion	Professor Donnelly	New project
An Improved Trawl Board for the New England Fishing Fleet	Professor J.K. Vandiver and Mr. A.B. Clifton	Continued and completed project; report will be published
Chemical and Structural Characterization of Chitin and Chitin Derivatives for Industrial Application	Professor B.L. Averbach	Continued project
Development of a Process for Skinning the Spiny Dogfish Shark	Professors D.G. Wilson and C.K. Rha	Continued and completed project; report will be published
The Role of Trace Metals on New England Red Tides	Professor F.M.M. Morel	Continued project
Longshore Sediment Transport	Professor O.S. Madsen	Continued project
Analysis of Offshore Brine Disposal Techniques	Professor K.D. Stolzenbach	Continued project
Surf Zone Hydrodynamics: A Field Investigation	Professor Madsen	Continued project
Sea Water Intrusion in Offshore Islands	Professor J.L. Wilson	New project

Vibration Response and the Structural Integrity of Deepwater Structures
MIT/Marine Industry Collegium

Opportunity Brief 10.
MITSG 78-10.
Massachusetts Institute of Technology, Cambridge, Massachusetts

The Economics and Engineering of Large-Scale Algae Energy Biomass Systems
MIT/Marine Industry Collegium

Opportunity Brief 11.
MITSG 78-11.
Massachusetts Institute of Technology, Cambridge, Massachusetts

Deep Ocean Mineral Mining
MIT/Marine Industry Collegium

Opportunity Brief 12.
MITSG 78-12.
Massachusetts Institute of Technology, Cambridge, Massachusetts

Computer-Aided Preliminary Design of Ships
MIT/Marine Industry Collegium

Opportunity Brief 13.
MITSG 78-13.
Massachusetts Institute of Technology, Cambridge, Massachusetts

The Proceedings of the First International Conference on Chitin/Chitosan
Pariser, E.R. and R.A.A. Muzzarelli

MITSG 78-7.
Massachusetts Institute of Technology, Cambridge, Massachusetts

The Seas and the Waterways: The New Frontier; Proceedings of the 6th Annual Sea Grant Lecture and Symposium

MITSG 78-1
Massachusetts Institute of Technology, Cambridge, Massachusetts

A Report on the Massachusetts Institute of Technology Sea Grant College Program

MITSG 78-2.
Massachusetts Institute of Technology, Cambridge, Massachusetts

Directory of MIT Sea Grant Program Publications 1970-1977

MITSG 78-6.
Massachusetts Institute of Technology, Cambridge, Massachusetts

Marine-Related Research at MIT: 1978
Passero, B.

MITSG 78-9
Massachusetts Institute of Technology, Cambridge, Massachusetts

Offshore Petroleum Engineering: A Bibliographic Guide to Publications and Information Sources
Chryssostomidis, M.

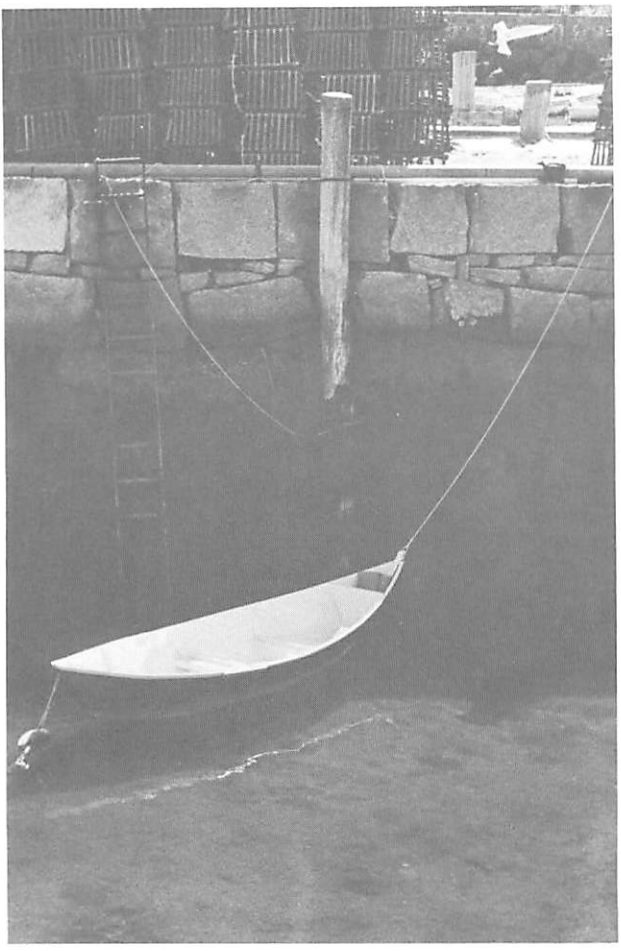
MITSG 78-5.
Nichols Publishing Company, New York, N.Y.

Landscaping the Seashore Cottage
Extension Sea Grant Advisory Program

Marine and Coastal Facts No. 4. University of Massachusetts, Amherst, Massachusetts

Theft-Proofing Boats
Extension Sea Grant Advisory Program

Marine and Coastal Facts No. 5, University of Massachusetts, Amherst, Massachusetts



LIVING RESOURCE DEVELOPMENT

The Processing of Chitosan Membranes
Averbach, B.L. and R.B. Clark

MITSG 78-14. Massachusetts Institute of Technology, Cambridge, Massachusetts

The Processing and Properties of Chitosan Membranes
Clark, R.B.

M.S. Thesis, Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 1978

Copper Sensitivity of *Gonyaulax tamarensis*
Anderson, D.M. and F.M.M. Morel

MITSG 78-15J. Reprinted from Limnology and Oceanography, 1978.

Potentiometric Determination of Copper Complexation by Phytoplankton Exudates
Swallow, K.C., J.C. Westall, D.M. McKnight, N.M.L. Morel, F.M.M. Morel

MITSG 78-19J. Reprinted from Limnology and Oceanography, 1978.

Potential Importance of Benthic Cysts of *Gonyaulax tamarensis* and *G. excavata* in Initiating Toxic Dinoflagellate Blooms
Anderson, D.M. and D. Wall

MITSG 78-20J. Reprinted from Journal of Phycology, 1978.

The Seeding of Two Red Tide Blooms by the Germination of Benthic *Gonyaulax tamarensis* Hypnocysts
Anderson, D.M. and F.M.M. Morel

Journal of Estuarine and Coastal Marine Science. In press, 1979.

Toxic Dinoflagellate Blooms in the Cape Cod Region of Massachusetts
Anderson, D.M. and F.M.M. Morel

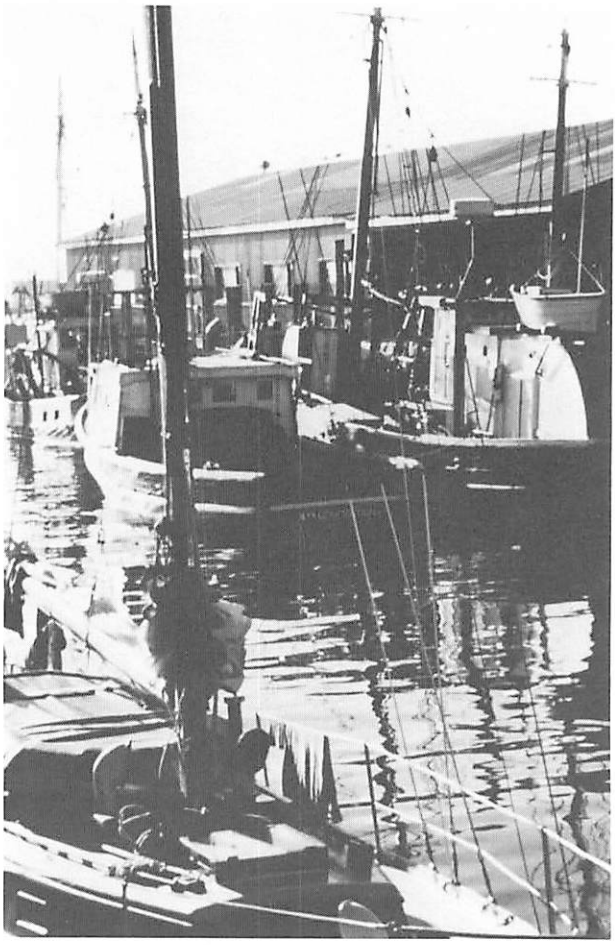
Proceedings of 2nd International Conference, Toxic Dinoflagellate Blooms, Elsevier-North Holland In press, 1979.

The Role of Chelators and Trace Metals in Toxic Blooms
Anderson, D.M. and M. Corbett.

Proceedings, 2nd International Conference, Toxic Dinoflagellate Blooms. Elsvier-North Holland. In press, 1979.

Chemical Characteristics Affecting the Initiation, Development, and Distribution of Toxic Dinoflagellate Blooms in New England
Anderson, D.M.

Ph.D. Thesis. Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts



A Cost Model of Deep Ocean Mining and Associated Regulatory Issues
Nyhart, J.D., L. Antrim, A. Capstaff, A. Kohler, and D. Leshaw

MITSG 78-4.
Massachusetts Institute of Technology, Cambridge, Massachusetts

An Experimental Study and Engineering Evaluation of the Salter Cam Wave Energy Converter
Carmichael, A.D.

MITSG 78-22
Massachusetts Institute of Technology, Cambridge, Massachusetts

Characteristics of Salter Cam for Extracting Energy from Ocean Waves
Mynett, A.E., D.D. Serman, C.C. Mei

MITSG 78-21J. Reprinted from Applied Ocean Research, January 1979.

The Feasibility of Wave Energy Converters
Baux, J.F.P.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Economic Feasibility of Cam-Type Wave Power Generators
Bisceglia, S.V.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Performance of a Salter Rocking Cam-Type Wave Energy Extractor – An Experimental Evaluation
Davis, N.B.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Predictions of Power Production by a Cam-Type Wave Energy Converter for Various Locations
Dinwell, R.E.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Theory of Salter's Wave Energy Device in Random Seas
D. Serman

M.S. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Numerical Methods in Water-Wave Diffraction
Mei, C.C.

MITSG 78-17J. Reprinted from the Annual Review of Fluid Mechanics.

Equivalent Parameters in Soil Profile Modeling
Baecher, G.B. and T.S. Ingra

Specialty Conference on Structural and Geotechnical Reliability, ASCE.

Performance of Foundations on Cohesionless Sands
Ingra, T.S.

M.S. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Underwater Stud Welding
Masubuchi, K. and H. Ozaki

Oceans '78 Conference, Marine Technology Society, September 1978.

Development of Techniques for Deep-Sea Welding Simulation and Study
Prasad, S.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Underwater Welding in the Deep Sea
Erickson, D.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Applications of Arc Stud Welding for Deep Sea Salvage Operations
Kataoka, T.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Underwater Fabrication and Construction Systems
Iimura, O.

M.S. Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

MANAGING THE COASTAL ZONE

Lynn Harbor: Planning for Coastal Development
Rosenbaum, L.T.

MITSG 78-3.
Massachusetts Institute of Technology, Cambridge, Massachusetts

A Longshore Current Model
Madsen, O.S., D.W. Ostendorf, and A.S. Reyman

MITSG 78-16J. Reprinted from Proceedings of Coastal Zone '78, ASCE Vol. 3, 1978.

A Note on Mass Transport in Deep Water Waves
Madsen, O.S.

MITSG 78-18J. Reprinted from the Journal of Physical Oceanography, November 1978.

Wave-Induced Pore Pressures and Effective Stresses in a Porous Bed
Madsen, O.S.

Geotechnique, December 1978.

Longshore Sediment Transport: A Review
Greer, M.N. and O.S. Madsen

Proceedings of the 16th Conference of Coastal Engineers, Hamburg, August 1978.

A Longshore Current Model
Ostendorf, D.W.

M.S. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

ONSHORE/OFFSHORE POLLUTION

Crisis Science: Investigations in Response to the Argo Merchant Oil Spill
Pollack, A.M. and K.D. Stolzenbach

MITSG 78-8.
Massachusetts Institute of Technology, Cambridge, Massachusetts

The Clean-Up of Oil Spills from Unprotected Waters: Technology and Policy
Milgram, J.

Oceanus, November 1977.

Mechanics of a Restrained Layer of Floating Oil Above a Water Current
Milgram, J. and R. Van Houten

Journal of Hydrodynamics July 1978.

The Role of Physical Studies Before, During and After Oil Spills
Milgram, J.

University of Rhode Island Symposium, In The Wake of the Argo Merchant, January 1978.

Dispersion Zone Characteristics of Ocean Discharges
Gaboury, D.R.

M.S. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Design Criteria for Submerged Discharges of Dense Effluents
Tong, S.S.

M.S. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

Summary of Expenditures by Activity

		NOAA Grant Funds	University Matching Funds
Program Management	Program Administration	$ 91,000	$137,422
	Program Development	35,400	19,430
Marine Education and Training	College Level	39,900	109,780
	Vocational Marine Technical Training	42,000	47,252
	Other Education	29,100	90,968
Socio-Economic and Legal Studies	Marine Economics	72,500	
Marine Resource Development	Marine Extracts—Other	43,600	19,643
Marine Technology Research and Development	Ocean Engineering	163,700	111,553
	Sea Floor Engineering	37,000	10,000
	Materials and Structures	37,500	31,597
	Commercial Fisheries	46,700	25,068
Marine Environmental Research	Pollution—Oil Spills	57,000	16,469
	Environmental Models—Physical Processes	180,900	80,718
	Biological Processess	56,000	38,627
Advisory Services	Extension Programs	248,800	108,887
	Other Advisory Services	90,000	8,000
National Projects	Forcing Function Near-shore Velocity	29,000	*
	Total	$1,300,100	$855,414

This summary is only approximate. In accordance with Federal grant requirements, the official financial report will be submitted by the MIT Comptroller to the Office of Sea Grant

*National Projects—matching not required

Fishing Industry Support-Massachusetts
Fugro Geotechnical Consultants-Holland
Henry L. and Grace Doherty Charitable Foundation Inc.
International Copper Research Association
Ishikawajima–Harima Heavy Industries, Co., Ltd.
Kawasaki Heavy Industries
Massachusetts Institute of Technology
Massachusetts Maritime Academy
Marine Industry Advisory Services Collegium Members
New England Aquarium
New England Fisheries Steering Committee
Rockefeller Foundation
Sea Grant Lecture Endowment Funds
Sun Shipbuilding and Dry Dock Company
University of Massachusetts
Westerbeake Fishing Gear Company-Boston
Wharf Forging and Welding-Boston
Woods Hole Oceanographic Institute

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Westinghouse Electric Corporation, Oceanic Division
Woodward-Clyde Consultants

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Written by
Elizabeth T. Harding

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PHOTOGRAPH CREDITS

Kathy Mannix
page 14, 18, 21, 28, 33, 35

Francis W. Sargent, Jr.
page 24, 27, 29

Andrew L. Gutman
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Richard C. Kelsey
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